California Grade 6–7
EP&Cs Exemplar Lesson Series

Strategies for Satisfying the California Science Framework Requirements for Teaching California's Environmental Principles and Concepts in Conjunction with the Next Generation Science Standards*

Created by State Education and Environment Roundtable
in collaboration with Ten Strands

PURPOSE

Created for publishers submitting to California's 2018 Science Adoption, to demonstrate how California's Environmental Principles and Concepts (EP&Cs) can be integrated into California NGSS Instructional Materials

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Introduction—Category 1 Requirements

This document provides an exemplar lesson series for publishers that demonstrates how one might create instructional materials that meet California's rigorous requirements for science instructional materials. With the 2016 adoption of a new Science Framework, California's State Board of Education (SBE) required that adopted materials must align with California's Next Generation Science Standards (CA NGSS) and include instructional content based upon California's Environmental Principles and Concepts (EP&Cs).

This document provides a model intended to demonstrate to publishers how the CA NGSS and EP&Cs can be integrated into instructional materials and activities and taught simultaneously with the three dimensions of the CA NGSS, thereby meeting the State Board's Category 1 requirement for both.

The exemplar lesson series presented conforms with the three "Instructional Strategies for Sequencing Lessons" identified in the CA Science Framework: the 5E Instructional Cycle, Problem-Based Learning, and Outdoor and Environmental Learning Experiences. Detailed descriptions of these three strategies are included in California's *2016 Science Framework* in Chapter 11: Instructional Strategies for CA NGSS Teaching and Learning in the Twenty-first Century.

Beyond the Three-Dimensions

Chapter 13 of California's *2016 Science Framework* states that, "All criteria statements in Category 1 must be met for a program to be adopted. The criteria for Category 1 must be met in the core resources or via the primary means of instruction, rather than in ancillary components."

As described throughout the framework, the SBE calls for instruction that goes well beyond the three dimensions represented by the Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices. The framework calls for an "Explicit focus on Environmental Principles and Concepts… that every student in the state should learn and be able to apply."

Specifically, in Chapter 13 under Category 1: Alignment with the CA NGSS Three-Dimensional Learning, California's *2016 Science Framework* states that:

> *All programs must include the following features:… Instructional resources, where appropriate,* ***examine humanity's place in ecological systems and the necessity for the protection of the environment*** *(EC Section 60041).* ***Resources include instructional content based upon the Environmental Principles and Concepts*** *developed by the California Environmental Protection Agency and adopted by the SBE (Public Resources Code Section 71301) in context and aligned to the CA NGSS, as exemplified in Appendix 2* (2016 Science Framework). [Emphasis added.]

The *Framework* states that, to be adopted, resources must meet Category 1: Alignment with CA NGSS Three-Dimensional Learning, in full, **including the EP&Cs**.

California's Environmental Principles and Concepts (EP&Cs)

As stated above, Category 1 requires that California's Environmental Principles and Concepts (see Table 1 below) be incorporated into instructional materials. *2016 Science Framework* Chapter 1: Overview of the California Next Generation Science Standards, introduces the role of the EP&Cs in California science education:

> *While the three dimensions are a major part of the CA NGSS,* ***the standards are based on principles that go beyond these three dimensions. Teachers must be mindful of these other***

> ***considerations, including principles of environmental literacy, engineering design, the nature of science…*** *twenty-first century skills, and integrating science with California's other standards…*
>
> *For many decades, California has been a national leader in educating students about the environment, and now more than ever, the state recognizes that environmental literacy is crucial to sustaining the economic and environmental well-being of all Californians...* ***Environmental literacy means more than knowing environmental content; it also encompasses civic engagement and community involvement in diverse settings.*** *Going beyond the walls of the classroom, environmental literacy can be developed through investigations on campus, in the local community, on the schoolyard, at nature centers and outdoor schools, as well as in the rich and diverse natural landscapes found throughout California…*
>
> *To help fulfill this goal, the California State Board of Education (SBE) approved a framework guideline that* ***calls for the Environmental Principles and Concepts (EP&Cs) to be incorporated into relevant subject matter frameworks,*** *including science.* [Emphasis added.]

The *2016 Science Framework* further calls for an explicit focus on California's EP&Cs:

> *A direct understanding of the connections between humans and the natural world prepares students to address the environmental challenges of today and of the future, to mitigate and prepare for natural hazards, and to interact in a responsible and sustainable manner with the natural systems that support all life.* ***California has identified several critical understandings, called the Environmental Principles and Concepts (EP&Cs; Table 1), that every student in the state should learn and be able to apply.*** *The State Board of Education (SBE) officially adopted the EP&Cs in 2004 and* ***they are an important piece of the curricular expectations for all California students.***

The commitment of the State Board of Education to the EP&Cs as an integral part of its curricular expectations is further demonstrated by their inclusion in the *2016 History-Social Science Framework* and SBE's requirement that they be incorporated in the *Health Framework* (currently under development).

Appendix 2 of the *2016 Science Framework* presents examples of alignments by grade among the EP&Cs, Performance Expectations, Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. Instructional materials that address the Performance Expectations are not sufficient; instruction *must* focus on Three-Dimensional Learning and the EP&Cs.

Table 1: California's Adopted Environmental Principles and Concepts

Principle I—The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.	
Concept a.	The goods produced by natural systems are essential to human life and to the functioning of our economies and cultures.
Concept b.	The ecosystem services provided by natural systems are essential to human life and to the functioning of our economies and cultures.
Concept c.	The quality, quantity and reliability of the goods and ecosystem services provided by natural systems are directly affected by **the** health of those systems.

Principle II—The long-term functioning and health of terrestrial, freshwater, coastal and marine ecosystems are influenced by their relationships with human society.

Concept a. Direct and indirect changes to natural systems due to the growth of human populations and their consumption rates influence the geographic extent, composition, biological diversity, and viability of natural systems.

Concept b. Methods used to extract, harvest, transport and consume natural resources influence the geographic extent, composition, biological diversity, and viability of natural systems.

Concept c. The expansion and operation of human communities influences the geographic extent, composition, biological diversity, and viability of natural systems.

Concept d. The legal, economic and political systems that govern the use and management of natural systems directly influence the geographic extent, composition, biological diversity, and viability of natural systems.

Principle III—Natural systems proceed through cycles that humans depend upon, benefit from, and can alter.

Concept a. Natural systems proceed through cycles and processes that are required for their functioning.

Concept b. Human practices depend upon and benefit from the cycles and processes that operate within natural systems.

Concept c. Human practices can alter the cycles and processes that operate within natural systems.

Principle IV—The exchange of matter between natural systems and human societies affects the long-term functioning of both.

Concept a. The effects of human activities on natural systems are directly related to the quantities of resources consumed and to the quantity and characteristics of the resulting byproducts.

Concept b. The byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect.

Concept c. The capacity of natural systems to adjust to human-caused alterations depends on the nature of the system as well as the scope, scale, and duration of the activity and the nature of its byproducts.

Principle V—Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.

Concept a. The spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions.

Concept b. The process of making decisions about resources and natural systems, and how the assessment of social, economic, political, and environmental factors has changed over time.

The glossary presented in Appendix A provides an introduction to key words and terms that are essential to understanding these Environmental Principles and Concepts.

In Appendix 2, the *2016 Science Framework* provides diverse examples of how teachers can make connections between the EP&Cs and all three dimensions of the CA NGSS, “by focusing instruction on the environment of their local community and the issues that it faces.” Table 2 shows examples of these connections.

Table 2: Examples of Instructional Connections Between the EP&Cs and the CA NGSS

EP&C	CA NGSS
Principle I The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.	LS4.D: Biodiversity and Humans "Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling."
Principle V Decisions affecting resources and natural systems are based on a wide range of considerations and decision-making processes.	ETS1.B Developing Possible Solutions "When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts."

Instructional Focus of this Exemplar

This Exemplar specifically relates to the Grade 6-7[1] three-dimensional content within:

- **MS-LS1: From Molecules to Organisms: Structures and Processes**
  - MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- **MS-ESS3: Earth and Human Activity**
  - MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

From the perspective of the Category 1 requirement for incorporating the EP&Cs into California instructional materials, as exemplified in Appendix 2 of the *2016 Science Framework*, instruction needs to go beyond the "basics" of the three-dimensional content encompassed in Performance Expectations MS-LS1-5 and MS-ESS3-3. High quality instructional materials should also address these concepts:

1. Natural systems, in which organisms live and where they obtain the resources for survival, interact with other systems including human-social systems.
2. Activities and products related to human-social systems generate byproducts which enter natural systems where they have detrimental, beneficial, or neutral influences on the viability of those systems, as well as the growth of the organisms that live there.
3. Cause and effect relationships can be used to predict the effects on natural systems of activities and products related to human-social systems.

[1] MS-LS1-5 appears in the California Science Framework with the Grade 6 Integrated Model and Grade 7 Discipline-Specific Model.

4. Criteria and constraints for engineering design solutions should take into account the spectrum of considerations and decision-making factors that can influence the availability of resources and the viability of natural systems.
5. When taken into account in engineering design solutions, the direct and indirect effects of human activities on natural systems, and on plants and animals (including humans), can be diminished, as can the influence of those activities on the geographic extent, composition, biological diversity, and viability of those natural systems.

Appendix 2 of the *2016 Science Framework* identifies these examples of specific connections to the Disciplinary Core Ideas:

MS-LS1: From Molecules to Organisms: Structures and Processes and **California's EP&Cs:**

> "As students learn that "Genetic factors as well as local conditions affect the growth of the adult plant" **(LS1.B)**, they should be developing an understanding:
>
> > "that the expansion and operation of human communities influences the geographic extent, composition, biological diversity, and viability of natural systems" **(Principle II Concept c)**
> >
> > and
> >
> > "that the byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect" **(Principle IV Concept b)**.

MS-ESS3-3: Earth and Human Activity and **California's EP&Cs:**

> As students learn that "Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise" **(ESS3.C)**, they should be developing an understanding:
>
> > "that the expansion and operation of human communities influences the geographic extent, composition, biological diversity, and viability of natural systems" **(Principle II Concept c)**.

MS-ETS1 Engineering Design can be integrated into opportunities for students to apply what they are learning in connection with **ESS3-3** and **California's EP&Cs:**

> "As students recognize that "There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem" **(ETS1.B: Developing Possible Solutions)**, they "should be developing an understanding of:
>
> > "the spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions" **(Principle V Concept a)**.

Learning Objectives and Direct Connections to the EP&Cs for this Exemplar

Lesson Series 1: Products and Byproducts

Learning Objective

Students explain that human-made products and activities produce byproducts, and describe how those byproducts can enter natural systems.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs IV.b. and II.c.** with the CA NGSS three-dimensional content through a student investigation of the byproducts produced by human activities and how they enter local natural systems.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems
CCCs: Cause and Effect; Systems and System Models
SEP: Obtaining, Evaluating, and Communicating Information

Lesson Series 2: Byproducts and Natural Systems

Learning Objective

Students identify examples of byproducts from human activities and products that enter natural systems, and they gather, read, and synthesize information about them.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs IV.b. and II.c.** with the CA NGSS three-dimensional content through a student investigation of the direct and indirect changes to environmental conditions that result from the byproducts of human activities and products entering natural systems.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems
CCCs: Cause and Effect; Systems and System Models
SEPs: Obtaining, Evaluating, and Communicating Information; Constructing Explanations and Designing Solutions.

Lesson Series 3: Byproducts—Good or Bad?

Learning Objective

Students construct an argument that the byproducts of human-made products and activities that enter natural systems may have beneficial, neutral, or detrimental influences on local conditions that affect the growth of plants.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs IV.b. and II.c.** with the CA NGSS three-dimensional content through a student-designed experiment that investigates the environmental changes caused by the byproducts of human activities and the beneficial, neutral, or detrimental influences of byproducts on the growth, survival, and reproduction of organisms.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems
CCCs: Cause and Effect; Systems and System Models
SEP: Constructing Explanations and Designing Solutions

Lesson Series 4: Criteria and Constraints

Learning Objective

Students develop criteria and constraints for selecting design solutions that minimize the effects on plant growth of the byproducts of human activity, while taking into account the spectrum of factors considered in making decisions about natural systems.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs V.a., IV.b., and II.c.** with the CA NGSS three-dimensional content through an engineering design process in which students develop and evaluate criteria and constraints that take into account the spectrum of considerations in making decisions about natural systems that that directly and indirectly influence plants and animals (including humans).

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems; ETS1.A Defining and Delimiting Engineering Problems
CCCs: Cause and Effect; Systems and System Models
SEP: Constructing Explanations and Designing Solutions

Lesson Series 5: Engineering Design Solutions

Learning Objective

Students design a method for monitoring and minimizing the direct and indirect effects, on plants and animals (including humans), of the byproducts of human-made products and activities entering natural systems.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs V.a., IV.b., and II.c.** with the CA NGSS three-dimensional content through a student-designed engineering solution that minimizes the effects of the byproducts of human-made products and activities on campus and local natural systems. The solution is designed to address the criteria and constraints related to the problem, as well as the decision-making factors related to environmental sustainability.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems; ETS1.A Defining and Delimiting Engineering Problems; ETS1.B: Developing Possible Solutions
CCCs: Cause and Effect; Systems and System Models
SEP: Constructing Explanations and Designing Solutions

Appendices B, C, and D of this document present further details about connections to CA NGSS, Common Core State Standards, and the EEI Model Curriculum:

Appendix B: Connections to the EP&Cs Identified in Appendix 2 of California's *2016 Science Framework* for the PEs, DCIs, CCCs, and SEPs

Appendix C: California Common Core State Standards Connections in Exemplar

Appendix D: Instructional Resources Curriculum that Can be Used to Support Implementation—identifies instructional resources from California's Education and the Environment Initiative (EEI) model curriculum which may be used by teachers in conjunction with this Exemplar.

Lesson Series 1: Products and Byproducts

Learning Objective

Students explain that human-made products and activities produce byproducts, and describe how those byproducts can enter natural systems.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs IV.b. and II.c.** with the CA NGSS three-dimensional content through a student investigation of the byproducts produced by human activities and how they enter local natural systems.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems
CCCs: Cause and Effect; Systems and System Models
SEP: Obtaining, Evaluating, and Communicating Information

Procedures

Engage and Explore:

> "Outdoor and environmental learning experiences are powerful tools for implementing key instructional shifts required by the CA NGSS and California's Environmental Principles and Concepts (EP&Cs)." (*California Science Framework, Chapter 11 Instructional Strategies for CA NGSS Teaching and Learning in the Twenty-first Century*)

1. Tell students that they will be exploring outside and inside the school building, looking for human-made products and activities that might affect the environment. Ask, "What examples of human-made products or activities that might affect the environment can you think of?" Introduce **Human-Made Products and Activities (Chart 1)** for students to record data. Draw this chart on chart paper to record class findings.

2. Have students copy **Human-Made Products and Activities (Chart 1)** into their science notebooks. Review the column labels on the chart to focus their exploration, and explain that in the first half of the lesson series they will record their findings in the boxes under Columns 1, 2, and 3. Note that they will address Column 4 and add Columns 5 and 6 in the second half of the lesson series. (*Note:* A sample completed version of this chart is provided later in this lesson series.)

   On the chart paper and in students' science notebooks, leave space for adding the term "*Byproducts*" later.

Chart 1: Human-Made Products and Activities

Human-Made Products or Activities that Might Affect the Environment	Where Observed	Amount of Each Byproduct Observed	Natural Resources/Raw Materials Used in Making the Products/Activities		
Activity:					
Products Used in This Activity:					
[Byproducts:] (A*dd this in Step 11.*)					
Activity:					
Products Used in This Activity:					
Activity:					
Products Used in This Activity:					

3. Have students label two more pages in their science notebooks—the first "**Campus Map**" and the second "**Inside Our School Building Map**." Explain that, as they explore, they should mark the locations on campus or in the school building where they observed human-made products or activities that might affect the environment. (*Note:* Post two sheets of chart paper for students to create maps when they return to the classroom, of the areas on campus and in the school building that they explored.)

4. Either as a whole class or in two groups, have teams of students explore (1) outside on campus and (2) inside the school building, and record their findings in Columns 1, 2, and 3 in their science notebooks.

> This lesson series begins with an <u>outdoor environmental learning experience</u> that introduces the environmental factors that can influence the growth of organisms (**LS1.B**). Students will explore the local conditions that can affect the growth of an adult plant. It thereby reinforces their understanding that the byproducts of human activity are not readily prevented from entering natural systems (**EP&Cs Principle IV Concept b)**.

Explore and Explain:

5. When the class has reconvened, have teams report their discoveries. Record the information on the class chart (Columns 1, 2, and 3), and have students note on the wall maps where these products and activities were observed. Have all students enter the class data in their science notebooks in the **Human-Made Products and Activities Chart,** the **Campus Map,** and the **Inside Our School Building Map**.
6. Have students label Column 4, "**Natural Resources/Raw Materials Used in Making the Products/Activities**." Have them work with a partner to identify natural resources and raw materials they think were used to manufacture or produce the "products" identified in Column 1, and enter their ideas in Column 4 in their science notebook. Discuss as a class and come to agreement, then add these natural resources and raw materials to the consensus-based class chart.
7. After the observations are recorded, ask students about the products they observed, with questions such as, "What were the natural resources used to make the products?," "Where did they come from?," "How were they extracted, harvested, and transported?," "How are they used?," and so on.
8. As the class discusses where the different natural resources came from (e.g., forests, rivers, mountains), ask students to volunteer examples of local natural systems that they are familiar with. (*Ponds, rivers, ocean, forests, deserts, etc.*) On the board, write the term *natural systems.* Facilitate a class discussion about the term and guide students through the process of developing their own definition, including the main aspects of natural systems. *(Natural systems: The interacting components, processes, and cycles within an environment, as well as the interactions among organisms and their environment.)* Have them enter their definition in their science notebooks.
9. Ask if any students are familiar with the word *consumption.* Have pairs of students discuss and develop definitions for this term. *(Consumption: The process of obtaining and using energy and matter from a natural system, such as using timber to build a house, or petroleum to fuel a car or produce plastic.)* Have students share their definitions, then develop a "consensus" class definition, and have students enter this into their science notebooks.
10. Ask this guiding question: "When people obtain energy or produce and consume something from a natural resource, is everything 'used up' or is

> This introduces students to some of the environmental factors, resulting from human activities, that can influence the health and viability of natural systems. **(EP&Cs Principle II a, b, c)**

there usually some extra material or something that is discarded in the process?" Following discussion about this question, ask if anyone is familiar with a word that describes the extra material and/or what is discarded. *(Waste.)* Ask student pairs to identify one or more waste items from one of the human activities or products they saw on campus. Have students share, then guide the discussion to introduce the term "*byproduct." (Byproduct: Something, such as waste materials or chemicals, produced when something else is manufactured or consumed*.)

11. Have students add the term "Byproducts" in the blank space in Column 1. Working with their partner, ask them to identify at least two byproducts that result from the products and human activities they found in school or on the campus.

    Have students label Column 5 "**Problems that Might Result from Using the Product or the Resulting Byproducts"** on Chart 1 in their science notebooks and add it to the class chart. Ask students to brainstorm and share examples of possible problems that might result on campus from the use of human-made products and the associated activities. (*Note:* Most of these "problems" result from humans consuming, using, and disposing of a product, producing litter and/or pollution.) Have students complete Column 5 in their science notebooks.

    This introduces students to some of the effects of human activities, that can influence the health and viability of natural systems. **(EP&Cs Principle II a, b, c)**

    It may be helpful to check for students' awareness of terminology such as *pollution* and *waste*, and discuss the meaning of these terms. *(Pollution: The contamination of the environment (including air, water, and soil) with chemicals or other damaging materials.) (Waste: Undigested foods and liquids that are not used by the body and are expelled; or, materials and products that humans cannot use*.)

Elaborate:

12. Ask, "What effects do you think the byproducts and waste you saw in school or on campus have in our community or local natural systems?" Facilitate a class discussion and make notes on the board.

13. On Chart 1, label Column 6 "**Possible Effects on Natural Systems of Using the Product or Resulting Byproducts"** and have students do the same in their science notebooks. Ask pairs of students to discuss and report out one or two ideas they have of possible effects on natural systems of using or consuming products or producing the byproducts identified in Column 1. For example, polluted air can cause breathing problems for children and adults. (*Note:* See additional examples below.)

14. Following this discussion, have student pairs complete Column 6 in their science notebooks. Have teams share their findings, then lead a class discussion and enter information into Column 6 of the class chart on the board. Then have students add new information and correct any errors in their science notebooks.

Chart 1 (Completed Sample, Steps 5–14): Human-Made Products and Activities

Human-Made Products and Activities That Might Affect the Environment	Where Observed	Amount of Each Byproduct Observed	Natural Resources/Raw Materials Used in Making the Products/Activities	Problems that Might Result from Using the Product or the Resulting Byproducts	Possible Effects on Natural Systems of Using the Product or the Resulting Byproducts
Activity: Food services, providing breakfast, lunch, and snacks	• cafeteria • classrooms • playground • park		• plants • animals • water • wood materials (paper products) • petroleum (plastic and transportation)	• littering • overflowing trash cans • food packaging and food waste on the floor in the cafeteria and on campus	• Litter on campus, may be blown into the garden area, and may not decompose for a long time • Litter in the garden may affect the growth and survival of plants • If not properly collected and disposed of or recycled, will end up in landfills • Litter may pollute water and affect other places (habitats) where plants live
Products Used in This Activity: Food, water, paper plates, plastic utensils, napkins, etc.					
Byproducts: "Waste" food, plastic bottles, wrappers, drink boxes, straws, packaging materials, extra food, milk cartons, food wrappers, etc.		• plastic bottles: 20 • drink boxes: 6 • straws: 8 • food wrappers: 25			
Activity: Transportation	• parking lot • streets near school • highways • stream • storm drains			• pollution from moving or idling cars, buses, etc. • oil on the ground in parking lots • polluted water from oil and rubber running into storm drains	• dirty, smelly polluted air can cause breathing problems for children and adults • oil and rubber that gets into storm drains can pollute water in rivers, marshes, bays, and oceans and harm plants and animals
Products Used in This Activity: Oil, gasoline, rubber, steel, plastic, etc.					
Byproducts: Odor from exhaust, oil, rubber, dirty water, smog, etc.		• Some cars and buses emit "clouds" or smelly air • Lots of oil spots on driveway and in streets • Many patches of rubber on the driveway and streets			

15. Have teams select one example of a "Byproduct" from Column 1 and use data from the chart to write 2–3 sentences in their science notebooks to answer this prompt: "How can the consumption, use, and disposal of human-made products result in byproducts in school and on campus?" [Example: *Drink boxes, straws, and plastic bottles are found in the cafeteria, classrooms, hallways, and outside on campus. Students and visitors may drop them without thinking or just don't bother taking them to the trash and recycling containers.*]

> An understanding of the interactions and interconnections between natural systems and human social systems is essential to developing students' knowledge of the EP&Cs.

16. If needed, review the term "*natural systems.*" Then, have students use data from their chart to write 2–3 sentences in their science notebooks to answer this question and share responses with the class: "If the byproducts you identified are not disposed of properly, how might they affect natural systems in and around our school?" [Example: *If these byproducts are not disposed of properly, they can enter natural systems, such as through storm water runoff. Water that flows over the ground and into streams and rivers will wash waste down storm drains and flow to the river or ocean*; *waste will pile up in areas where plants grow, preventing the Sun's energy from reaching the plants, and can harm animals that may eat the materials or get caught, for example, in plastic rings. If not collected for recycling, additional resources will need to be gathered or harvested to make more products. If transported to landfills, there are still ways for the "byproducts" to enter natural systems.*]

Explore and Explain:

17. As a community investigation, instruct students to create a new chart, **Byproducts from Human Activities in Our Community (Chart 2),** in their science notebooks. This is a duplicate of Chart 1, but with observations in the community rather than at school. Tell them to make observations on the way home of one or two "**Human-Made Products and Activities That Might Affect the Environment,**" and complete one or two rows.

> This community investigation provides an opportunity for a formative assessment of students' developing understanding of EP&Cs Principle II Concept c and Principle IV Concept b.

18. Tell them that, based on their observations in this new chart, they should write one or two paragraphs that describe what they observed, specifically including information about:
    - The byproducts they observed
    - Where they observed the byproducts
    - The quantities of different byproducts
    - The human activities that produced the byproducts (cause and effect)
    - The natural resources used to produce the products that resulted in the byproducts
    - The potential effects these byproducts could have if they enter natural systems

Example of Student Writing:

It was raining when we drove home from school. My friend and I passed a convenience store next to a vacant lot that was close to a storm drain. There was a lot of trash (paper [from plant materials] and plastic [from petroleum materials]) in the vacant lot and in the parking lot. The heavy rain caused the trash and mud to move off the vacant lot into the parking lot and street. As it moved out into the street it flowed toward a large storm drain. Some of the waste was small enough to go down the drain. I think that some chemicals from the waste and mud (which we could not see) also went down the drain. My friend and I didn't know where the water would flow so we looked it up on the internet and found out that it eventually flows to the local river. We think that this must be bad for the river and want to do some research to find out what effects this pollution can have on the plants and animals that live in the river.

Lesson Series 2: Byproducts and Natural Systems

Learning Objective

Students identify examples of byproducts from human activities and products that enter natural systems, and they gather, read, and synthesize information about them.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs IV.b. and II.c.** with the CA NGSS three-dimensional content through a student investigation of the direct and indirect changes to environmental conditions that result from the byproducts of human activities and products entering natural systems.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems
CCCs: Cause and Effect; Systems and System Models
SEPs: Obtaining, Evaluating, and Communicating Information; Constructing Explanations and Designing Solutions.

Procedures

Explain and Elaborate:

1. Copy **Human-Made Products and Activities in Our Community (Chart 2)** on chart paper.

Chart 2: Human-Made Products and Activities in Our Community

Human-Made Products and Activities That Might Affect the Environment	Where You Observed	Amount of Each Byproduct Observed	Natural Resources/Raw Materials Used in Making the Products	Problems that Might Result from Using the Product or the Resulting Byproducts	Possible Effects on Natural Systems of Using the Product or the Resulting Byproducts
Activity:					
Products Used in This Activity:					
Byproducts:					
Activity:					
Products Used in This Activity:					
Byproducts:					
Activity:					
Products Used in This Activity:					
Byproducts:					

2. Have students share what they observed on the way home or in their community. Ask volunteers each to complete one row of **Human-Made Products and Activities in Our Community (Chart 2),** starting with "Human-Made Products and Activities That Might Affect the Environment." Ask the class if they see any interesting patterns or findings on the chart. Do the findings raise any questions? Note students' comments and contributions on the class chart, then facilitate a class discussion and work with them to revise their statements and add new observations. Have students record their own observations as well as those of other students in their science notebooks.

> Environmental topics and issues comply with one of the three Key Instructional Shifts identified in the 2016 Science Framework. "CA NGSS instruction is:… Relevant to local communities and student interests." (*California Science Framework, Chapter 1 Overview of the CA NGSS*)

3. Post **Human-Made Products and Activities (Chart 1)** to the side of **Chart 2**. Ask the class to review both charts and compare what they observed on campus and in their communities. Have them start by looking for similarities and differences in the data, recorded in Column 1, between campus and community. Have students discuss with a partner, "What can we conclude from these observations/findings regarding human activities and byproducts entering natural systems?" (For example: *Most human activities result in byproducts that can be found both where they were produced [e.g., litter on campus, oil dripping from cars onto a driveway] and in other places where they may have been moved [e.g., litter and oil from campus or a driveway flowing into a storm drain].)*

4. Ask students to brainstorm other human activities that produce byproducts. Record their responses on the board.

Explore and Explain:

5. Explain to students that they will be watching a series of 2–3 minute video clips in which they will be able to observe a variety of examples of the byproducts of human-made products and activities entering into and affecting natural systems. Show videos that present examples of water pollution, air pollution, dumping of waste, and/or conversion of land from one use to another (e.g., Illegal Dump Cleanup; Keeping California Water Clean; or Clearing California Skies).

> This introduces students to the movement of the byproducts of human activities into natural systems, and initiates their understanding of how these byproducts can influence the health and viability of natural systems (EP&Cs Principle IV b).

6. Ask volunteers to describe what they observed in the videos, including different types of byproducts, how the byproducts entered the natural systems, and the effects of the byproducts on the natural systems and the organisms that live there. Record responses on the class chart. Open the discussion to other student observations about byproducts.

7. Tell students that, based on this discussion, they will have an opportunity to investigate byproducts further. Instruct them that they will work with a partner to select one of the videos and gather more detailed information about the human-made product/activity, and the resulting byproducts that are entering the natural system. Have students make a chart

in their science notebook, like the sample below, **Byproducts and Impacts on Natural Systems (Chart 3)**. They can watch the selected video again if needed.

Chart 3: Byproducts and Impacts on Natural Systems

Human-Made Products or Activities	Byproducts and Impacts on Natural Systems
Transportation: • Idling vehicles (cars, buses in school parking lot), school buses or families taking students home	• Exhaust from idling vehicles, cars and trucks moving causes air pollution • Oil on the ground carried by rain and other water activities to storm drains—water pollution
Littering: • Littering in schools, buildings, highways, construction sites; overflowing garbage cans at high school football games and at the mall	• Waste, excess packaging materials: plastic bottles, wrappers drink boxes, straws—land pollution • Unconsumed foods, drinks—land pollution • Runoff—water pollution
Water Usage: • Daily usage for variety of purposes: construction, manufacturing, agriculture, business activities, government, family homes, schools (e.g., school sprinkler system or hoses on playground in school parking lot); people washing cars, cleaning driveways • Runoff from campus and from local farmers' fields (may include pesticides or herbicides or oil from tractors) into storm drains, ponds, etc. • Water flowing, picking up oil, chemicals, and trash	• Wastewater, e.g., containing detergents, chemicals from washing cars, sidewalks, etc., flowing into streets and storm drains—water pollution

Explore:

8. Explain to students that they will work in teams of 3–4 to undertake a research project about byproducts of human activities entering and influencing natural systems. Have students work in teams to choose topics from among the phenomena they observed on campus, in their community, or in the videos. The research topics teams choose will depend on their individual interest and observations. For example:

    - Pollutants entering storm drains can move into bodies of fresh water and saltwater. The resulting pollution can decrease plant growth, which in turn can affect the growth and survival of the animals that feed on the plants.
    - Pesticides and herbicides used in agriculture and gardening can get into the air, water, and soil. The resulting pollution can affect the growth of the plants and animals that live in the water and soil, or breathe the polluted air.
    - Exhaust from vehicles, particulates from factory smokestacks, and smoke from forest fires can result in air pollution that decreases the growth and survival of plants and/or animals.

- Soil erosion from activities like the construction of homes, roads, shopping centers, and conversion to farmland, can result in the loss of topsoil and nutrients, resulting in decreased growth of plants.
- Disposal of paper, plastics, toxic substances, and food can enter aquatic environments where they may kill plants and animals, or they may be disposed of on land in waste piles that will slowly decompose and may release damaging chemicals.

Have teams share their research ideas with the class.

9. Once teams have identified their research topics, explain that the goal of their research is to identify byproducts flowing from human-made products or activities into natural systems, and how those byproducts affect the systems and the organisms that live there.

   Present them with a list of the aspects they need to research, including:

   - The human-made product or activity under investigation
   - How the byproducts result from the product or activity (e.g., extraction, harvesting, manufacturing, transportation, or consumption)
   - How the byproducts enter natural system(s)
   - The effects of byproducts on the natural systems which they enter
   - How the byproducts affect the survival and growth of organisms (plants and/or animals)

   Lead a class discussion about the types and sources of information students will need to complete this research. (*Note:* If it has not been previously discussed, have a class discussion about appropriate sources of "scientific information," so that students can do a basic evaluation of the quality of information they are collecting.)

10. Review the established class research guidelines and protocols, discuss the timeline for gathering data, and summarize how they will be sharing their findings. Have students create a "Research" section in their science notebooks to record their findings, including these headings: "Focus of Research," "Human-Made Products and Activities," "Byproducts," "How Byproducts Enter Natural Systems," "Effects of Byproducts on Natural Systems," "Effects of Byproducts on Growth of Organisms," and "Information Sources."

11. Explain that teams will share research responsibilities and that each team member will conduct his/her own component of the research, including:

    - Gathering relevant information from multiple print and digital sources (primary and secondary)
    - Drawing evidence from informational texts to support analysis, reflection, and research
    - Citing specific textual evidence to support analysis of science and technical texts
    - Analyzing and summarizing data to share with teammates
    - Writing arguments based on available evidence

12. Guide the teams throughout the process of data collection and analysis, as well as writing their evidence-based arguments.

13. Explain that they will be sharing their presentations during a Gallery Walk during which they identify problems; present ideas, documents, and images, and identify information sources; suggest potential solutions; and share their findings. Provide guidance as they prepare their presentations.

Explain:

14. Conduct a Gallery Walk for students to share their findings with the class.
15. Following the Gallery Walk, lead a class discussion by asking, "What were some of the examples in our shared research about how byproducts can affect the growth of plants?" (For example: *Oil from the driveway was washed into the creek and covered the leaves of some of the plants. This killed some of the leaves and appeared to decrease the amount of vegetation in the area.*)

    Record students' ideas on the board and have them record conclusions in their science notebooks.

    Mention that during the next lesson series, students will be designing and conducting an experiment about how some of the byproducts of human activities can affect plant growth.

Lesson Series 3: Byproducts—Good or Bad?

Learning Objective

Students construct an argument that the byproducts of human-made products and activities that enter natural systems may have beneficial, neutral, or detrimental influences on local conditions that affect the growth of plants.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs IV.b. and II.c.** with the CA NGSS three-dimensional content through a student-designed experiment that investigates the environmental changes caused by the "byproducts" of human activities and the beneficial, neutral, or detrimental influences of byproducts on the growth, survival, and reproduction of organisms.

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems
CCCs: Cause and Effect; Systems and System Models
SEP: Constructing Explanations and Designing Solutions

Procedures

Engage:

This introduces students to the idea that the effects of human activities on natural systems are not all negative, but in some cases, may be beneficial or neutral **(EP&Cs Principle IV b)**.

1. Tell students that, although they have so far focused on human activities' *negative* impacts on natural systems and organisms, there are many examples where human activities can be beneficial. Lead a class discussion with the prompt, "What are some of the human-made materials and activities that can *positively* influence natural systems and organisms?" (For example: *Adding fertilizer to soil, removing litter from campus, cleaning oil from a driveway, reducing exhaust emissions near the school.*) Record students' ideas on a class chart under the header "Human Activities and Materials That Can Benefit the Environment." Have them record ideas in their science notebooks.

Explore and Explain:

2. Discuss with students that, as a follow-up to the research they completed during Lesson Series 2, they are now going to design and conduct an *experiment* focusing on the potential effects of byproducts of human activities, like soapy/foamy water runoff from behind a house, apartment, or business flowing into an area with plants (such as a garden, pasture, or wooded area). Remind students that there are many other examples of how human activities can benefit the environment, such as restoring soils that have been eroded, thereby increasing the growth of plants in natural systems.

3. Tell students that they will be working in teams to investigate how byproducts and human activities can affect the growth of plants in natural systems.

   > Developing students' knowledge that the effects of human activity may be beneficial, neutral, or detrimental is an important element of **EP&Cs Principle IV b**.

   Give students time to work in their teams to select a *research topic*. After they have selected a topic, guide them in the process of developing a *research question,* for example, "Do detergents in the water supply affect plant growth?" (**Note**: Research topics are large and can only be answered by addressing a series of research questions. Research questions should be focused at the level which students can feasibly explore through experiments and observations. To strengthen their skills in Planning and Carrying Out Investigations, the experiments and observations should be designed by the students.)

4. Review the research topics and questions as a class, and allow students the opportunity to make suggestions to each other. Record students' ideas on the board. Have teams record their chosen research topic and research question in their science notebooks.

5. Initiate a discussion of class guidelines and protocols for designing and conducting experiments safely. Then have students develop a consensus about the components that they will all include in their experiments. Record students' ideas on the board and have them make a record in their science notebooks.

6. Instruct students to work in their teams to summarize their experimental plans in their science notebooks, including:

   - research topics
   - research questions
   - experimental design
   - materials
   - procedures
   - data to be collected
   - data analysis plans

   Remind students that the purpose of their experiments is to help the class determine the effects (negative, beneficial, or neutral) of the byproducts of human activities on the growth of plants. Mention the importance of taking great care as they conduct their experiments and collect their data, because they will use their findings as the basis for constructing written arguments about their results and conclusions.

   Summarize the timeline for designing, conducting, and analyzing data.

   Once all of the teams' plans have been reviewed and approved, support students as they undertake their experiments, including helping them obtain supplies, identify the plants they will be working with, etc.

7. When students have completed their experiments, and recorded and analyzed their data, guide them in selecting an appropriate way to display their numerical data.

8. Have teams report to the class on the results of their experiments in presentations or a Gallery Walk. Record students' research results on the board and have students make a record in their science notebooks.

Elaborate:

9. Conduct a class discussion to remind students of the important elements of written arguments and scientific explanations. Then, explain that they will be constructing an argument based on the evidence they have gathered in the lessons thus far.
10. Introduce the prompt, "Support or refute this statement: Some of the byproducts of human activities, such as pollutants, can be detrimental to plant growth, while other human activities can positively influence the viability of natural systems and organisms." Give students time to write an argument responding to this prompt.
11. When students have completed their writing assignment, have them share their arguments through a class discussion, poster session, newsletter, or Gallery Walk.
12. Tell students that in the next lesson series, they will identify a problem that relates to their local observations, and they will design potential solutions that could help to minimize the effects of human activities and byproducts on plant growth.

Lesson Series 4: Criteria and Constraints

Learning Objective

Students develop criteria and constraints for selecting design solutions that minimize the effects on plant growth of the byproducts of human activity, while taking into account the spectrum of factors considered in making decisions about natural systems.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs V.a., IV.b., and II.c.** with the CA NGSS three-dimensional content through an engineering design process in which students develop and evaluate criteria and constraints that take into account the spectrum of considerations in making decisions about natural systems that that directly and indirectly influence plants and animals (including humans).

CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems; ETS1.A Defining and Delimiting Engineering Problems
CCCs: Cause and Effect; Systems and System Models
SEP: Constructing Explanations and Designing Solutions

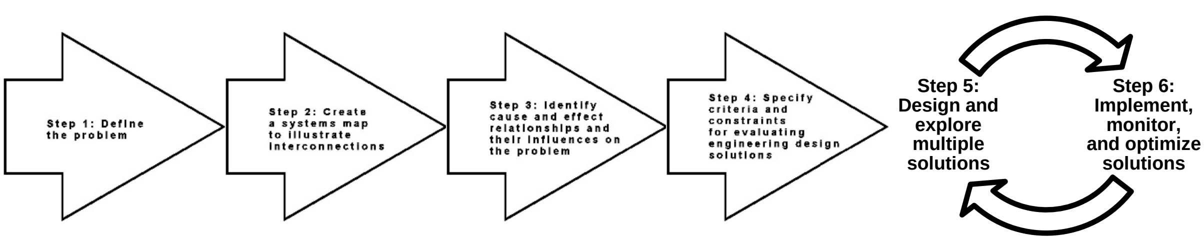
Procedures

Engage and Explore:

1. Initiate a discussion to review students' understanding of the key elements of the engineering design cycle: defining the problem, developing solutions, and optimizing a solution.

   If a review is needed, display a diagram of the engineering design cycle like the one below.

   Students should have examined the engineering design cycle in earlier grades; however, their understanding may need to be strengthened.



2. In Lesson Series 5, students will work on all the steps of this cycle. The focus of this lesson series is on understanding *criteria* and *constraints* (Step 4). Tell students that once a problem has been identified and defined, even if it is a very simple problem, it is necessary to identify the *criteria* and *constraints* by which the success of a solution will be determined.

   Discuss the term "*criteria*": if students are familiar with this term, record their initial ideas on the board and have them make a record in their science notebooks; if they are not familiar with the term, start the conversation with an example, such as asking, "What things would you consider when you are making decisions about what to plant in a garden?"

Continue to discuss until students have a clear understanding that the term criteria describes "how we evaluate possible solutions to a problem, the desired features of a successful design, plan, or engineering solution, and what we want our solution to achieve."

Ask students what criteria would be important for evaluating competing engineering design solutions. Be sure they identify that in planning design solutions, they should take into account the potential impacts of the solution on people and the natural environment.

Planning Engineering Design Solutions:

3. Explain that in this lesson they will be examining the concept of *criteria* through an engineering design problem related to minimizing the amount of potentially harmful laundry detergent that gets released into the environment.

> Environmental topics and issues provide engaging opportunities for students to engage in Problem-Based Learning activities. These problems should engage them in solving challenging problems with real-world applications. "Problem-based learning (PBL) is particularly well suited to the CA NGSS" (*California Science Framework, Chapter 11 Instructional Strategies for CA NGSS Teaching and Learning in the Twenty-first Century*)

Ask students to record in their science notebooks their initial ideas about how engineering design strategies and criteria apply to solving problems related to the byproducts of human activities entering into natural systems. They can refer back to human activities discussed in previous lessons if desired.

Have a few students share their ideas, then present this scenario:

The Willbeclean Laundry Detergent Company has discovered that some of the laundry detergents it produces are entering the local environment and damaging some of the plants in local streams and lakes. The company has hired our class to design a way to keep clothes clean that minimizes the amount of potentially harmful laundry chemicals released into the environment.

Ask the class to brainstorm a list of criteria to consider when they are developing a design solution for this laundry detergent problem. (For example, the solution should: *clean clothes effectively; keep costs low; be safe to use; etc*.) Record students' ideas on the board and have them record in their science notebooks.

4. Ask students to think back to their experiment from Lesson Series 3 and consider the evidence they gathered about the impacts of byproducts on plants. Share the term "*environmentally sound and sustainable*" and facilitate a discussion about the meaning of this phrase by asking, "What are some of the questions we should ask ourselves to determine if a solution is "environmentally sound and sustainable"?

Have students share their questions, for example:

- Will it reduce the amount of laundry chemicals released into the environment?
- Will the chemicals in the detergent be harmful to plants and animals?
- Will there be any consequences for the viability of the natural environment resulting from implementing the solution? Are the consequences short-term or long-term? Positive or negative?
- Is it likely that the plan will result in impacts to any other natural systems?

- Has the solution been proven effective in other situations?

In their science notebooks, have students record conclusions about the factors that must be considered in determining if a solution is environmentally sound and sustainable.

5. Based on students' responses, ask additional questions, such as, "What are some other factors we need to consider when we are making decisions about resources and natural systems?" For example:
   - Public health effects
   - Laws, regulations, and policies
   - Land ownership
   - Differing views based on culture and socio-economic conditions
6. Facilitate a discussion about the identified criteria by asking, "Did we identify all the different criteria that we will need to develop a successful solution? If not, what other criteria would you add?"

   Post **Criteria for Evaluating Engineering Design Solutions (Chart 4)** and explain that these are some general categories of criteria that can be considered when evaluating engineering design solutions.

Chart 4: Criteria for Evaluating Engineering Design Solutions

1. **Solves the Problem Effectively**
   a. Achieves stated goals and meets the identified needs
   b. Functions in the context in which the problem exists
2. **"Do-able"**
   a. Meets constraints
   b. Technologically feasible
   c. Reliable
3. **Acceptable Costs Compared to Benefits**
   a. Environmentally sound and sustainable
   b. Economically practical and sustainable
   c. Socio-culturally acceptable

Have teams develop specific criteria for any of the categories that they had not previously addressed. (For example, *minimizing the effects of the detergent on natural systems and the organisms that live there.*)

Ask teams to share their new ideas for criteria. Record their ideas on the board and have them record in their science notebooks.

7. Discuss the term "*constraints*": if they are familiar with this term, record their initial ideas on the board and have them record in their science notebooks; if they are not familiar with this term, start the conversation with an example, such as asking, "Thinking back to the idea

of planting a garden, what might limit the size of the garden and what you can plant?" (For example: *available space, water, cost of fertilizer, availability of plants and seeds*.) Continue to facilitate this discussion until they have a clear understanding of the term *constraints* as "the things that limit if a solution can be implemented, such as time, materials, costs, resources, safety concerns, potential negative environmental effects, etc."

This develops students' ability to analyze the diverse factors that influence the impacts of alternative engineering design solutions on environmental health, communities, and natural systems **(EP&Cs Principle V)**.

Ask students to identify other examples of constraining factors, for example, *the needs and hopes of the people involved, possible negative environmental effects, safety considerations,* and so on. Facilitate a conversation about the decision-making factors related to the use of natural systems and resources. If students are not familiar with these factors, help them to focus some of the discussion on legal factors, economic factors, socio-cultural factors, and public health. (**Principle V Concept a:** "There is a spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions.")

8. In their science notebooks, have students record conclusions about the constraints that might limit a solution to an engineering design problem—particularly constraints that must be considered in determining if a solution is environmentally sound and sustainable.
9. In their science notebooks, have students respond to the prompt: "Identify and justify which criteria and constraints are the most important to consider when developing a design solution for the problem of laundry detergents produced by the Willbeclean Laundry Detergent Company entering the local environment and damaging some of the plants in local streams and lakes."

Lesson Series 5: Engineering Design Solutions

Learning Objective

Students design a method for monitoring and minimizing the direct and indirect effects, on plants and animals (including humans), of the byproducts of human-made products and activities entering natural systems.

Direct Connections to EP&Cs

This lesson exemplifies the integration of California's **EP&Cs V.a., IV.b., and II.c.** with the CA NGSS three-dimensional content through a student-designed engineering solution that minimizes the effects of the byproducts of human-made products and activities on campus and local natural systems. The solution is designed to address the criteria and constraints related to the problem, as well as the decision-making factors related to environmental sustainability.

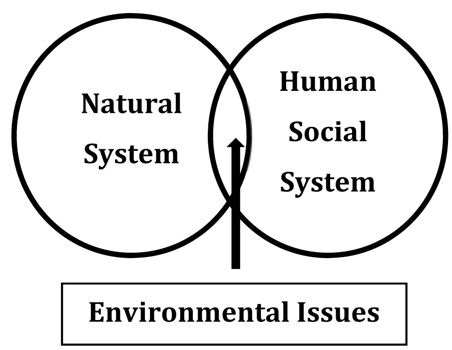
CA NGSS Three-Dimensional Content

DCIs: LS1.B Growth and Development of Organisms; ESS3.C: Human Impacts on Earth Systems; ETS1.A Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
CCCs: Cause and Effect; Systems and System Models
SEP: Constructing Explanations and Designing Solutions

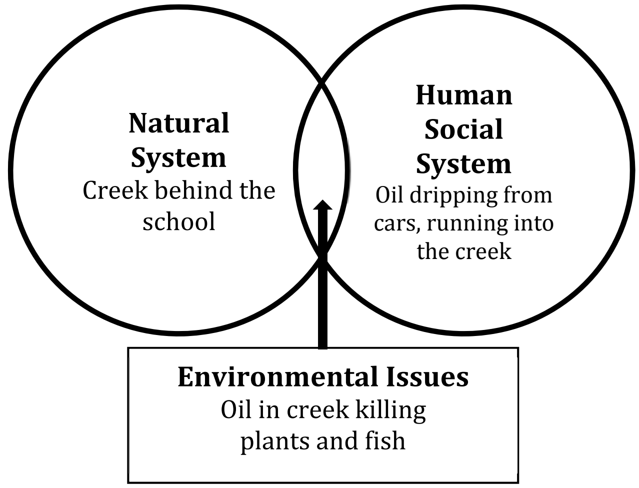
Procedures

Engage and Explore:

1. Ask students to think about the natural and human social systems they have been studying, and discuss when they think detrimental environmental issues occur. If needed, create a diagram on the board like the one here to help students think about the interactions between natural systems and human social systems.



Following the class discussion, have students draw a simple model in their science notebooks, such as this Venn diagram, to represent one of the interactions that they have observed during the past several lesson series.



After completing their Venn diagrams and having a brief class discussion, have students write in their science notebooks responses to the prompt: "What evidence, if any, do you have that environmental issues, like those that arise from the byproducts of human-made products and activities entering natural systems, are most often observed when systems interact?" If necessary, refer them to the results of their experiments during Lesson Series 3, and their findings about the effects of the byproducts of human activities on the growth of plants. (Example response: *In our experiment, when we used a solution of water and laundry detergent to water the plants, over time the leaves changed colors and shriveled—we might see this when pollutants enter natural systems*.)

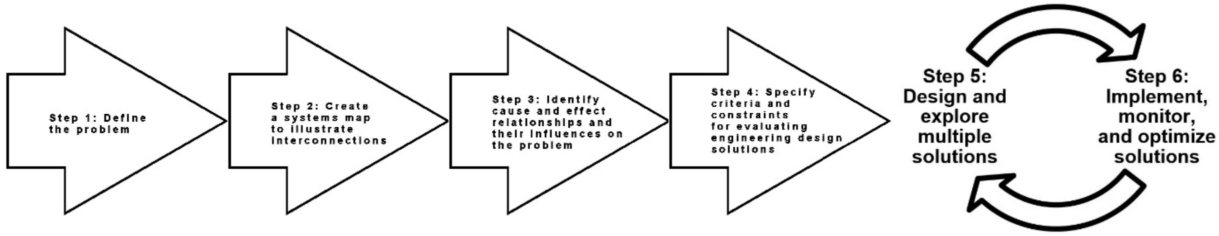
This prompt provides an opportunity for a formative assessment of students' developing understanding of **EP&Cs Principle II Concept c and Principle IV Concept b**.

2. Facilitate a discussion with this prompt: "Do you think that understanding the interactions between natural systems and human social systems would help us develop better engineering design solutions? If so, why?"

Engineering Design Strategies:

3. Explain to the class that they are now going to use what they learned during their campus and community investigations, experiments, studies of environmental problems, as well as engineering design strategies criteria and constraints to design a method for monitoring and minimizing an environmental problem on campus. They will design a strategy to reduce the effects of the byproducts of human activities entering natural systems.
4. Discuss the process of using engineering design strategies to define and resolve problems, as exemplified in the diagram below.

This series of activities involves students in developing engineering design solutions for a local environmental problem that they have identified and studied, thereby applying and strengthening their understanding of the EP&Cs, engineering design, and the three-dimensional content in **MS-LS1-5**: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms; **MS-ESS3-3**: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment; and, **MS-ETS1-1:** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.



Use the procedures below as an example of this process, so that students understand how to work through each step, focused on the campus problem each team will select.

5. **Step 1: Define the problem**

Ask the class how they think they should start the process of identifying the campus problem they want to focus on. Remind them that as they start to identify their team's problem, they should use all available background information.

> Problem-Based Learning activities related to the environment "build on students' existing experience to learn about and solve real-world problems" (e.g., habitat restoration, energy consumption, and waste reduction). (*California Science Framework, Chapter 1 Overview of the CA NGSS*)

Using the campus littering problem as an example, explain that they would focus on the information gathered and recorded in their science notebooks during Lesson Series 1 and 2 in **Human-Made Products and Activities (Chart 1)**, **Human-Made Products and Activities in Our Community (Chart 2)**, **Byproducts and Impacts on Natural Systems (Chart 3)**, as well as their analysis from Lesson Series 1 (in which they wrote about the byproducts they observed; where they observed them; the quantities of different byproducts; the human activities that produced the byproducts [cause and effect]; the natural resources used to produce the products that resulted in the byproducts; and, the potential effects these byproducts could have if they enter natural systems).

Give teams time to work together to choose their campus problem, using the information they collected during Lesson Series 1–3. This problem will be the focus of their efforts to develop an engineering design solution that could achieve the goal of minimizing the impacts of their campus problem on natural systems.

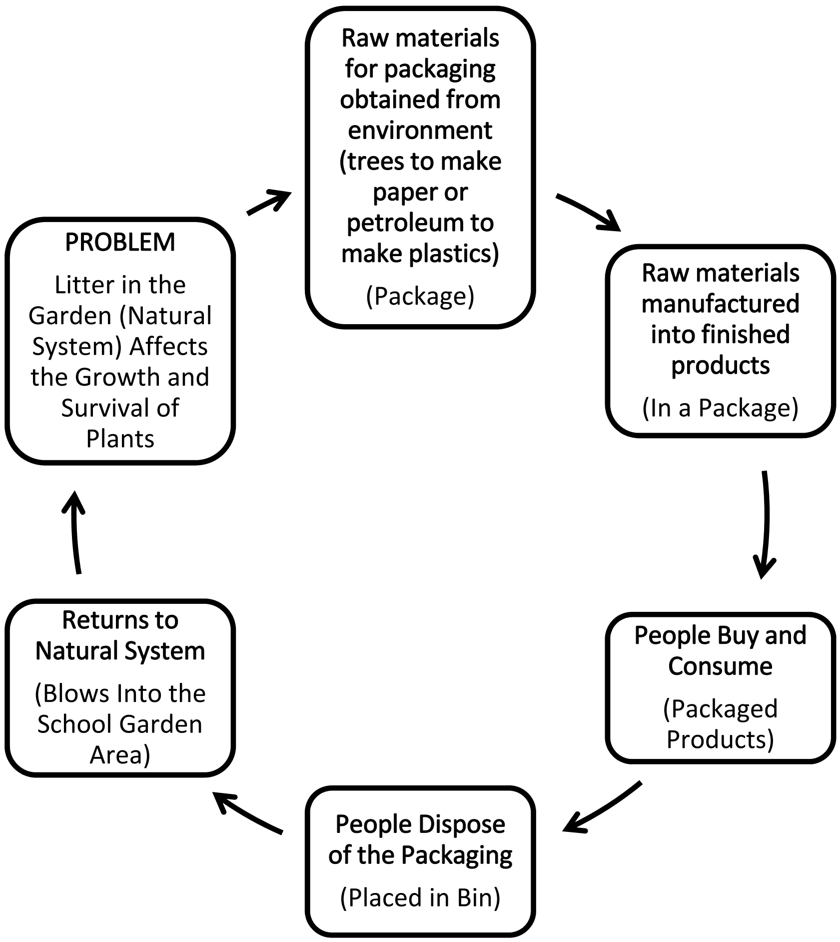
6. **Step 2: Create a systems map to illustrate interconnections**

Begin a class discussion by asking, "How do you think we can model the interconnections and interactions within and between systems?" Suggest that they think back to their earlier studies of food webs. If needed, use a diagram of a food web as an example of a systems map, mentioning that maps like this offer an effective way to model the interconnections and interactions within and between systems.

> Food webs are examined in **5-LS2 Ecosystems: Interactions, Energy, and Dynamics.**

Using the campus littering problem as an example, have the class work together to create a **Campus Littering Problem Systems Map** on the board. Provide the first step in the process by drawing a box that identifies the starting point as harvesting or extracting raw materials from a natural system. Guide the class through the process of identifying the remaining parts of the systems map, concluding with the problem that results from the litter ending up in the school garden area. A **Campus Littering Problem Systems Map** might look like this:

Campus Littering Problem Systems Map



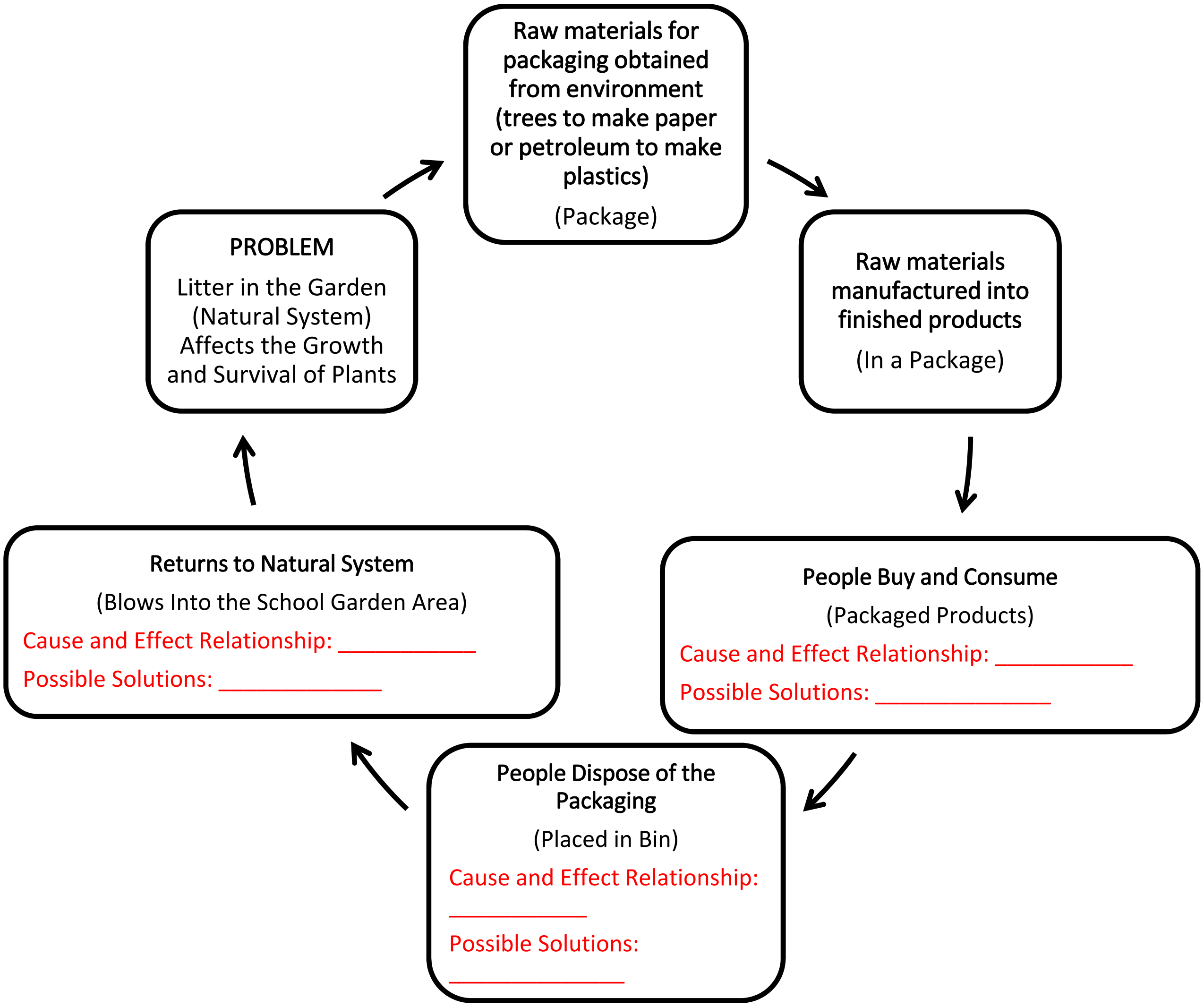
Give teams time to work together to develop a systems map for their selected problem.

7. **Step 3: Identify cause and effect relationships and their influences on the problem**

   Facilitate a class discussion by asking, "How do you think we might be able to use systems maps like the ones you created for your team's campus problem?" Through this discussion, encourage students to make the connection to the crosscutting concept "cause and effect." Then, guide a discussion about using cause and effect relationships as an important aspect in the process of identifying potential problems and developing engineering design solutions.

   On the board, add space on the class **Campus Littering Problem Systems Map** for writing brief statements about relevant "Cause and Effect Relationships"—see the example below. (*Note:* Cause and effect relationships can be identified for each part of the systems map; however, in this example, we have focused on only three parts of the systems map.)

Campus Littering Problem Systems Map
With Cause and Effect Relationships and Possible Solutions



Working as a class, have students identify cause and effect relationships that are related to the indicated stages of the **Campus Littering Problem Systems Map**. For example, based on what they observed on campus, when people bought and consumed packaged products, they disposed of the packaging, then the wind blew some packaging out of the trash bin and into the school garden area. In the school garden area, the litter covered some of the plants, and because they did not get enough sunlight, they were not able to grow. Some of the other litter contained printing ink that entered the soil, so the vegetables might not be safe to eat.

Give teams time to work together to choose which stages of their systems maps they want to examine for cause and effect relationships. Have them add one or more cause and effect statements to each of those stages.

Ask one or two teams to share examples of the cause and effect relationships they identified. Provide time for teams to add to or edit their ideas about cause and effect relationships, and enter the results in their science notebooks.

8. **Step 4: Specify criteria and constraints for evaluating engineering design solutions**

   Refocus students' attention on what they learned during Lesson Series 4 about identifying criteria and constraints. If needed, remind them about the categories of criteria identified in **Criteria for Evaluating Engineering Design Solutions (Chart 4)**. Suggest that they pay particular attention to criteria related to design solutions that are "environmentally sound and sustainable."

   Ask them to reference their science notebooks to review their discussion about constraints—the things that impact whether a solution can be implemented, including the needs and desires of the individuals and groups involved in or affected by an engineering design solution. As they develop their statements about constraints, it may be helpful to review what they learned in Lesson Series 4 about the spectrum of factors that should be considered in making decisions that can affect the viability and functioning of natural systems.

   Before they begin the development of their team's statement of criteria and constraints, remind them that their primary criterion is developing an engineering design solution that will minimize and monitor the direct and indirect effects on plants and animals (including humans), of the byproducts of human-made products and activities entering natural systems.

   Provide students with a template for presenting their statements of criteria and constraints, for example:

Sample Template for Statement of Criteria and Constraints

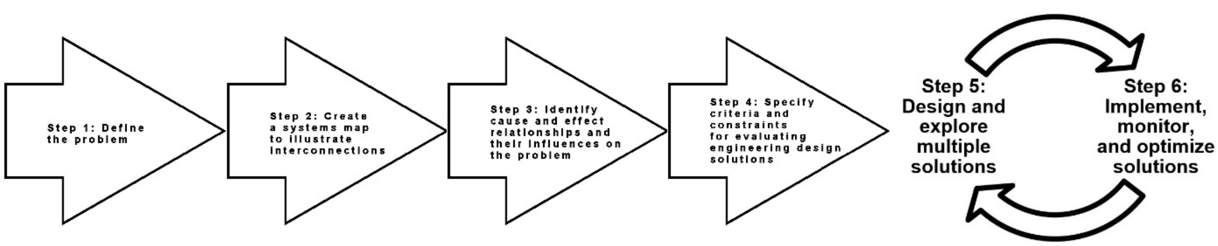
Problem Statement: Litter in the garden (natural system) affects the growth and survival of plants
Spectrum of factors involved in making decisions about the problem and engineering design solution: i. How the engineering solution will look to the school and community. ii. iii.
Criteria for evaluating multiple engineering design solutions: i. Decreases the amount of litter on campus ii. iii.
Constraints associated with implementation of the engineering design solution: i. Time and skills for students to implement a litter clean-up project ii. iii.

Give teams time to work together to develop statements of criteria and constraints related to their selected campus problem.

Ask one or two teams to summarize the problem they are seeking to resolve and share their statements of criteria and constraints. Provide time for teams to add to or edit their statements of criteria and constraints and enter the results in their science notebooks.

9. **Step 5: Design and explore multiple solutions**

   Ask students to recall again the diagram of the engineering design cycle.



   Explain that all their work on Steps 1–4 of this process have prepared them to start developing their own design solutions for the campus problems that their teams selected. To help them better understand this step in the engineering design process, ask, "How many different designs do you think an engineer might make when creating something like a digital audio player?" Follow-up by facilitating a discussion of how initial designs might be successful, but typically designing requires multiple different possible solutions to a problem, which all need to be considered in terms of criteria and constraints, as well as other decision-making factors. Point out that the need to develop, implement, and test different solutions is represented by the cycle that takes place between Steps 5 and 6.

Tell students that their teams will be working on developing ideas and specific designs to help resolve their selected campus problem. After they have thought about alternative solutions to their problem, they need to consider those solutions from the perspective of the criteria, constraints, and other decision-making factors, such as environmental sustainability.

Provide a template like the one below that students can use to present descriptions of their proposed alternative design solutions, and a comparative analysis of the pros and cons of each solution.

Sample Template for Statement and Analysis of Alternative Engineering Design Solution Plans

<table>
<tr><td colspan="2">Problem: Litter in the garden (natural system) affects the growth and survival of plants</td></tr>
<tr><td colspan="2">Description of solution:</td></tr>
<tr><td>Solution 1

Construct a wind fence around the garden area to prevent litter from blowing into the garden and affecting the growth and survival of plants.</td><td>Solution 2

Develop school guidelines for handling “packaging waste” and design a strategy for sharing the guidelines with the school and community.</td></tr>
<tr><td colspan="2">Pros and cons related to decision-making factors:</td></tr>
<tr><td>Solution 1

<u>Environmental sustainability</u>: Litter will not reach garden and the growth and survival of plants will not be affected. (pro)

<u>Appearance to school and community</u>:

Adding a wind fence around the garden will be visible on the playground and people in nearby homes may not like its appearance. (con)</td><td>Solution 2

<u>Environmental sustainability</u>: Recycling of “packaging waste” will reduce the use of natural resources. (pro)

<u>Appearance to school and community</u>:

Developing and sharing guidelines would not make any difference in what students and neighbors would see when they look at the garden. (pro)</td></tr>
<tr><td colspan="2">Pros and cons related to criteria:</td></tr>
<tr><td>Solution 1

Adding a wind fence may decrease the amount of litter that reaches the garden, but monitoring will be needed to determine if it is successful and there is less damage to plants in the garden. (Unknown before building and monitoring the effects)</td><td>Solution 2

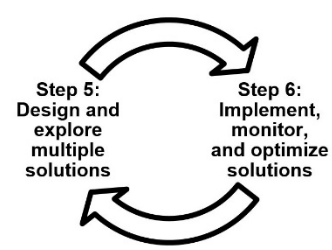
Developing and sharing guidelines may decrease the amount of litter on campus, but monitoring will be needed to determine if it successful and there is less damage to plants in the garden. (Unknown before developing and sharing the guidelines and monitoring the effects)</td></tr>
</table>

Pros and cons related to constraints:	
Solution 1 Building a wind fence around the garden will require that students have the time and skills to design and build a fence. (con) The mother of one of our team members has worked in construction and has offered to guide students in the skills and supply materials for the fence. (pro)	**Solution 2** Developing and sharing guidelines will require us to: research possible guidelines; decide which ones we want to propose; present them to our teacher and principal before we can share them; and plan how to present them to other students and the community. The father of one of our team members works for the city and may be able to guide us in this process. (pro)
Monitoring Strategy:	
See Step 6 below.	

Give teams time to work together to consider a variety of possible solutions, develop brief written descriptions of two alternative design solutions, and make notes about the comparative pros and cons of each of their designs in terms of their identified criteria and constraints, as well as relevant decision-making factors. During the design process, meet with teams and review their engineering design solutions and ask questions to further their thinking. (*Note:* If possible, invite older students to serve as mentors to student teams for this part of the process (e.g., high school students from an environmental science class).)

Have each team prepare a short presentation addressing each component of their **Statement and Analysis of Alternative Engineering Design Solution Plans**. Ask one or two teams to share their presentations. (All teams will share their full presentations later in the lesson). Have them start by summarizing the problem they are seeking to resolve, then describe their proposed alternative solutions and share their analysis of each solution in connection with their statements of decision-making factors, as well as criteria and constraints. Provide time for teams to add to or edit their **Statement and Analysis of Proposed Alternative Engineering Design Solution Plans** and enter the results in their science notebooks.

10. **Step 6: Implement, monitor, and optimize solutions**



Ask students, "Why do you think it is important to monitor the implementation of an engineering design solution?" If necessary, draw their attention to Steps 5 and 6 of the engineering design cycle, and continue the discussion.

Ask, "How do you think we could use the information we get from monitoring the implementation of engineering design solutions?" Guide the conversation until students recognize that monitoring the effectiveness of their engineering design solutions, during implementation, is an important component of the engineering design process because it provides evidence that can be used to think about and make improvements to initial design solutions.

An example of a basic monitoring strategy is shown below.

Sample Monitoring Strategy

Monitoring Strategy:
The monitoring strategy for a wind fence around a garden area includes: • Take baseline photos of the garden area affected by litter prior to the construction of the wind fence. Document the date, time (beginning of the school day, after lunch and recess), weather conditions, and human activity around the garden area at the time of the photo. • Create a weekly schedule for making observations, taking photos, and recording the same data. (*Note:* If there are extreme weather events, e.g., wind, rain, etc., take additional photos and record data for comparison.) • At end of the monitoring phase, analyze photos and other data. Make written and quantitative comparisons of photos and data. Discuss the effectiveness of the wind fence in terms of diminishing the amount of packaging waste entering the garden and affecting the health of plants. • Based on the monitoring results, consider and make appropriate changes to improve the effectiveness of the engineering design solution. Repeat monitoring to gather data on the effectiveness of changes to the engineering design solution.

Following the class discussion, provide teams with time to develop strategies for monitoring the implementation of their engineering design solutions. Ask them to add **Monitoring Strategy** to their team's **Statement and Analysis of Alternative Engineering Design Solution Plans**.

Ask one or two teams to share their monitoring strategy. Provide time for teams to add to or edit their **Monitoring Strategy** and enter the results in their science notebooks.

11. Have teams finalize the presentations they started in Step 9 by adding information about the monitoring strategy they developed in Step 10. Give all teams an opportunity to make their presentations either within the class or to students in other classes.

    Following the presentations, with permission from the administration, it is ideal to give teams an opportunity to implement and monitor their engineering design strategies on campus.

Elaborate and Evaluate:

12. Have students write an essay that: explains their team's campus problem; summarizes the solution they selected; explains why they chose that solution over the other possible solutions; and describes how it would solve the problem of byproducts of human-made products and activities entering natural systems. Have them include a discussion of how well the proposed solution addresses the decision-making factors, as well as the criteria and constraints related to their problem, specifically as it relates to environmental sustainability.

Appendices

Appendix A: Key Words and Terms in California's EP&Cs[2]

Biological diversity (biodiversity and species richness): A measure of the number of different species of organisms in a specific area, also used as a general description of species richness, ecosystem complexity, and genetic variation.

Byproduct: Something, such as waste materials or chemicals, produced when something else is manufactured or consumed.

Composition: The make-up of a natural system including the mixture of components (e.g., species) and relative numbers of those components.

Cultural system: The way of life defined by human communities and societies through their tangible objects, as well as their beliefs, behaviors, values, and traditions.

Economic factors: Considerations related to the production, distribution, and consumption of goods and services that affects outcomes.

Economic system: The means and methods a society uses to manage the production, distribution, exchange, and consumption of goods and services, including income, expenses, and labor.

Ecosystem goods: Tangible materials, such as timber and food, produced by natural systems, that are essential to human life, economies, and cultures.

Ecosystem services: The functions and processes that occur in natural systems, such as pollination, that support or produce ecosystem goods and help sustain human life, economies, and cultures.

Environmental management: Human practices that influence an ecosystem so that it produces particular goods and services that are useful to people.

Exchange of matter: Substances moving within and between systems, particularly human-social systems and natural systems.

Geographic extent (range): The area through which a species or ecosystem is naturally found.

Human activity: The full range of behaviors, actions, and practices of humans as individuals and as members of communities and societies.

Human practices: The ways individual people, communities, and societies do things, such as harvesting or extracting of materials, as well as producing and consuming goods and services from natural systems and human social systems.

Human social system: The functions, processes, and interactions among individuals, human communities, and societies including political, social, cultural, economic, and legal systems.

Legal system: The means and methods of establishing, interpreting, and enforcing laws.

Natural cycle: A regularly repeated event, or sequence of events, that occur in a natural system over time, e.g., carbon cycle, life cycles, nitrogen cycle, nutrient cycle, reproductive cycle, and water cycle.

Natural process: A generally sequential and interconnected series of related events, activities, or phenomena, e.g., decomposition, erosion, evaporation, photosynthesis, and pollination.

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[2] Based primarily on the Glossary developed for the model curriculum developed for California Education and Environment Initiative.

Natural resources: Materials, such as water, minerals, energy, and soil, that people use from nature and natural systems, to produce food, and build shelters and other products.

Natural system: The interacting components, processes, and cycles within an environment, as well as the interactions among organisms and their environment.

Political factors: Considerations and aspects of decisions related to the operation of governments and political systems.

Political system: The means and methods by which governments are managed, including decision-making processes such as elections.

Social factors: Considerations and aspects of decisions related to the operation of human society and its members.

Systems: Groups of interacting components, processes, and cycles that form a complex whole, such as natural systems, political systems, and economic systems.

Viability of natural systems: The likelihood that the components, processes, and cycles in a natural system, such as an ecosystem, will continue to function over time.

Appendix B: Connections to the EP&Cs Identified in Appendix 2 of California's Science Curriculum Framework for the PEs, DCIs, CCCs, and SEPs

The California Science Framework describes the state's Environmental Principles and Concepts (EP&Cs) as providing "a meaningful way to teach and amplify many of the ideas that are already embedded in the CA NGSS. Appendix 2 of this CA Science Framework presents diverse examples of the connections that can be made between the EP&Cs and instruction in the three dimensions of the CA NGSS."[3]

Performance Expectations (PEs)

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.]

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

Disciplinary Core Ideas (DCIs)

LS1.B: Growth and Development of Organisms: "Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)"

ESS3.C: Human Impacts on Earth Systems: "Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)

Crosscutting Concepts (CCCs)

Cause and Effect: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS1-4), (MS-LS1-5); Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS1-8)[4]

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[3] California's *Science Framework 2016*. Chapter 1 Overview of the California Next Generation Science Standards

[4] Does not appear in Appendix 2, but can be directly connected to the three-dimensions assessed within PE MS-LS1-5.

Systems and System Models: Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS1-3)[5]

Science and Engineering Practices (SEPs)

Constructing Explanations and Designing Solutions: Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (MS-LS1-5, MS-LS1-6); Apply scientific principles to design an object, tool, process or system. (MS-ESS3-3)

Obtaining, Evaluating, and Communicating Information: Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. (MS-LS1-8)[5]

Engaging in Argument from Evidence: Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon. (MS-LS1-3)[5]; Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-LS1-4)[5]

Environmental Principles and Concepts (EP&Cs)

Students should be developing an understanding that:

Principle II Concept c: "The expansion and operation of human communities influences the geographic extent, composition, biological diversity, and viability of natural systems."

Principle IV Concept b: "The byproducts of human activity are not readily prevented from entering natural systems and may be beneficial, neutral, or detrimental in their effect."

Principle V Concept a: "There is a spectrum of what is considered in making decisions about resources and natural systems and how those factors influence decisions." (ESS3.C)

In connection with ESS3-3, make connections to ETS:

ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. (MS-ETS1-1)

ETS1.B: Developing Possible Solutions

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)

Appendix C: California Common Core State Standards Connections in Exemplar

English Language Arts/Literacy

WHST.6–8.1.a–e Write arguments focused on *discipline-specific content*.[5]

WHST.6–8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

WHST.6–8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.[6]

WHST.6–8.8 Gather relevant information from multiple print and digital sources **(primary and secondary)**, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.[5]

WHST.6–8.9 Draw evidence from informational texts to support analysis, reflection, and research.
SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.)[5]

[5] Not directly connected to MS-LS1-5 in CA NGSS, but supported in this Exemplar unit.

Appendix D: Instructional Resources Curriculum that Can be Used to Support Implementation

These instructional resources from California's Education and the Environment Initiative (EEI) model curriculum may be used by teachers in conjunction with this Exemplar.

Sixth Grade *Energy: Pass It On!*

Seventh Grade *Shaping Natural Systems through Evolution*

Seventh Grade *Responding to Environmental Change*