High School AP Environmental Science Curriculum

Course Description: This course is designed to be the equivalent of a one-semester introductory college course in Environmental Science. Its goal is to provide students with the scientific principles, concepts, and methodologies required to understand the interrelationships of the natural world, to identify and analyze environmental problems (pollution, global warming, dwindling resources) both natural and human-made, to evaluate the relative risks associated with these problems, and to examine alternative solutions for resolving and/or preventing them. Topics covered will include: Earth systems and resources, ecology, population dynamics, energy resources and consumption, alternative energy, pollution, global change, global warming and human’s impact on the Earth.
### Scope and Sequence:

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Unit</th>
<th>Instructional Topics</th>
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| 2 Weeks   | Earth Systems and Resources | Topic 1: Fundamentals of Environmental Science  
|           |                          | Topic 2: Earth Science Concepts  
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| 2 Weeks   | The Living World         | Topic 1: Ecosystem Structure  
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| 2 Weeks   | Population Dynamics      | Topic 1: Population Biology  
|           |                          | Topic 2: Human Population Dynamics                                                  |
| 3 Weeks   | Land and Water Use       | Topic 1: Land Use  
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| 2 Weeks   | Global Change            | Topic 1: Stratospheric Ozone  
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|           |                          | Topic 3: Loss of Biodiversity                                                        |
Unit 1: Earth Systems and Resources

**Subject:** AP Environmental Science  
**Grade:** 10-12  
**Name of Unit:** Earth Systems and Resources  
**Length of Unit:** 2 weeks  
**Overview of Unit:** The student will understand the makeup of all Earth systems and their importance to living organisms.

**Unit Themes:**

- Science is a process.
  - Science is a method of learning more about the world.
  - Science constantly changes the way we understand the world.
- Energy conversions underlie all ecological processes.
  - Energy cannot be created; it must come from somewhere.
  - As energy flows through systems, at each step more of it becomes unusable.
- The Earth itself is one interconnected system.
  - Natural systems change over time and space.
  - Biogeochemical systems vary in ability to recover from disturbances.
- Humans alter natural systems.
  - Humans have had an impact on the environment for millions of years.
  - Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
- Environmental problems have a cultural and social context.
  - Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
- Human survival depends on developing practices that will achieve sustainable systems.
  - A suitable combination of conservation and development is required.
  - Management of common resources is essential.

**Essential Questions:**

1. How can we achieve sustainability?
2. How are ecological footprints affecting the earth?
3. Why do we have environmental problems?
4. How do environmental scientists solve environmental issues?
5. How do ecosystems respond to change?

**Enduring Understanding/Big Ideas:**

1. Nature has sustained itself for billions of years by relying on solar energy, biodiversity, and nutrient cycling. Our lives and economies depend on energy from the sun and on
natural resources and natural services provided by the earth. Living sustainably means living off the earth’s natural income without depleting or degrading the natural capital that supplies it.

2. As our ecological footprints grow, we are depleting and degrading more of the earth’s natural capital.

3. Major causes of environmental problems are population growth, wasteful and unsustainable resource use, poverty, and the exclusion of environmental costs of resource use from the market prices of goods and services.

4. Scientists collect data and develop theories, models, and laws about how nature works.

5. Ecosystems have inputs, flows, and outputs of matter and energy, and feedback can affect their behavior.

**Unit Vocabulary:**

<table>
<thead>
<tr>
<th>Academic Cross-Curricular Words</th>
<th>Content/Domain Specific</th>
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<tbody>
<tr>
<td>Tragedy of the Commons</td>
<td>Controlled Experiment</td>
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<td>Latitude</td>
<td>Ecological Footprint</td>
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<td>Weather</td>
<td>Geologic Time Scale</td>
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<td>Climate</td>
<td>Plate Tectonics</td>
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<td>Earthquake</td>
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<td>Volcanism</td>
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<td>Seasons</td>
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<td>Solar Intensity</td>
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<td>Atmosphere Composition</td>
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<td>Atmosphere Structure</td>
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<td>Atmospheric Circulation</td>
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<td>Coriolis Effect</td>
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<td>ENSO (El Nino Southern Oscillation)</td>
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<td>Freshwater</td>
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<td>Saltwater</td>
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<td>Ocean Circulation</td>
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<td>Water Resources</td>
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<td>Surface Runoff</td>
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<td>Groundwater</td>
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<td>Conservation</td>
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<td>Rock Cycle</td>
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<td>Soil Composition</td>
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<td>Soil Formation</td>
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<td>Physical Properties of Soil</td>
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<td>Chemical Properties of Soil</td>
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<td>Soil Types</td>
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<td>Erosion</td>
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**Resources for Vocabulary Development:** textbook, lecture notes, online resources
Topic 1: Fundamentals of Environmental Science

Engaging Experience 1
Title: Tragedy of the Commons
Suggested Length of Time: 1 class period
Themes Addressed:
Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.
Humans alter natural systems.
- Humans have had an impact on the environment for millions of years.
- Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
Environmental problems have a cultural and social context.
- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.
- Management of common resources is essential.

Detailed Description/Instructions: This activity allows students to explore the “tragedy of the commons” in which common usage of a limited, potentially renewable resource invariably leads to its exploitation. In this simulation, students imagine that they are fisherman sharing access to a common fishing pond - the “fish” can be candy, goldfish, trinkets, etc. The independent variable is the different fishing strategies and the dependent variable is the size of the resource. At the end of this simulation, students should understand resource depletion, exploitation and sustainability and be able to construct strategies that are more sustainable.

Bloom’s Levels: Analyze, Create
Webb’s DOK: 3

Engaging Experience 2
Title: Ecological Footprint
Suggested Length of Time: 2 class periods
Themes Addressed:
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**Detailed Description/Instructions:** This activity allows students to investigate their personal ecological footprint - the area required to support their lifestyle. An ecological footprint is the amount of biologically productive land and natural resources that are entirely devoted to supporting a human’s needs; ecological footprints vary widely among individuals and societies. If the ecological footprint per person exceeds the biological capacity per person to replenish the renewable resources and absorb the resulting waste products, it is said to have an ecological deficit. In this activity, students calculate their individual ecological footprints based on food, shelter, transportation, goods, and waste using an internet program. After assessing their ecological deficit (or credit), students compare their footprints to that of the average American and other world citizens in order to analyze the relative magnitude of their impact on the sustainability of Earth’s natural resources. After assessing their personal impact, students are asked to construct a detailed, realistic plan to reduce their personal ecological footprint to a more sustainable level.

**Bloom’s Levels:** Analyze, Create

**Webb’s DOK:** 4
Engaging Experience 1
Title: How Are Rocks Formed?
Suggested Length of Time: 1 class period
Themes Addressed:
   Science is a process.
   ● Science is a method of learning more about the world.
   ● Science constantly changes the way we understand the world.
   The Earth itself is one interconnected system.
   ● Natural systems change over time and space.
   ● Biogeochemical systems vary in ability to recover from disturbances.
Detailed Description/Instructions: In this activity, students use crayons to simulate the phases of the rock cycle. Students will create “sediment,” deposit it, press it into “sedimentary rock”, then melt it to change it into “metamorphic rock” and finally cool it quickly (extrusive rock) or slowly (intrusive igneous rock). Students will analyze how weathering and erosion affect the rate of sedimentation. Students will compare the physical and chemical properties of each type of rock relating the processes of compaction, pressure and heat to the formation of different types of rock. Students will use the knowledge gained to identify an “unknown” mineral or rock.
Bloom’s Levels: Analyze, Create
Webb’s DOK: 3
Topic 3: The Atmosphere

Engaging Experience 1
Title: Uncovering the Atmosphere
Suggested Length of Time: 1 class period
Themes Addressed:
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Detailed Description/Instructions: In this activity, students will explore the importance of the atmosphere in sustaining life. Through analysis of air pressure, humidity, cloud cover, light intensity, air temperature, and other abiotic factors, students will learn about the composition of the atmosphere, the development of frontal systems and wind, and how the atmosphere regulates and circulates heat. Then students will design their own experiment to examine the temperature effects of altering the energy radiation balance in a model system.

Bloom’s Levels: Analyze, Create
Webb’s DOK: 3
Engaging Experience 1
Title: Quality of Natural Waters - Stream Team
Suggested Length of Time: 2 class periods
Themes Addressed:

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Detailed Description/Instructions: This lab activity enables students to monitor water quality and determine the Water Quality Index (WQI) for several local test sites. Students gather water samples and test for dissolved oxygen, coliform bacteria, biochemical oxygen demand, total solids, turbidity, nitrates, phosphates, pH, and change in temperature on the rate of macroinvertebrate population density. Students will then design an investigation on the effect of pollution runoff on the rate of macroinvertebrate sensitivity.

Bloom’s Levels: Analyze, Create
Webb’s DOK: 3
Engaging Experience 1
Title: Physical and Chemical Properties of Soil
Suggested Length of Time: 2-3 class periods
Themes Addressed:

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Detailed Description/Instructions: In this investigation, students investigate the physical and chemical characteristics of soil: structure, texture, particle size, consistency, bulk density, water holding capacity, capillary action, permeability, percolation rate, pH, and nutrient availability. Students will perform both field and laboratory tests to determine the properties of soil that affect a plant's ability to absorb water and nutrients to sustain life. Students will then design their own investigations into the effect of altering any chemical or physical characteristic of soil on plant growth.

Bloom’s Levels: Analyze, Create
Webb’s DOK: 3
Culminating Activity

1. Plate-tectonic theory states that the Earth’s lithosphere is broken into very slowly moving pieces or plates. Plate movements over vast stretches of time have led to the current orientation of our continents and oceans. Individual events along plate boundaries, such as earthquakes and volcanic eruptions, pose periodic threats to human activity and ecosystems. The “Ring of Fire” is a term that describes the location of increased seismic and volcanic activity around the margins of the Pacific Ocean basin. On the map above, each dot represents a volcano or an earthquake.
   a. Japan, Indonesia, and the Philippines are examples of volcanic island chains that have formed along subduction zones between plates in the western Pacific.
      i. **Describe** what happens when two tectonic plates collide along a subduction zone.
      ii. **Explain** how subduction leads to volcanic activity.
   b. Although the landscape following a volcanic eruption may appear unable to support ecological communities, over time the area can be transformed through succession.
      i. What is primary succession?
      ii. **Explain** how primary succession can lead to soil formation on a newly formed volcanic landscape.
   c. In addition to volcanic activity, highly destructive tsunamis are generated along Pacific Plate subduction zones.
      i. **Explain** how a tsunami is generated along a subduction zone.
      ii. **Describe** one negative ecological impact that tsunamis have on coastal environments.
d. Southern California experiences periodic devastating earthquakes along the San Andreas Fault, which is a transform boundary located along the eastern edge of the Pacific Plate.
   i. **Describe** what happens to the tectonic plates along a transform boundary at the moment when an earthquake occurs.
   ii. **Describe** what happens to the tectonic plates along a transform boundary during the time between earthquakes.

1. The active ingredients in many pesticides are chemical compounds that kill organisms such as insects, molds, and weeds. Proponents claim that the use of pesticides improves crop yields and thus protects land and soil by reducing the conversion of forests and wetlands to cropland. Opponents of pesticide use claim that pesticides degrade water and soil quality and that other modern agricultural techniques and practices are responsible for the improved crop yields in recent years.
   a. Design a laboratory experiment to determine whether or not a new pesticide (product X) is toxic to minnows, a type of small fish. For the experiment you design. Be sure to do all of the following.
      i. **State the hypothesis**
      ii. **Describe the method you would use to test your hypothesis**
      iii. **Identify the control**
      iv. **Identify the dependent variable**.
   b. Describe experimental results that would lead you to reject your hypothesis in part (a)(i). (Be specific)
   c. One strategy for dealing with agricultural pests is integrated pest management (IPM).
      i. **Describe** IPM. As part of your description, include **TWO** specific pest-control approaches that are part of IPM.
      ii. **Identify one environmental benefit of using** IPM.
   d. Describe **TWO** agricultural practices, other than those involving pest control, that increase crop yields.

2. Suppose that you have just started a summer internship working for a cooperative extension service, where you will collect soil samples, conduct laboratory field tests, and make recommendations on soil conservation and agricultural practices.
   a. Identify and describe one chemical soil test and one physical soil test that could be performed and explain how the results of these tests will allow the cooperative extension service to make specific recommendations for sustainable agriculture.
   b. Explain one advantage and one disadvantage to using inorganic chemical fertilizers.
   c. Describe **TWO** soil conservation practices that are designed to decrease soil erosion.
d. Identify one biome that is characterized by soil that is rich in humus. Describe how humus originated in the soils of this biome and TWO ways that humus improves soil conditions for plant growth.

3. The Colorado River runs from the Colorado Rockies to the Gulf of California. The primary source of Colorado River water is melting Rocky Mountain snowpack. Once the river descends from the Rockies, it flows through a landscape that is dominated by desert. Colorado River water carries a high load of sediments.
   a. Multiple dams have been erected along the Colorado River. Identify TWO benefits other than agriculture and recreation that people derive from that system of dams.
   b. Discuss TWO potential environmental consequences of damming a major river.
   c. Competition for access to Colorado River water has increased dramatically due to increased population size and intensive agricultural use. Describe TWO conservation strategies for reducing agricultural water consumption.
   d. Identify TWO possible environmental consequences of climate change on the hydrology of the Colorado River system.
   e. In addition to impacts on the Colorado River system, climate change is impacting the hydrology of coastal ecosystems. Identify and describe TWO possible consequences of climate change on coastal ecosystems.
## Summary of Engaging Learning Experiences for Topics

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<thead>
<tr>
<th>Topic</th>
<th>Engaging Experience Title</th>
<th>Description</th>
<th>Suggested Length of Time</th>
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<td>Fundamentals of Environmental Science</td>
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<td>This activity allows students to investigate their personal ecological footprint - the area required to support their lifestyle. An ecological footprint is the amount of biologically productive land and natural resources that are entirely devoted to supporting a human’s needs; ecological footprints vary widely among individuals and societies. If the ecological footprint per person exceeds the biological capacity per person to replenish the renewable resources and absorb the resulting waste products, it is said to have an ecological deficit. In this activity, students calculate their individual ecological footprints based on food, shelter, transportation, goods, and waste using an internet program. After assessing their ecological deficit (or credit), students compare their footprints to that of the average American and other world citizens in order to analyze the relative magnitude of their impact on the environment.</td>
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After assessing their personal impact, students are asked to construct a detailed, realistic plan to reduce their personal ecological footprint to a more sustainable level.

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Unit 2: The Living World

Subject: AP Environmental Science
Grade: 10-12
Name of Unit: The Living World
Length of Unit: 2 weeks
Overview of Unit: The study of the interactions between living organisms and their environment.

Unit Themes:
Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

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Supporting Standards:
- ISTE-EMPOWERED LEARNER.1: Students leverage technology to take an active role in choosing, achieving and demonstrating competency in their learning goals, informed by the learning sciences.
- ISTE - KNOWLEDGE COLLECTOR.3: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.
**Essential Questions:**
1. How does energy flow in an ecosystem?
2. How do scientists study ecosystems?
3. How does the earth’s life change over time?
4. How do speciation, extinction, and human activities affect biodiversity?
5. How does climate affect the nature and location of biomes?

**Enduring Understanding/Big Ideas:**
1. The amount of chemical energy available to organisms at each successive feeding level in food chains and webs decreases as it flows through ecosystems. About 10% of the energy is transferred to the next trophic level; the remaining 90% is used by those organisms or lost as heat.
2. Scientists use both field research and laboratory research, as well as mathematical and other models to learn about ecosystems.
3. The scientific theory of evolution explains how life on earth changes over time through changes in the genes of populations. Populations evolve when genes mutate and give some individuals genetic traits that enhance their abilities to survive and to produce offspring with these traits (natural selection).
4. As environmental conditions change, the balance between the formation of new species and the extinction of existing species determines the earth’s biodiversity. Human activities are decreasing biodiversity by causing the extinction of many species and by destroying or degrading habitats needed for the development of new species.
5. Differences in long-term average annual precipitation and temperature lead to the formation of tropical, temperate, and cold deserts, grasslands, and forests, and largely determine their locations.

**Unit Vocabulary:**

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<td>Ecological Niche</td>
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<td>Community</td>
<td>Keystone Species</td>
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<td>Climate Shift</td>
<td>Biodiversity</td>
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<td>Terrestrial Biomes</td>
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<td>Aquatic Biomes</td>
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<td>Photosynthesis</td>
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<td>Cellular Respiration</td>
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<td>Food Web</td>
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<td>Trophic Level</td>
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<td>Ecological Pyramid</td>
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<td>Ecosystem Services</td>
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<td>Species Movement/Migration</td>
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<td>Ecological Succession</td>
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<td>Biogeochemical Cycle</td>
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<td>Carbon Cycle</td>
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<td>Water Cycle</td>
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<td>Conservation of Matter &amp; Energy</td>
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<td>Symbiosis</td>
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</table>

**Resources for Vocabulary Development:** textbook, lecture notes, online resources.
Engaging Experience 1

Title: What’s In An Ecosystem?

Suggested Length of Time: 2-3 class periods

Themes Addressed:

Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

Energy conversions underlie all ecological processes.
- Energy cannot be created; it must come from somewhere.
- As energy flows through systems, at each step more of it becomes unusable.

The Earth itself is one interconnected system.
- Natural systems change over time and space.
- Biogeochemical systems vary in ability to recover from disturbances.

Humans alter natural systems.
- Humans have had an impact on the environment for millions of years.
- Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.

Environmental problems have a cultural and social context.
- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.
- Management of common resources is essential.

Detailed Description/Instructions: In this activity, students will investigate the structure and function of a local ecosystem. This exercise is designed for a forest ecosystem but can be adapted easily for use in any ecosystem, even a weedy urban lot, schoolyard, or backyard. Students will explore how organisms are influenced by their physical environment and by interactions with other living organisms. Students will perform both field and laboratory exercises to explore the abiotic and biotic features of a natural ecosystem. Students will investigate the effect of minor alterations in abiotic or biotic factors on the interconnected systems in a local ecosystem.

Bloom’s Levels: Apply, Analyze

Webb’s DOK: 3
Engaging Experience 1

Title: Primary Consumer Energy Flow

Suggested Length of Time: 5 class periods

Themes Addressed:

Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

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- Energy cannot be created; it must come from somewhere.
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Human survival depends on developing practices that will achieve sustainable systems.
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Detailed Description/Instructions: In this activity, students will explore the movement of energy within an ecosystem. Energy moves from one organism to another when one organism consumes another and the chemical energy contained within the biomass of the eaten organism is used by the other for maintenance and growth. Understanding the movement of biomass energy is useful in situations where the ecosystem is being managed. The efficiency with which energy can be transferred from one trophic level to the next is referred to as ecological efficiency and can be calculated as gross primary productivity vs net primary productivity. Students will germinate a seed and introduce a primary consumer to calculate the change in biomass as energy is transferred from producer to consumer to decomposer. After the food web is established, a species may be removed from the food web, so students can determine the ramifications of the loss of this species to the web as a whole and make decisions about which species are keystone species.

Bloom’s Levels: Understand, Apply, Analyze

Webb’s DOK: 3
Topic 3: Ecosystem Diversity

Engaging Experience 1
Title: Forest Plot Analysis - Community Ecology
Suggested Length of Time: 1 class period
Themes Addressed:

Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

Energy conversions underlie all ecological processes.
- Energy cannot be created; it must come from somewhere.
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- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.

Detailed Description/Instructions: In this activity, students will investigate biological diversity of a forest plot; however, the activity can easily be adapted to analysis any plot including a weedy urban lot or backyard. Using field and laboratory exercises, students will identify different morphotypes of organisms per isolated habitat island. Using species richness indices, students will calculate the effect of habitat type on species richness and diversity. Students will create habitat islands of varying sizes or styles and set out traps to collect and sample organisms found at those islands to determine community diversity. A discussion of ecological diversity requires an understanding of the various levels of an ecosystem: species; population; community; ecosystem; and biome. Diverse communities are generally less susceptible to perturbation than otherwise similar but less diverse communities. One reason for this is that in diverse communities there are often species with overlapping niches. If one species is lost, the other still serves a similar role in the functioning of the ecosystem. Students will be asked to explore how ecosystem diversity can be quantified and analyzed and whether those sampling methods violate any assumptions about an ecosystem not altered by human intervention.

Bloom’s Levels: Understand, Analyze, Create
Webb’s DOK: 3
Engaging Experience 1
Title: Modeling a Closed Ecosystem
Suggested Length of Time: 3-4 weeks
Themes Addressed:

Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

Energy conversions underlie all ecological processes.
- Energy cannot be created; it must come from somewhere.
- As energy flows through systems, at each step more of it becomes unusable.

The Earth itself is one interconnected system.
- Natural systems change over time and space.
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Environmental problems have a cultural and social context.
- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.

Supporting Standards:
- ISTE-EMPOWERED LEARNER.1: Students leverage technology to take an active role in choosing, achieving and demonstrating competency in their learning goals, informed by the learning sciences.
- ISTE - KNOWLEDGE COLLECTOR.3: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.

Detailed Description/Instructions: In this activity, students will design and construct a model of one of Earth’s major biomes to observe and record the interactions among the living and nonliving components of the biome to calculate the rate of ecological succession. A biome is a large group of ecosystems characterized by communities of plants, animals and other organisms that have become adapted to the relatively uniform climatic conditions of the biome. Earth’s major terrestrial biomes include the forests, grasslands, deserts, and tundra. Earth’s aquatic biomes are either saltwater or freshwater environments. Students will choose one of Earth’s terrestrial or aquatic biomes and research the type of soil/water, average annual temperature, average yearly precipitation, average day length, and some of the organisms that characterize
that biome. Students will then use their research to design a “mini-biome in a bottle.” Students will include a detailed sketch as well as detailed description of biotic and abiotic factors required for their proposed model. Once students receive teacher approval, students will build their mini-biome by placing soil/water/seeds/organisms/etc. into an inverted 2-liter bottle according to their proposed design. Students will then provide the abiotic factors necessary to maintain that biome by regulating the light, temperature, precipitation, humidity, and nutrients, as needed. Students will observe, monitor, and measure the ecosystem changes in their mini-biome on a daily basis for several weeks. At the conclusion of the project, students will evaluate the efficiency and accuracy of their model to the actual biome - did it undergo a growth in population size, density, dispersion? Which model mini-biome was the most successful in terms of ecological diversity? Which modeled the most biogeochemical cycles - was there evidence of the water cycle? Was their evidence of growth and decomposition? etc.

**Bloom’s Levels:** Evaluate, Create

**Webb’s DOK:** 3
Culminating Activity

1. Over the last few decades, scientists have come to realize the importance of top-down control of the ecosystem by tertiary predators. An example of this was seen with the removal of the grey wolves from Yellowstone National Park. Many local ranchers encouraged this removal of the predator, as they were starting to feed on their livestock. After the wolves were removed in the 1920s, many organisms in the Yellowstone ecosystem started to suffer. Naturally, wolves feed on the local elk population. Elk typically feed on the aspen trees that were abundant in Yellowstone prior to the wolves being removed. Other organisms also benefit from the wolves, such as ravens and coyotes that often get the wolves’ “leftovers” from an elk kill. Wolves were reintroduced to the park in 1995. In 2008, the grey wolf was removed from the endangered species list.
   a. Diagram a natural food web that could exist in Yellowstone Park based on information provided in the article.
   b. Describe TWO environmental problems that could be associated with the removal of grey wolves from Yellowstone National Park.
   c. Discuss a possible societal or economic concern that could arise from reintroducing wolves back into the area.
   d. Besides human interaction, describe TWO other environmental factors that could regulate the wolf population in the park.
   e. Identify and describe one law or treaty currently in place to protect endangered terrestrial organisms.

2. Scientists have observed severe declines in honeybee populations. They call this colony collapse disorder. Without honey bees, flowers are not pollinated, crops don’t thrive, and overall plant growth suffers. In fact, apple growers are almost totally dependent on insects for pollination, with honeybees responsible for over 90%. Pumpkin growers need bees to pollinate their plants too. On average, growers paid $95 to $105 per colony in 2007, compared to $55 to $65 per colony in 2008 due to the decline in bees available.
   a. From the preceding information, can honeybees be considered a keystone species in certain agricultural ecosystems?
   b. Describe a possible effect of drastic honey bee population declines as a species.
   c. How could the population drop in honeybee population affect the habitats of other local denizens?
   d. Ultimately, where does all food come from (i.e., what major components are necessary?)?
<table>
<thead>
<tr>
<th>Topic</th>
<th>Engaging Experience Title</th>
<th>Description</th>
<th>Suggested Length of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem Structure</td>
<td>What’s In An Ecosystem</td>
<td>In this activity, students will investigate the structure and function of a local ecosystem. This exercise is designed for a forest ecosystem but can be adapted easily for use in any ecosystem, even a weedy urban lot, schoolyard, or backyard. Students will explore how organisms are influenced by their physical environment and by interactions with other living organisms. Students will perform both field and laboratory exercises to explore the abiotic and biotic features of a natural ecosystem. Students will investigate the effect of minor alterations in abiotic or biotic factors on the interconnected systems in a local ecosystem.</td>
<td>2-3 class periods</td>
</tr>
<tr>
<td>Energy Flow</td>
<td>Primary Consumer Energy Flow</td>
<td>In this activity, students will explore the movement of energy within an ecosystem. Energy moves from one organism to another when one organism consumes another and the chemical energy contained within the biomass of the eaten organism is used by the other for maintenance and growth. Understanding the movement of biomass energy is useful in situations where the ecosystem is being managed. The efficiency with which energy can be transferred from one trophic level to the next is referred to as ecological efficiency and can be calculated as gross primary productivity vs net primary productivity. Students will germinate a seed and introduce a primary consumer to calculate the change in biomass as energy is transferred from producer to consumer to decomposer. After the food web is established, a species may be removed from the food web, so students can determine the ramifications of the loss of this species to the web as a whole and make decisions about which species are keystone species.</td>
<td>5 class periods</td>
</tr>
<tr>
<td>Ecosystem Diversity</td>
<td>Forest Plot Analysis - Community Ecology</td>
<td>In this activity, students will investigate biological diversity of a forest plot; however, the activity can easily be adapted to analysis any plot including a weedy urban lot or backyard. Using field and laboratory exercises, students will identify different morphotypes of organisms per isolated habitat island. Using species richness indices, students will calculate the effect of habitat type on species richness and diversity. Students will create habitat islands of varying sizes or styles and set out traps to collect and sample organisms found at those islands to determine community diversity. A discussion of ecological diversity requires an understanding of the various levels of an ecosystem: species; population; community; ecosystem; and biome. Diverse communities are generally less susceptible to perturbation than otherwise similar but less diverse communities. One reason for this is that in diverse communities there are often species with overlapping niches. If one species is lost, the other still serves a similar role in the functioning of the ecosystem. Students will be asked to explore how ecosystem diversity can be quantified and analyzed and whether those sampling methods violate any assumptions about an ecosystem not altered by human intervention.</td>
<td>1 class period</td>
</tr>
<tr>
<td>Natural Ecosystem Change</td>
<td>Modeling a Closed Ecosystem</td>
<td>In this activity, students will design and construct a model of one of Earth’s major biomes to observe and record the interactions among the living and nonliving components of the biome to calculate the rate of ecological succession. A biome is a large group of ecosystems characterized by communities of plants, animals and other organisms that have become adapted to the relatively uniform climatic conditions of the biome. Earth’s major terrestrial biomes include the forests, grasslands, deserts, and tundra. Earth’s aquatic biomes are either saltwater or freshwater environments. Students will choose one of Earth’s terrestrial or aquatic biomes and research</td>
<td>3-4 weeks</td>
</tr>
</tbody>
</table>
the type of soil/water, average annual temperature, average yearly precipitation, average day length, and some of the organisms that characterize that biome.

Students will then use their research to design a “mini-biome in a bottle.” Students will include a detailed sketch as well as detailed description of biotic and abiotic factors required for their proposed model. Once students receive teacher approval, students will build their mini-biome by placing soil/water/seeds/organisms/etc. into an inverted 2-liter bottle according to their proposed design.

Students will then provide the abiotic factors necessary to maintain that biome by regulating the light, temperature, precipitation, humidity, and nutrients, as needed. Students will observe, monitor, and measure the ecosystem changes in their mini-biome on a daily basis for several weeks. At the conclusion of the project, students will evaluate the efficiency and accuracy of their model to the actual biome - did it undergo a growth in population size, density, dispersion? Which model mini-biome was the most successful in terms of ecological diversity? etc.
Unit 3: Population Dynamics

Subject: AP Environmental Science
Grade: 10-12
Name of Unit: Population Dynamics
Length of Unit: 2 weeks
Overview of Unit: A study of human population trends and the impact of the increasing human population on the environment.

Unit Themes:
Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.
Energy conversions underlie all ecological processes.
- Energy cannot be created; it must come from somewhere.
- As energy flows through systems, at each step more of it becomes unusable.
The Earth itself is one interconnected system.
- Natural systems change over time and space.
- Biogeochemical systems vary in ability to recover from disturbances.
Humans alter natural systems.
- Humans have had an impact on the environment for millions of years.
- Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
Environmental problems have a cultural and social context.
- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.
- Management of common resources is essential.

Essential Questions:
1. How do species interact in an ecosystem?
2. How do communities and ecosystems respond to changing environmental conditions?
3. How is the growth of a population limited and how does a population’s age structure affect its growth or decline?
4. How can we slow human population growth?
5. Why are marine aquatic systems important and how have human activities affected marine ecosystems.
Enduring Understanding/Big Ideas:

1. There are five types of species interactions (competition, predation, parasitism, mutualism, and commensalism) that affect the resource use and population sizes of the species in an ecosystem.
2. The structure and species composition of communities and ecosystems change in response to changing environmental conditions through a process called ecological succession.
3. No population can continue to grow indefinitely because of limitations on resources and because of competition among species for those resources. The numbers of males and females in young, middle, and older age groups determine how fast a population grows or declines.
4. We can slow human population growth by reducing poverty, elevating the status of women, and encouraging family planning.
5. Saltwater ecosystems are irreplaceable reservoirs of biodiversity and provide major ecological and economic services. Human activities threaten aquatic biodiversity and disrupt ecological and economic services provided by saltwater systems.

Unit Vocabulary:

<table>
<thead>
<tr>
<th>Academic Cross-Curricular Words</th>
<th>Content/Domain Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>demographic transition</td>
<td>population biology</td>
</tr>
<tr>
<td>population policies</td>
<td>carrying capacity</td>
</tr>
<tr>
<td>population density</td>
<td>age structure diagram</td>
</tr>
<tr>
<td>reproductive strategies</td>
<td>exponential growth model</td>
</tr>
<tr>
<td>competition</td>
<td>logistic growth model</td>
</tr>
<tr>
<td>fertility rates</td>
<td>survivorship curves</td>
</tr>
<tr>
<td>growth rates</td>
<td>symbiotic relationship</td>
</tr>
<tr>
<td>hunger</td>
<td>resource partitioning</td>
</tr>
<tr>
<td>disease</td>
<td>ecological succession</td>
</tr>
<tr>
<td>resource use</td>
<td>primary succession</td>
</tr>
<tr>
<td>total fertility rate (TFR)</td>
<td>secondary succession</td>
</tr>
<tr>
<td>infant mortality</td>
<td>K-selected species</td>
</tr>
<tr>
<td>replacement-level fertility</td>
<td>r-selected species</td>
</tr>
<tr>
<td>population pyramid</td>
<td>habitat destruction</td>
</tr>
<tr>
<td>gross domestic product (GDP)</td>
<td>doubling time</td>
</tr>
</tbody>
</table>

Resources for Vocabulary Development: textbook, lecture notes, online resources
Engaging Experience 1

Title: Population Density and Biomass Study

Suggested Length of Time: 2-3 class periods

Themes Addressed:

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Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.
- Management of common resources is essential.

Detailed Description/Instructions: In this activity, students will use a quadrat sampling to determine the population density of a species in a selected study site - this investigation is designed to calculate the standing crop biomass in a grassland but can easily be adapted to study any plot such as a forest or even a weedy urban lot or backyard. In ecology, energy transfer between one trophic level and another is an important focus. In this activity, students will determine the population density and standing crop biomass of a species within a measured area. Students will consider the energy stored in that standing crop biomass in relation to the trophic levels above and/or below it. Additional field observations will enable the students to develop an awareness of how populations within a single ecosystem are connected. Students will select a target species (primary producer) for their study site, place the quadrat in the site and count the number of individuals within that square meter. The number per square meter will give an average population density; however, students will also be asked to observe and calculate the relative dispersion of the population - clumped, random, even. Students will use this information to calculate the ecological rule of thumb - for a food chain in their quadrat sample. By analyzing
the abiotic and biotic elements within the study site, students should be able to design a population biomass study for a detrital food chain.

Bloom’s Levels: Analyze, Create
Webb’s DOK: 3
Topic 2: Human Population Dynamics

Engaging Experience 1
Title: Population Growth
Suggested Length of Time: 1 class period
Themes Addressed:

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  ● Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
Human survival depends on developing practices that will achieve sustainable systems.
  ● A suitable combination of conservation and development is required.
  ● Management of common resources is essential.

Detailed Description/Instructions: In this exercise, students will use current data from the CIA World Fact Book to make predictions about world population growth over the next decades. Students will use current population growth rates and age structure demographics to predict population growth in ten year periods and use graphical plots of these growth rates to determine what areas of the world will have the highest growth rates. Students should analyze the social, cultural and biological factors that contribute to varying rates of population growth. This activity works best if students/student groups generate data from countries of four different regions such as Asia, Central/South America, Europe, and Africa. Students then predict the environmental issues that will arise due to the population growth rates and synthesize solutions to future problems.

Bloom’s Levels: Analyze
Webb’s DOK: 3
Culminating Activity

Culminating Activity:
1. In 1900, the average American could expect to live just 47 years. Today, the average American lives 75 years—an increase of nearly three decades of life in just a century’s time.
   a. Explain two possible things that have occurred within the last 100 years that can account for the increase in human life span.
   b. What are the greatest current and projected risks to human health?
   c. Explain the concept and components of risk analysis. How would information gained from studies of risk analysis increase the human lifespan?

2. The diagram below illustrates the demographic transition model of the relationship between economic status and population.

   a. In phases 2 and 3, there is a large difference between the birth rate and the death rate. Describe the effects on the overall population as a result of this difference. Explain why the population doubling time during these phases is short.
   b. Choose one of the four phases and describe an economic factor that would account for the differences between birth rate and death rate.
   c. Describe one biological method of birth control.
   d. Population experts have reported that in some developing countries, the population is experiencing a reverse transition from phase 2 to phase 1. Describe what would happen to a country’s population and describe one event that would cause this reverse transition.
3. Answer the following regarding world human population.
   a. Create a graph of the data from table 1 below on the axes provided.

<table>
<thead>
<tr>
<th>Year</th>
<th>TFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>5.0</td>
</tr>
<tr>
<td>1960</td>
<td>4.9</td>
</tr>
<tr>
<td>1970</td>
<td>4.7</td>
</tr>
<tr>
<td>1980</td>
<td>3.7</td>
</tr>
<tr>
<td>1990</td>
<td>3.4</td>
</tr>
<tr>
<td>2000</td>
<td>3.0</td>
</tr>
</tbody>
</table>

   b. Identify and discuss TWO of the causes for the trend in the worldwide TFR that you graphed in part (a).

   c. Consider the data in table 2 above. Identify and discuss TWO economic or societal factors that account for the difference between the TFR of Kenya and that of the United States.

   d. Describe TWO human activities related to the rapidly growing world population that are having an impact on Earth’s biodiversity.
<table>
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| Population Biology       | Population Density and Biomass Study     | In this activity, students will use a quadrat sampling to determine the population density of a species in a selected study site - this investigation is designed to calculate the standing crop biomass in a grassland but can easily be adapted to study any plot such as a forest or even a weedy urban lot or backyard. In ecology, energy transfer between one trophic level and another is an important focus.  
  In this activity, students will determine the population density and standing crop biomass of a species within a measured area. Students will consider the energy stored in that standing crop biomass in relation to the trophic levels above and/or below it. Additional field observations will enable the students to develop an awareness of how populations within a single ecosystem are connected. Students will select a target species (primary producer) for their study site, place the quadrat in the site and count the number of individuals within that square meter. The number per square meter will give an average population density; however, students will also be asked to observe and calculate the relative dispersion of the population - clumped, random, even. Students will use this information to calculate the ecological rule of thumb - for a food chain in their quadrat sample. By analyzing the abiotic and biotic elements within the study site, students should be able to design a population biomass study for a detrital food chain. | 2-3 class periods        |
| Human Population Dynamics| Population Growth                        | In this exercise, students will use current data from the CIA World Fact Book to make predictions about world population growth over the next decades. Students will use current population | 1 class period           |
growth rates and age structure demographics to predict population growth in ten year periods and use graphical plots of these growth rates to determine what areas of the world will have the highest growth rates. Students should analyze the social, cultural and biological factors that contribute to varying rates of population growth. This activity works best if students/student groups generate data from countries of four different regions such as Asia, Central/South America, Europe, and Africa. Students then predict the environmental issues that will arise due to the population growth rates and synthesize solutions to future problems.
Unit 4: Land and Water Use

Subject: AP Environmental Science
Grade: 10-12
Name of Unit: Land and Water Use
Length of Unit: 3 weeks
Overview of Unit: A study of humans’ use of valuable land and water resources, consequences of their overuse, and the ability of humans to create a sustainable future.

Unit Themes:
1. Science is a process.
   ● Science is a method of learning more about the world.
   ● Science constantly changes the way we understand the world.
2. Energy conversions underlie all ecological processes.
   ● Energy cannot be created; it must come from somewhere.
   ● As energy flows through systems, at each step more of it becomes unusable.
3. The Earth itself is one interconnected system.
   ● Natural systems change over time and space.
   ● Biogeochemical systems vary in ability to recover from disturbances.
   ● Humans have had an impact on the environment for millions of years.
   ● Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
5. Environmental problems have a cultural and social context.
   ● Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
6. Human survival depends on developing practices that will achieve sustainable systems.
   ● A suitable combination of conservation and development is required.
   ● Management of common resources is essential.

Supporting Standards:
● ISTE - CREATIVE COMMUNICATOR.6: Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.

Essential Questions:
1. Why is food security difficult to attain and how can we improve food security?
2. How can we produce food more sustainably?
3. How can we use water more sustainably?
4. Why is water scarcity an issue?
5. How long will supplies of nonrenewable mineral resources last and how can we use mineral resources more sustainably?

Enduring Understanding/Big Ideas:
1. Many people in less-developed countries have health problems as a result of not getting enough food, while many people in more-developed countries suffer health problems from eating too much food. The greatest obstacles in providing enough food for everyone are poverty, corruption, political upheaval, war, bad weather, and the harmful environmental effects of industrialized food production. We can improve food security by creating programs to reduce poverty and chronic malnutrition, relying more on locally grown food, and cutting food waste.
2. More sustainable food production will require using resources more efficiently, sharply decreasing the harmful environmental effects of industrialized food production, and eliminating government subsidies that promote such harmful impacts.
3. We can use water more sustainably by cutting water waste, raising water prices, slowing population growth, and protecting aquifers, forests, and other ecosystems that store and release water.
4. We are using available freshwater unsustainably by wasting it, polluting it, and charging too little for this irreplaceable natural resource. One of every six people does not have sufficient access to clean water, and this situation will almost certainly get worse.
5. All nonrenewable mineral resources exit in infinite amounts, and as we get closer to depleting any mineral resource, the environmental impacts of extracting it generally become more harmful. Raising the price of a scarce mineral resource can lead to an increase in its supply, but there are environmental limits to this effect. We can try to find substitutes for scarce resources, reduce resource waste, and recycle and reuse minerals.

Unit Vocabulary:

<table>
<thead>
<tr>
<th>Academic Cross-Curricular Words</th>
<th>Content/Domain Specific</th>
</tr>
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<tbody>
<tr>
<td>Agriculture</td>
<td>Human Nutritional Requirements</td>
</tr>
<tr>
<td>Green Revolution</td>
<td>Genetic Engineering</td>
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<tr>
<td>Cost/Benefit Analysis</td>
<td>Crop Production</td>
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<td>EPA (Environmental Protection Agency)</td>
<td>Deforestation</td>
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<td>USDA (US Department of Agriculture)</td>
<td>Irrigation</td>
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<td>Urbanization</td>
<td>Sustainable Agriculture</td>
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<td>Suburban Sprawl</td>
<td>Integrated Pest Management</td>
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<td>Infrastructure</td>
<td>Pesticide</td>
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<td>Highway System</td>
<td>FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act)</td>
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<td>Preservation</td>
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<td>Remediation</td>
<td>Old Growth Forest</td>
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<td>Mitigation</td>
<td>Forest Management</td>
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<td>Restoration</td>
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<td>Mining</td>
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<td>Extraction</td>
<td>Forest Fire</td>
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<td>Globalization</td>
<td>Overgrazing</td>
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<td>World Bank</td>
<td>Desertification</td>
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<td>Wetland</td>
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<td>Sustainable Land Use</td>
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<td>Mineral Formation</td>
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<td>Mineral Reserve</td>
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<td>Surface Mining Control and Reclamation Act</td>
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<td>Clean Water Act</td>
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<td>Overfishing</td>
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<td>Aquaculture</td>
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<td>Safe Drinking Water Act</td>
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<td>USFWS (US Fish and Wildlife Services)</td>
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</table>

**Resources for Vocabulary Development:** textbook, lecture notes, online resources
**Topic 1: Land Use**

**Engaging Experience 1**

**Title:** Does Land Use Affect Soil Texture and Permeability?

**Suggested Length of Time:** 1-2 class periods

**Themes Addressed:**

- Science is a process.
  - Science is a method of learning more about the world.
  - Science constantly changes the way we understand the world.
- Energy conversions underlie all ecological processes.
  - Energy cannot be created; it must come from somewhere.
  - As energy flows through systems, at each step more of it becomes unusable.
- The Earth itself is one interconnected system.
  - Natural systems change over time and space.
  - Biogeochemical systems vary in ability to recover from disturbances.
- Humans alter natural systems.
  - Humans have had an impact on the environment for millions of years.
  - Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
- Environmental problems have a cultural and social context.
  - Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
- Human survival depends on developing practices that will achieve sustainable systems.
  - A suitable combination of conservation and development is required.
  - Management of common resources is essential.

**Detailed Description/Instructions:** In this activity, students will evaluate the effect of land use, such as agricultural, urban, suburban, construction, etc., on the physical and chemical characteristics of soil. Students will collect samples of soil from different land use areas, recommended areas can include a weedy urban lot, a neatly manicured suburban lawn, a homegrown garden, a flower bed, an agricultural cropland or rangeland, a forest floor, etc. Students will then use these soil samples to investigate the effect of land use on soil: are the heights of the soil horizons different for the various land use samples? Is the soil composition different (percent silt, clay, sand, etc)? Do land use variances affect the permeability rate of the soil? What leachate/chemicals are found in the different land use samples? Students use the collected data to compare the pros and cons of various land use strategies on soil conservation.

**Bloom’s Levels:** Analyze

**Webb’s DOK:** 3
Topic 2: Water Use

**Engaging Experience 1**

**Title:** Know Your Neighborhood - Analyze Local Watershed

**Suggested Length of Time:** 1-2 class periods

**Themes Addressed:**

- Science is a process.
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  - Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

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  - A suitable combination of conservation and development is required.
  - Management of common resources is essential.

**Supporting Standards:**

- ISTE - CREATIVE COMMUNICATOR.6: Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.
**Detailed Description/Instructions:** In this activity, students will investigate water samples from their local watershed to determine local environmental issues surrounding it. Students will use the USGS and EPA websites to gather general data on local and regional watersheds, describing the watershed and current environmental issues surrounding it, such as frequency of pollution, analysis of runoff, erosion rates, etc. Students will then use this data to predict the quality of the water in their local watershed. Using field investigations and laboratory exercises, students will investigate the health of their local watershed - measuring macroinvertebrate samples; particulate turbidity; runoff pollutant concentration; etc. Students will then present their findings to the class in a “town hall meeting format.” Students will present to the “city council” whether limitations should be put on neighborhoods for outdoor water use such as washing a car, watering a yard, filling a swimming pool, fertilizer applications to yards, etc.

**Bloom’s Levels:** Analyze

**Webb’s DOK:** 4
Topic 3: Mining

Engaging Experience 1
Title: Cookie Mining
Suggested Length of Time: 1 class period

Themes Addressed:

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Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.
- Management of common resources is essential.
Detailed Description/Instructions: In this activity, students explore the economics, application and consequences of mining by “mining” for chocolate chips from a chocolate chip cookie. The general definition of an ore is a naturally occurring material from which minerals of economic value can be extracted at a profit. In this investigation, the chocolate chip in a chocolate chip cookie is the “ore” being mined. The worthless rock that is associated with the ore and must be separated from the ore is called the gangue. The rest of the cookie (excluding the chocolate chip) is the gangue. This simulation allows students to purchase “land areas” and “mining equipment” as well as paying for mining operations and reclamation. In return, the “miners” receive money for the “ore” mined. Although the primary goal is to introduce the economics of mining, the environmental, societal and global issues should not be ignored. Each “miner” is responsible for tracking all mining costs, including the cost of the cookie, mining equipment rental, and reclamation time and costs. Students will evaluate first-hand the pros and cons to surface mining vs. strip mining and the environmental issues associated with each. At the conclusion, students should be able to predict the short-term and long-term consequences of a mining company harvesting a valuable ore in their neighborhood, or even in their own backyard.

Bloom’s Levels: Evaluate
Webb’s DOK: 3
Culminating Activity

1. The Colorado River flows from the Colorado Rockies to the Gulf of California. The primary source of Colorado River water is melting Rocky Mountain snowpack. Once the river descends from the Rockies, it flows through a landscape that is dominated by desert. Colorado River water carries a high load of sediment.
   a. Multiple dams have been erected along the Colorado River. Identify TWO benefits other than agriculture and recreation that people derive from that system of dams.
   b. Discuss TWO potential environmental consequences of damming a major river.
   c. Competition for access to Colorado River water has increased dramatically due to increased population size and intensive agricultural use. Describe TWO conservation strategies for reducing agricultural water consumption.
   d. Identify TWO possible environmental consequences of climate change on the hydrology of the Colorado River system.
   e. In addition to impacts on the Colorado River system, climate change is impacting the hydrology of coastal ecosystems. Identify and describe TWO possible consequences of climate change on coastal ecosystems.

2. Over the last few decades, scientists have been monitoring the beluga whale populations in the St. Lawrence River. Examinations of fat tissue in the whales have shown an accumulation of many different chemical toxins present in the waterways. Two of the toxins the scientist tested for were elemental mercury and methylmercury.
   a. Describe how chemical toxins can accumulate to such high levels in beluga whales.
   b. Identify TWO possible chemical toxins, other than mercury, that could be found in high concentrations in the belugas’ fat tissue and describe how they get into the St. Lawrence River.
   c. For one of the toxins you identified in part b, describe a human health impact that could be caused by exposure to that toxin.
   d. Explain one way to reduce the beluga whale population’s possible exposure to mercury.
### Summary of Engaging Learning Experiences for Topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Engaging Experience Title</th>
<th>Description</th>
<th>Suggested Length of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use</td>
<td>Does Land Use Affect Soil Texture and Permeability?</td>
<td>In this activity, students will evaluate the effect of land use, such as agricultural, urban, suburban, construction, etc., on the physical and chemical characteristics of soil. Students will collect samples of soil from different land use areas, recommended areas can include a weedy urban lot, a neatly manicured suburban lawn, a homegrown garden, a flower bed, an agricultural cropland or rangeland, a forest floor, etc. Students will then use these soil samples to investigate the effect of land use on soil: are the heights of the soil horizons different for the various land use samples? Is the soil composition different (percent silt, clay, sand, etc.)? Do land use variances affect the permeability rate of the soil? What leachate/chemicals are found in the different land use samples? Students use the collected data to compare the pros and cons of various land use strategies on soil conservation.</td>
<td>1-2 class period</td>
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<td>Water Use</td>
<td>Know Your Neighborhood - Analyze Local Watershed</td>
<td>In this activity, students will investigate water samples from their local watershed to determine local environmental issues surrounding it. Students will use the USGS and EPA websites to gather general data on local and regional watersheds, describing the watershed and current environmental issues surrounding it, such as frequency of pollution, analysis of runoff, erosion rates, etc. Students will then use this data to predict the quality of the water in their local watershed. Using field investigations and laboratory exercises, students will investigate the health of their local watershed - measuring macroinvertebrate samples; particulate turbidity; runoff pollutant concentration; etc. Students will then present their findings to the class in a “town</td>
<td>1-2 class periods</td>
</tr>
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</table>
hall meeting format.” Students will present to the “city council” whether limitations should be put on neighborhoods for outdoor water use such as washing a car, watering a yard, filling a swimming pool, fertilizer applications to yards, etc.

<table>
<thead>
<tr>
<th>Mining</th>
<th>Cookie Mining</th>
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<tbody>
<tr>
<td>In this activity, students explore the economics, application and consequences of mining by “mining” for chocolate chips from a chocolate chip cookie. The general definition of an ore is a naturally occurring material from which minerals of economic value can be extracted at a profit. In this investigation, the chocolate chip in a chocolate chip cookie is the “ore” being mined. The worthless rock that is associated with the ore and must be separated from the ore is called the gangue. The rest of the cookie (excluding the chocolate chip) is the gangue. This simulation allows students to purchase “land areas” and “mining equipment” as well as paying for mining operations and reclamation. In return, the “miners” receive money for the “ore” mined. Although the primary goal is to introduce the economics of mining, the environmental, societal and global issues should not be ignored. Each “miner” is responsible for tracking all mining costs, including the cost of the cookie, mining equipment rental, and reclamation time and costs. Students will evaluate first-hand the pros and cons to surface mining vs. strip mining and the environmental issues associated with each. At the conclusion, students should be able to predict the short-term and long-term consequences of a mining company harvesting a valuable ore in their neighborhood, or even in their own backyard.</td>
<td>1 class period</td>
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Unit 5: Energy Resources and Consumption

Subject: AP Environmental Science
Grade: 10-12
Name of Unit: Energy Resources and Consumption
Length of Unit: 3 weeks
Overview of Unit: Students will study energy consumption, the current and future needs of nonrenewable energy sources and the development of renewable energy and alternative energy sources. The conservation of energy will also be addressed.

Unit Themes:

Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

Energy conversions underlie all ecological processes.
- Energy cannot be created; it must come from somewhere.
- As energy flows through systems, at each step more of it becomes unusable.

The Earth itself is one interconnected system.
- Natural systems change over time and space.
- Biogeochemical systems vary in ability to recover from disturbances.

Humans alter natural systems.
- Humans have had an impact on the environment for millions of years.
- Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.

Environmental problems have a cultural and social context.
- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

Human survival depends on developing practices that will achieve sustainable systems.
- A suitable combination of conservation and development is required.
- Management of common resources is essential.

Supporting Standards:
- ISTE - KNOWLEDGE COLLECTOR.3: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.
- TT.AB.I.4: Students will express pride, confidence and healthy self-esteem without denying the value and dignity of other people.
**Essential Questions:**

1. How do nonrenewable energy resources affect the environment? Discuss the advantages and disadvantages of using oil, natural gas, coal, and nuclear energy?
2. How can renewable energy resources be used to produce electricity? Discuss the advantages and disadvantages of using solar energy, hydropower, wind power, biomass, geothermal energy?
3. How can we cut energy waste?
4. How can we make the transition to a more sustainable energy future?

**Enduring Understanding/Big Ideas:**

1. Conventional oil is currently abundant, has a high net energy yield, and is relatively inexpensive, but using it causes air and water pollution and releases greenhouse gases to the atmosphere. Conventional natural gas is more plentiful than oil, has a high net energy yield and a fairly low cost, and has the lowest environmental impact of all fossil fuels. Conventional coal is plentiful and has a high net energy yield and low cost, but it has a very high environmental impact. Nuclear power has a low environmental impact and a very low accident risk, but its use has been limited by a low net energy yield, high costs, fear of accidents, long-lived radioactive wastes, and the potential for spreading nuclear weapons technology.

2. Passive and active solar heating systems can heat water and buildings effectively, and the costs of using direct sunlight to produce high-temperature heat and electricity are coming down. We can use water flowing over dams, tidal flows, and ocean waves to generate electricity, but environmental concerns and limited availability of suitable sites may limit our use of these energy resources. When we include the environmental costs of using energy resources in the market prices of energy, wind power is the least expensive and least polluting way to produce electricity. Solid biomass is a renewable resource for much of the world’s population, but burning it faster than it is replenished produces a net gain in atmospheric greenhouse gases, and creating biomass plantations can degrade soil and biodiversity. Geothermal energy has great potential for supplying many areas with heat and electricity, and it has a generally low environmental impact, but the sites where it can be used economically are limited.

3. We have a variety of technologies for sharply increasing the energy efficiency of industrial operations, motor vehicles, appliances, and buildings.

4. We can make the transition to a more sustainable energy future by greatly improving energy efficiency, using a mix of renewable energy resources, and including the environmental costs of energy resources in their market prices.
**Unit Vocabulary:**

<table>
<thead>
<tr>
<th>Academic Cross-Curricular Words</th>
<th>Content/Domain Specific</th>
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<tbody>
<tr>
<td></td>
<td>Power</td>
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<td>Units</td>
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<td>Laws of Thermodynamics</td>
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<td>Nonrenewable Energy</td>
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<td>Renewable Energy</td>
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<td>Synfuel</td>
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<td>Nuclear Fission</td>
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<td>Nuclear Fusion</td>
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<td>Energy efficiency</td>
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<td>Hybrid electric vehicles</td>
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<td>Mass transit</td>
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<td>Solar energy</td>
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<td>Hydrogen fuel cells</td>
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<td>Biomass</td>
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<td>Wind energy</td>
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<td>Geothermal</td>
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<td>CAFE</td>
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<td>Fossil fuel</td>
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<td>Cogeneration</td>
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<td>Petroleum</td>
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<td>Crude oil</td>
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<td>Oil sands</td>
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<td>Bitumen</td>
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<td>Radioactive waste</td>
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<td>Energy conversion</td>
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<td>Biofuel</td>
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<td>Ethanol</td>
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<td>Biodiesel</td>
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<td>Hydroelectricity</td>
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<td>Tidal energy</td>
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<td>Smart grid</td>
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<td>Active solar energy</td>
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<td>Passive solar energy</td>
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<td>Photovoltaic solar cell</td>
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</tbody>
</table>

**Resources for Vocabulary Development:** textbook, lecture notes, online resources
Engaging Experience 1
Title: Personal Energy Audit Lab
Suggested Length of Time: 2 class periods
Themes Addressed:

- Science is a process.
  - Science is a method of learning more about the world.
  - Science constantly changes the way we understand the world.
- Energy conversions underlie all ecological processes.
  - Energy cannot be created; it must come from somewhere.
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Detailed Description/Instructions: Students will read their electric meter at the same time every day for a 10-day period and record the values. Students will also calculate their monthly energy consumption (in Kilowatt-Hours) and cost for electrical appliances. Then, students will determine the amount of CO₂ and SO₂ released by their electricity consumption each month. They will inspect and report on different characteristics (such as the amount, location, and quality of insulation, the condition, composition, and color of the roof, the air circulation in the attic, and the color of outer walls) of their house or apartment and explain how these affect their use of electricity. Students will compare their calculated cost and kWh to their actual cost and kWh and explain what could be the reason(s) for the difference. They will also discuss the amount of CO₂ and SO₂ their household emits in a month and explain how that affects the environment. They will also make some detailed suggestions about they can conserve energy by changing patterns of consumption.

Bloom’s Levels: Analyze
Webb’s DOK: 3
Engaging Experience 1

Title: Nonrenewable Energy Debate

Suggested Length of Time: 1 class period

Themes Addressed:

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Supporting Standards:
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- TT.AB.I.4: Students will express pride, confidence and healthy self-esteem without denying the value and dignity of other people.
**Detailed Description/Instructions:** Each group of students will present their research on their assigned nonrenewable energy during the debate. The groups will have three minutes to state their case and explain their viewpoint. While presenting, other teams will be taking notes on talking points to use during the rebuttal. At the end of each group’s presentation, the teacher will ask a few questions pertaining to that particular energy source. After each team has stated their viewpoint, each team will have two minutes to prepare for their rebuttal. Then, each team will have two minutes to criticize the arguments presented from the other teams. During this time, teams may address as many viewpoints as they can. After the rebuttal is finished, each team will have two minutes to prepare for closing remarks. After the two minutes, each team will have two minutes to state their closing remarks.

**Bloom’s Levels:** Apply, Analyze, Evaluate, Create

**Webb’s DOK:** 3
Engaging Experience 1
Title: Renewable Energy Debate
Suggested Length of Time: 1 class period
Themes Addressed:

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**Detailed Description/Instructions:** Each group of students will present their research on their assigned renewable energy during the debate. The groups will have three minutes to state their case and explain their viewpoint. While presenting, other teams will be taking notes on talking points to use during the rebuttal. At the end of each group’s presentation, the teacher will ask a few questions pertaining to that particular energy source. After each team has stated their viewpoint, each team will have two minutes to prepare for the rebuttal. Then, each team will have two minutes to criticize the arguments presented from the other teams. During this time, teams may address as many viewpoints as they can. After the rebuttal is finished, each team will have two minutes to prepare for closing remarks. After the two minutes, each team will have two minutes to state their closing remarks.

**Bloom’s Levels:** Apply, Analyze, Evaluate, Create

**Webb’s DOK:** 3
Culminating Activity:

1. Battery electric vehicles (BEVs) have been introduced to consumers as an alternative way to reduce the environmental effects caused by use of internal-combustion engine (ICE) vehicles. A comparison of both vehicle types can help determine whether the use of BEVs would be beneficial in the future. Where calculations are required, show your work.
   a. **Identify** THREE strategies that the federal government could implement to encourage the use of BEVs.
   b. Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs $3.75 per gallon (gal). **Calculate** the cost of gasoline per mile.
   c. The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is $0.11 per kilowatt-hour (kWh).
      i. **Calculate** the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with.
      ii. **Calculate** the cost of electricity per mile to drive the BEV.

When it is driven 100 miles, the ICE vehicle contributes 72.8 pounds (lbs) of CO$_2$ from the burning of gasoline. The drilling, refining, and transportation costs of getting the gasoline to the gas station add an additional 17.7 lb of CO$_2$ per 100 miles. The BEV does not emit any CO$_2$ itself, but the extraction, transportation, and combustion of the coal that produced the electricity at the power plant add 63.3 lb of CO$_2$ for the same 100 miles.

d. **Calculate** the difference in the amount of CO$_2$ that would enter the atmosphere if both cars were driven 100 miles.

e. **Describe** TWO economic impacts (excluding costs related to climate change resulting from CO$_2$ emissions or the cost of gasoline at the pump) that result from an increased number of BEVs on the road.

2. Read the following article from the *Fremont Gazette* and answer the questions that follow.
Natural Gas from Rock

The Marcellus Shale is a large domestic natural gas reserve that could meet the United States energy needs for 25 years. The 350-million-year-old geologic formation stretches from New York to West Virginia on land that is largely undeveloped. It was once thought that it was too difficult to extract natural gas from the Marcellus Shale, but new drilling technology allows energy companies to tap this vast reserve. The natural gas is removed by a process called hydraulic fracturing, or fracking. During this process, the shale is drilled and millions of gallons of water, sand, and chemicals are pumped into the shale at high pressure, shattering the shale and releasing the natural gas trapped within. While some of this water remains below ground, contaminated water is also stored in ponds, trucked to wastewater treatment plants, or disposed of by spraying it on nearby land.

a. Identify and describe TWO water-related environmental problems associated with fracking.

b. Natural gas is considered to be a better fossil fuel for the environment than coal is. Discuss TWO environmental benefits of using natural gas as a fuel compared to using coal.

c. Describe TWO environmental drawbacks, not related to water use, of using the fracking process to extract natural gas from shale.

d. Describe one economic benefit to society of using fracking to obtain natural gas from shale.

e. Nuclear power is an alternative to using natural gas or coal as a fuel for generating electricity. However, there are also problems associated with nuclear power plants. Describe TWO negative environmental impacts associated with nuclear power.
### Summary of Engaging Learning Experiences for Topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Engaging Experience Title</th>
<th>Description</th>
<th>Suggested Length of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Concepts: Consumption and Conservation</strong></td>
<td>Personal Energy Audit Lab</td>
<td>Students will read their electric meter at the same time every day for a 10-day period and record the values. Students will also calculate their monthly energy consumption (in Kilowatt-Hours) and cost for electrical appliances. Then, students will determine the amount of CO₂ and SO₂ released by their electricity consumption each month. They will inspect and report on different characteristics (such as the amount, location, and quality of insulation, the condition, composition, and color of the roof, the air circulation in the attic, and the color of outer walls) of their house or apartment and explain how these affect their use of electricity. Students will compare their calculated cost and kWh to their actual cost and kWh and explain what could be the reason(s) for the difference. They will also discuss the amount of CO₂ and SO₂ their household emits in a month and explain how that affects the environment. They will also make some detailed suggestions about they can conserve energy by changing patterns of consumption.</td>
<td>2 class periods</td>
</tr>
<tr>
<td><strong>Nonrenewable Energy</strong></td>
<td>Nonrenewable Energy Debate</td>
<td>Each group of students will present their research on their assigned nonrenewable energy during the debate. The groups will have three minutes to state their case and explain their viewpoint. While presenting, other teams will be taking notes on talking points to use during the rebuttal. At the end of each group’s presentation, the teacher will ask a few questions pertaining to that particular</td>
<td>1 class period</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>Renewable Energy Debate</td>
<td>Each group of students will present their research on their assigned renewable energy during the debate. The groups will have three minutes to state their case and explain their viewpoint. While presenting, other teams will be taking notes on talking points to use during the rebuttal. At the end of each group’s presentation, the teacher will ask a few questions pertaining to that particular energy source. After each team has stated their viewpoint, each team will have two minutes to prepare for the rebuttal. Then, each team will have two minutes to criticize the arguments presented from the other teams. During this time, teams may address as many viewpoints as they can. After the rebuttal is finished, each team will have two minutes to prepare for closing remarks. After the two minutes, each team will have two minutes to state their closing remarks.</td>
<td>1 class period</td>
</tr>
</tbody>
</table>
Unit 6: Pollution

Subject: AP Environmental Science
Grade: 10-12
Name of Unit: Pollution
Length of Unit: 3 weeks

Overview of Unit: Students will study sources of pollution, major pollutants, effects of pollutants on the environment and human health, the economic impacts of pollution, and relevant laws dealing with pollution.

Unit Themes:
- Science is a process.
  - Science is a method of learning more about the world.
  - Science constantly changes the way we understand the world.
- Energy conversions underlie all ecological processes.
  - Energy cannot be created; it must come from somewhere.
  - As energy flows through systems, at each step more of it becomes unusable.
- The Earth itself is one interconnected system.
  - Natural systems change over time and space.
  - Biogeochemical systems vary in ability to recover from disturbances.
- Humans alter natural systems.
  - Humans have had an impact on the environment for millions of years.
  - Technology and population growth have enabled humans to increase both the rate and scale of their impact on the environment.
- Environmental problems have a cultural and social context.
  - Understanding the role of cultural, social, and economic factors is vital to the development of solutions.
- Human survival depends on developing practices that will achieve sustainable systems.
  - A suitable combination of conservation and development is required.
  - Management of common resources is essential.

Essential Questions:
1. How can we evaluate chemical hazards?
2. How do we perceive risks and how can we avoid the worst of them?
3. What are the health effects of air pollution and how should we deal with air pollution?
4. Why is acid deposition a problem?
5. How can we best deal with water pollution?
6. How should we deal with solid waste and how can we make the transition to a more sustainable low-waste society?
**Enduring Understanding/Big Ideas:**

1. Scientists use live laboratory animals, case reports of poisonings, and epidemiological studies to estimate the toxicity of chemicals, but these methods have limitations. Many health scientists call for much greater emphasis on pollution prevention to reduce our exposure to potentially harmful chemicals.

2. We can reduce the major risks we face by becoming informed, thinking critically about risks, and making careful choices.

3. Air pollution can contribute to asthma, chronic bronchitis, emphysema, lung cancer, heart attack and stroke. Legal, economic, and technological tools can help us to clean up air pollution, but the best solution is to prevent it.

4. Acid deposition is caused mainly by coal-burning power plants and motor vehicle emissions, and in some regions it threatens human health, aquatic life and ecosystems, forests, and human-built structures.

5. Reducing water pollution requires that we prevent it, work with nature to treat sewage, cut resource use and waste, reduce poverty, and slow population growth.

6. A sustainable approach to solid waste is first to reduce it, then to reuse or recycle it, and finally to safely dispose of what is left. Shifting to a low-waste society requires individuals and businesses to reduce resource use and to reuse and recycle wastes at local, national, and global levels.

**Unit Vocabulary:**

<table>
<thead>
<tr>
<th>Academic Cross-Curricular Words</th>
<th>Content/Domain Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution</td>
<td>Point source</td>
</tr>
<tr>
<td>Risk Assessment</td>
<td>Nonpoint source</td>
</tr>
<tr>
<td>Cost Benefit Analysis</td>
<td>Biochemical oxygen demand</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Indicator species</td>
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<tr>
<td>Epidemic</td>
<td>Fecal coliform bacteria</td>
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<tr>
<td>Pandemic</td>
<td>Septic system</td>
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<tr>
<td>Infectious disease</td>
<td>Acidification</td>
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<tr>
<td>Carcinogen</td>
<td>Acid deposition</td>
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<tr>
<td></td>
<td>Thermal pollution</td>
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<td></td>
<td>Maximum contaminant level (MCL)</td>
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<td></td>
<td>Primary pollutant</td>
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<td>Secondary pollutant</td>
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<td></td>
<td>Major air pollutants</td>
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<td></td>
<td>Smog</td>
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<td></td>
<td>Ozone</td>
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<td>Particulate matter</td>
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<td></td>
<td>Photochemical smog</td>
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<td>Industrial smog</td>
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<td></td>
<td>Sick building syndrome</td>
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<td></td>
<td>Acid deposition</td>
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<td>Heat island</td>
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<td>Temperature inversion</td>
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<td>Indoor air pollution</td>
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<td>Remediation</td>
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<tr>
<td>Clean Air Act</td>
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<td>Clean Water Act</td>
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<td>Safe Drinking Water Act</td>
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<td>Eutrophication</td>
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<td>Cultural Eutrophication</td>
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<td>Water Treatment Systems</td>
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<td>Toxicology</td>
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<td>Dose-Response Curve</td>
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<td>Hazardous Waste</td>
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<td>Bioremediation</td>
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<tr>
<td>Biomagnification</td>
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<tr>
<td>Municipal solid waste (MSW)</td>
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<td>Closed-loop recycling</td>
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<td>Open-loop recycling</td>
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<td>Composting</td>
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<td>Leachate</td>
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<td>Sanitary landfill</td>
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<td>Incineration</td>
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<td>Superfund Acts</td>
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<td>Brownfields</td>
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<td>Cradle-to-grave analysis</td>
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<td>Mutagen</td>
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<td>Neurotoxin</td>
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<td>LD50</td>
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<tr>
<td>Bioaccumulation</td>
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<tr>
<td>Biomagnification</td>
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<tr>
<td>Parts per million (ppm)</td>
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</table>

**Resources for Vocabulary Development:** textbook, lecture notes, online resources
Topic 1: Pollution Types

Engaging Experience 1
Title: Air Pollution Generated by Combustion
Suggested Length of Time: 3 class periods
Themes Addressed:

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Detailed Description/Instructions: In this activity, students will explore air pollution resulting from the combustion of fossil fuels. Whether inside a city apartment or outside in the fresh air, the body requires oxygen to function. Oxygen makes up only \( \frac{1}{5} \) of the atmospheric gases inhaled, most of what is inhaled is much more than bargained for. City dwellers get exposed to traffic congested highways with vehicles spewing out air pollutants that form a yellow-brown haze over the city. But even in the pristine wilderness, global wind and water patterns carry pollutants from one environment to the next. Steps have been taken to improve the air, land, and water quality with the Clean Water Act and Clean Air Acts of the 1990s. Students will place pollutant “traps” - petri dish covered with a layer of petroleum jelly, to collect dust, pollen and particulates from air pollution. Students will also use probes to measure ozone, ultraviolet radiation, carbon monoxide, and vehicle emissions for various types of automobiles. Students will compare different environments on the rate of air pollution and discuss the ramifications of their type of transportation on the Air Quality Index.

Bloom’s Levels: Apply
Webb’s DOK: 3
Engaging Experience 1
Title: Human Health Risk Assessment
Suggested Length of Time: 1 class period
Themes Addressed:

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Detailed Description/Instructions: In this laboratory exercise, students will analyze the long term cancer risk for adults and children exposed to benzene, methylene chloride and carbon tetrachloride in a fictitious community with a contaminated water system. A dataset with the measurements of contamination in the town’s well system is provided along with specific directions for using the Excel Data Analysis Tool Pak.

Bloom’s Levels: Evaluation
Webb’s DOK: 3
Engaging Experience 1

Title: Applying and Analyzing Cost Benefit Analysis

Suggested Length of Time: 1 class period

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Detailed Description/Instructions: This laboratory exercise is a simulation exercise where students will apply a cost-benefit analysis model to a proposed utility project. Students will familiarize themselves with the National Environmental Policy Act of 1969 and the Congressional Declaration of National Environmental Policy and then calculate the costs and benefits (in the form of energy savings) for the proposed project and 9 different alternatives.

Bloom’s Levels: Apply
Webb’s DOK: 3
Culminating Activity:

1. Read the article below from the Fremont Free Press and answer the questions that follow.

Fremont City Council Considers Nitrogen Ban to Fight Smog!

At Tuesday’s council meeting, Susan Lanza, a local environmental scientist, spoke about the role that nitrogen compounds play in the photochemical smog episodes that have recently plagued Fremont. Noting how successful the ban on the sale of phosphate detergents had been in improving conditions in Lake Fremont, Councilman Peter Budd proposed a ban on the use of all nitrogen-containing fertilizers in Fremont to solve the local photochemical-smog problem.

Councilwoman Nita Smith made a statement that “although nitrogen-based fertilizers can cause other environmental problems, the ban on nitrogen fertilizers won’t solve the smog problem in Fremont.” After a heated discussion, the council tabled the motion on the ban.

a. Support Councilwoman Smith’s statement that nitrogen-based fertilizers cause other environmental problems by describing one such problem.
b. Identify a nitrogen-containing primary pollutant that contributes to the formation of photochemical smog. Describe how that primary pollutant forms and explain why Councilman Budd was wrong.
c. Identify one secondary pollutant that is a component of photochemical smog and describe the following.
   i. How the secondary pollutant forms
   ii. ONE human health effect of the pollutant
   iii. ONE environmental effect of the pollutant
d. Earth’s natural nitrogen cycle occurs in several steps. Describe one chemical transformation that occurs in the natural nitrogen cycle and discuss the importance of that transformation to an ecosystem.

2. According to atmospheric temperature and CO₂ concentration records derived from Antarctic ice cores, Earth’s climate has undergone significant changes over the past 200,000
years. Two graphs are shown below. The upper graph shows the variation in atmospheric CO$_2$ concentrations and the lower graph shows the variation in air temperature. Both graphs cover the same time period from approximately 200,000 years ago up until the year 1950, which is represented as year 0 on the graphs.

a. Answer the following questions that relate to the graphs above. Remember that for any calculations you must clearly indicate how you arrived at your answer. Answers must also include appropriate units.
   i. Determine the net change in atmospheric CO$_2$ concentration between 140,000 years ago and 125,000 years ago.
   ii. Calculate the ratio of the change in mean global temperature to the change in atmospheric CO$_2$ concentration between 140,000 years ago and 125,000 years ago.
   iii. Scientists predict that between 1950 and 2050, the atmospheric CO$_2$ concentration will increase by 200 ppm. Predict the change in mean global temperature between 1950 and 2050 using the ratio that you calculated in part (ii).
   iv. Describe one major assumption that was necessary to make the prediction in part (iii) above. Discuss the validity of the assumption.

b. Identify and describe TWO major causes for the predicted 200 ppm increase in atmospheric CO$_2$ concentration between 1950 and 2050.

c. Identify TWO gases other than CO$_2$ that contribute to the anthropogenic increase in mean global temperature. For each gas, describe a major human activity that leads to its release.
# Summary of Engaging Learning Experiences for Topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Engaging Experience Title</th>
<th>Description</th>
<th>Suggested Length of Time</th>
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<td>Pollution Types</td>
<td>Air Pollution Generated by Combustion</td>
<td>In this activity, students will explore air pollution resulting from the combustion of fossil fuels. Whether inside a city apartment or outside in the fresh air, the body requires oxygen to function. Oxygen makes up only ⅕ of the atmospheric gases inhaled, most of what is inhaled is much more than bargained for. City dwellers get exposed to traffic congested highways with vehicles spewing out air pollutants that form a yellow-brown haze over the city. But even in the pristine wilderness, global wind and water patterns carry pollutants from one environment to the next. Steps have been taken to improve the air, land, and water quality with the Clean Water Act and Clean Air Acts of the 1990s. Students will place pollutant “traps” - petri dish covered with a layer of petroleum jelly, to collect dust, pollen and particulates from air pollution. Students will also use probes to measure ozone, ultraviolet radiation, carbon monoxide, and vehicle emissions for various types of automobiles. Students will compare different environments on the rate of air pollution and discuss the ramifications of their type of transportation on the Air Quality Index.</td>
<td>3 class periods</td>
</tr>
<tr>
<td>Impacts on Environmental Health</td>
<td>Human Health Risk Assessment</td>
<td>In this laboratory exercise, students will analyze the long term cancer risk for adults and children exposed the benzene, methylene chloride and carbon tetrachloride in a fictitious community with a contaminated water system. A dataset with the measurements of contamination in the town’s well system is provided along with specific directions for using the Excel Data Analysis Tool Pak.</td>
<td>1 class period</td>
</tr>
<tr>
<td>Economic Impacts</td>
<td>Applying and Analyzing Cost Benefit Analysis</td>
<td>This laboratory exercise is a simulation exercise where students will apply a cost-benefit analysis model to a proposed utility project. Students will familiarize themselves with the National Environmental Policy Act of 1969 and the Congressional Declaration of National Environmental Policy and then calculate the costs and benefits (in the form of energy savings) for the proposed project and 9 different alternatives.</td>
<td>1 class period</td>
</tr>
</tbody>
</table>
Unit 7: Global Change

Subject: AP Environmental Science  
Grade: 10-12  
Name of Unit: Global Change  
Length of Unit: 2 weeks  
Overview of Unit: Students will explore the benefits and consequences of human activity on the environment.

Unit Themes:
Science is a process.
- Science is a method of learning more about the world.
- Science constantly changes the way we understand the world.

Energy conversions underlie all ecological processes.
- Energy cannot be created; it must come from somewhere.
- As energy flows through systems, at each step more of it becomes unusable.

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Environmental problems have a cultural and social context.
- Understanding the role of cultural, social, and economic factors is vital to the development of solutions.

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Essential Questions:
1. How might the earth’s temperature and climate change in the future?
2. How would a warmer atmosphere affect our lives?
3. How have we depleted ozone in the stratosphere and what can we do about it?
4. How does transportation affect urban environmental impacts?
5. How can cities become more sustainable and livable?
**Enduring Understanding/Big Ideas:**

1. Considerable scientific evidence indicates that the earth’s atmosphere is warming, because of a combination of natural effects and human activities, and that this warming is likely to lead to significant climate disruption during this century.

2. The projected rapid change in the atmosphere’s temperature could have severe and long-lasting consequences, including increased drought and flooding, rising sea levels, and shifts in the locations of croplands and wildlife habitats.

3. Our widespread use of certain chemicals has reduced ozone levels in the stratosphere, which has allowed more harmful ultraviolet radiation to reach the earth’s surface. To reverse ozone depletion, we must stop producing ozone-depleting chemicals and adhere to the international treaties that ban such chemicals.

4. In some countries, many people live in dispersed urban areas and depend mostly on motor vehicles for their transportation, which greatly expands their ecological footprints.

5. An eco-city allows people to choose walking, biking, or mass transit for most transportation needs; to recycle or reuse most of their wastes; to grow much of their food; and to protect biodiversity by preserving surrounding land.

**Unit Vocabulary:**

<table>
<thead>
<tr>
<th>Academic Cross-Curricular Words</th>
<th>Content/Domain Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyoto Protocol</td>
<td>Stratospheric Ozone</td>
</tr>
<tr>
<td>Skin Cancer</td>
<td>Ultraviolet Radiation</td>
</tr>
<tr>
<td>Greenhouse Gas</td>
<td>Ozone Depletion</td>
</tr>
<tr>
<td>Greenhouse Effect</td>
<td>CFC (Chlorofluorocarbon)</td>
</tr>
<tr>
<td>Global Warming</td>
<td>Montreal Protocol</td>
</tr>
<tr>
<td>Climate Change</td>
<td>Invasive Species</td>
</tr>
<tr>
<td>Habitat Loss</td>
<td>Endangered Species</td>
</tr>
<tr>
<td>Paris Accord (ICCA)</td>
<td>Extinct Species</td>
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<td></td>
<td>Loss of Biodiversity</td>
</tr>
</tbody>
</table>

**Resources for Vocabulary Development:** textbook, lecture notes, online resources
Engaging Experience 1
Title: Comparing Sunscreens
Suggested Length of Time: 1 class period
Themes Addressed:
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    ● Science constantly changes the way we understand the world.
  Humans alter natural systems.
    ● Humans have had an impact on the environment for millions of years.
    ● Technology and population growth have enabled humans to increase both the rate
      and scale of their impact on the environment.
  Environmental problems have a cultural and social context.
    ● Understanding the role of cultural, social, and economic factors is vital to the
      development of solutions.
  Human survival depends on developing practices that will achieve sustainable systems.
    ● A suitable combination of conservation and development is required.
    ● Management of common resources is essential.

Detailed Description/Instructions: In this experiment, students will measure the amount of
UVB light that passes through various sunscreens. Students will then compare it with the amount
of UVB light from direct sun and analyze the relationship between them. Students will prepare
test cards that are covered with plastic wrap. Then they will apply sunscreen to test cards and,
using UVB sensors, will measure the amount of light that passes through the different sunscreens
they are testing. Students will collect and graph the collected data and describe how the UVB
light intensity changed with different SPF values. As an extension to this lab, students will test a
wider variety of sunscreens to confirm or deny their conclusions.
Bloom’s Levels: Analyze
Webb’s DOK: 3
Engaging Experience 1
Title: Greenhouse Effect
Suggested Length of Time: 1 class period
Themes Addressed:

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Detailed Description/Instructions: In this activity, students will prepare model atmospheres containing different amounts of water vapor and carbon dioxide. Students will predict the relative temperature changes in the model atmospheres when they are exposed to sunlight and will compare the actual temperature changes in the model atmospheres. They will then calculate the temperature change for all three model atmospheres by subtracting the initial temperature of each (at 1 minute) from the final temperature of each (at 10 minutes) and will graph their data. Based on their results, students will discuss and explain with reasoning the effect of carbon dioxide and water vapor on the ability of the atmosphere to retain heat. For the research and communications component of this lab, students will find out how human activities affect the concentrations of greenhouse gases, including gases other than water vapor and carbon dioxide and will present their findings in a written or an oral report.

Bloom’s Levels: Apply
Webb’s DOK: 4
Topic 3: Loss of Biodiversity

Engaging Experience 1
Title: Creating LD50 Graphs for Different Substances
Suggested Length of Time: 1 class period
Themes Addressed:

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Detailed Description/Instructions: Students will determine the lethal dose 50 (LD50) level of different substances given and based on the substances’ LD50; students will then determine which substance is more dangerous. Then, using a given lethal dose data for two toxic chemical compounds, students will graph each, calculate their LD50 levels, and determine which is more dangerous based on the data. Student will discuss why the LD50 data is so useful in dealing with human health and environmental toxins.

Bloom’s Levels: Apply
Webb’s DOK: 2
The Floridian Daily
May 21, 2013

The small community located on the edge of the magnificent wetlands of Florida’s Everglades was the site of a press conference today where Governor Gayle Moss announced that the restoration of the Everglades is successfully underway. She noted that the Everglades ecosystem has suffered threats to its water quality, water quantity, and habitats in recent decades. Moss noted that intensive urban and agricultural development in adjacent areas has diverted substantial amounts of freshwater resources and impaired water quality. Governor Moss then emphasized that the preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state. She closed the press conference by saying, “The Everglades is a gem not only for Florida but for the entire world. Each of us has the responsibility to do our part to preserve this magnificent resource.”

a. **Describe** how TWO human activities, other than those that result in anthropogenic climate change, have resulted in a decrease in the amount of freshwater flowing into the Everglades ecosystem.

b. In addition to water quantity problems, the Everglades is faced with a variety of water quality issues. For example, phosphorus concentrations in the Everglades have increased since the 1960s.
   i. **Describe** how one specific human activity contributes to increased phosphorus levels in the Everglades.
   ii. **Explain** one way in which an increase in phosphorus levels can adversely affect the Everglades ecosystem.
   iii. **Describe** one step that could be taken to reduce phosphorus inputs from the activity you identified in part (i).

c. Climate change could have a variety of impacts on water quantity, water quality, and habitat. For EACH of these three factors, **identify and describe** one specific example of an impact on the Everglades likely to result from climate change.

d. The article states that Governor Moss believes that the “preservation and enhancement of the Everglades, key goals of the restoration program, are absolutely essential for the continued environmental and economic health of the state.”
i. **Describe** one way that restoring water quantity and water quality in the Everglades is expected to improve the structure and function of the ecosystem.

ii. **Describe** one way that restoring the Everglades is expected to provide economic benefits to Florida.

2. Scientific evidence shows a direct relationship between sea level and the global mean atmospheric temperature at Earth’s surface. Increases in the global mean atmospheric temperature during the past century have been accompanied by a gradual increase in sea level; currently the average rate of increase in sea level is 3.0 mm/yr. Additional increases in sea level are expected during the next century as global mean atmospheric temperatures continue to rise. These increases in sea level will affect coastal ecosystems as well as human activity along coastal margins.

   a. Based on the rate cited above, calculate the expected increase in sea level, in meters, during the next 50 years.

   b. Identify TWO phenomena that result from an increase in global mean atmospheric temperature and that contribute to increases in sea level. For each phenomenon that you identify, explain how it causes sea level to increase.

   c. Describe TWO environmental impacts that increasing sea level will have on an estuarine ecosystem such as those in the Mississippi Delta, Chesapeake Bay, and San Francisco Bay.

   d. Although sea level has been rising for over a century, human populations in coastal areas have increased dramatically during this period.

      i. **Describe** one negative economic impact that an increase in sea level will have on people who live along a coastline.

      ii. **Describe** TWO viable strategies that governments could use to discourage people from moving to coastal areas.

3. In the mid-1970s, Sherwood Rowland and Mario Molina predicted a thinning of the stratospheric ozone layer over Antarctica. The thinning was confirmed in the late twentieth century and has continued into the twenty-first century.

   a. Identify the class of chemical compounds that is primarily responsible for the thinning of the stratospheric ozone layer and describe TWO major uses for which these chemicals were manufactured.

   b. Describe how the chemical compounds that you identified in part (a) destroy stratospheric ozone molecules. You may include chemical equations as part of your answer.

   c. Identify the major environmental consequence of the depletion of stratospheric ozone.

   d. **Ozone** formed at ground level is a harmful pollutant. Describe TWO effects that ground-level ozone can have on ecosystems and/or human health.
### Summary of Engaging Learning Experiences for Topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Engaging Experience Title</th>
<th>Description</th>
<th>Suggested Length of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratospheric Ozone</td>
<td>Comparing Sunscreens</td>
<td>In this experiment, students will measure the amount of UVB light that passes through various sunscreens. Students will then compare it with the amount of UVB light from direct sun and analyze the relationship between them. Students will prepare test cards that are covered with plastic wrap. Then they will apply sunscreen to test cards and, using UVB sensors, will measure the amount of light that passes through the different sunscreens they are testing. Students will collect and graph the collected data and describe how the UVB light intensity changed with different SPF values. As an extension to this lab, students will test a wider variety of sunscreens to confirm or deny their conclusions.</td>
<td>1 class period</td>
</tr>
<tr>
<td>Global Warming</td>
<td>Greenhouse Effect</td>
<td>In this activity, students will prepare model atmospheres containing different amounts of water vapor and carbon dioxide. Students will predict the relative temperature changes in the model atmospheres when they are exposed to sunlight and will compare the actual temperature changes in the model atmospheres. They will then calculate the temperature change for all three model atmospheres by subtracting the initial temperature of each (at 1 minute) from the final temperature of each (at 10 minutes) and will graph their data. Based on their results, students will discuss and explain with reasoning the effect of carbon dioxide and water vapor on the ability of the atmosphere to retain heat. For the research and communications component of this lab, students will find out how human activities affect the concentrations of greenhouse gases, including gases other than water.</td>
<td>1 class period</td>
</tr>
<tr>
<td>Loss of Biodiversity</td>
<td>Creating LD50 Graphs for Different Substances</td>
<td>Students will determine the lethal dose 50 (LD50) level of different substances given and based on the substances’ LD50; students will then determine which substance is more dangerous. Then, using a given lethal dose data for two toxic chemical compounds, students will graph each, calculate their LD50 levels, and determine which is more dangerous based on the data. Student will discuss why the LD50 data is so useful in dealing with human health and environmental toxins.</td>
<td>1 class period</td>
</tr>
</tbody>
</table>
Unit of Study Terminology

**Appendices:** All Appendices and supporting material can be found in this course’s shell course in the District’s Learning Management System.

**Assessment Leveling Guide:** A tool to use when writing assessments in order to maintain the appropriate level of rigor that matches the standard.

**Big Ideas/Enduring Understandings:** Foundational understandings teachers want students to be able to discover and state in their own words by the end of the unit of study. These are answers to the essential questions.

**Engaging Experience:** Each topic is broken into a list of engaging experiences for students. These experiences are aligned to priority and supporting standards, thus stating what students should be able to do. An example of an engaging experience is provided in the description, but a teacher has the autonomy to substitute one of their own that aligns to the level of rigor stated in the standards.

**Engaging Scenario:** This is a culminating activity in which students are given a role, situation, challenge, audience, and a product or performance is specified. Each unit contains an example of an engaging scenario, but a teacher has the ability to substitute with the same intent in mind.

**Essential Questions:** Engaging, open-ended questions that teachers can use to engage students in the learning.

**Priority Standards:** What every student should know and be able to do. These were chosen because of their necessity for success in the next course, the state assessment, and life.

**Supporting Standards:** Additional standards that support the learning within the unit.

**Topic:** These are the main teaching points for the unit. Units can have anywhere from one topic to many, depending on the depth of the unit.

**Unit of Study:** Series of learning experiences/related assessments based on designated priority standards and related supporting standards.

**Unit Vocabulary:** Words students will encounter within the unit that are essential to understanding. Academic Cross-Curricular words (also called Tier 2 words) are those that can be found in multiple content areas, not just this one. Content/Domain Specific vocabulary words are those found specifically within the content.

**Symbols:**

- This symbol depicts an experience that can be used to assess a student’s 21st Century Skills using the rubric provided by the district.

- This symbol depicts an experience that integrates professional skills, the development of professional communication, and/or the use of professional mentorships in authentic classroom learning activities.