
Sustainability Unit Example: High School Science

Designer(s): *Sarah Franchino, Somers (NY) Public Schools*

How do curriculum and instruction change when sustainability becomes the guiding approach? How does the content become richer? How does the level of inquiry deepen? This document provides an example of a teacher-created unit that is grounded in the content and pedagogy of sustainability education.

Background

The unit described was an outcome of the 2007 Summer Sustainability Institute sponsored by the Children's Environmental Literacy Foundation (CELf: www.celfoundation.org), with facilitation provided by Creative Change Educational Solutions (www.creativechange.net), and Scott Beall consulting. During the intensive week-long institute, teachers gained content knowledge, resources and strategies to redesign their approach to curriculum and instruction using the lens of sustainability. Guided planning time and one-on-one mentoring at the institute enabled teachers to walk away with a draft unit plan to implement during the school year.

After the week-long institute, the teachers were provided on-going support and communication. Teachers sent their in-progress lesson plans to Creative Change and CELf, and received feedback and mentoring via phone and e-mail. This document is an outcome of this process.

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Unit Overview

Title of Unit: *Humans in the Environment*

Subject/Course: *Environmental Science*

Topic: Sustainability

Designer(s): *Sarah Franchino, Somers (NY) Public Schools*

State Standards and District Goals: (NY State and/or District goal)

- NYS Standard 4/Key Idea 6: Plants and animals depend on each other and their physical environment.
- NYS Standard 4/Key Idea 7: Human decisions and activities have a profound impact on the physical and living environment.
- Somers High School Instructional Vision: We believe that our instructional program should provide for relevant connections to the real world, active participation/ownership/initiative by students, critical thinking and problem solving, and interdisciplinary connections based on thematic/essential questions.

Big Ideas:

- The environment acts as the sources for all materials and the sink into which all wastes go.
- Increases in population, affluence, and technology increase the stresses placed in available resources.
- Living things interact with and alter their environment.
- The ways in which humans use resources and interact with their environment are determined by societal attitudes, ethics, and culture.

Essential Questions:

- In what ways do humans rely on the environment?
- How do changes in human population and lifestyle alter the stresses placed on natural resources?
- How do various factors shape changes in the physical environment?
- What factors influence the ways in which humans use resources and interact with the environment?

Goals:

Students will be able to:

- Determine the steps in the life cycle of a manufactured product by comparing the life cycle of a product manufactured by large-scale globalized economy versus that of a product manufactured organically and locally.
- Learn what their ecological footprint is and compare the ecological footprint of an individual in the United States with that of an individual in a developing nation.
- Understand relative environmental impacts of industrial, agriculture, and hunter-gatherer societies and look at the differences between these.

- Understand the difference between the frontier ethic and sustainable development ethic.
- Identify practices in modern society that reflect environmental ethics.
- Understand the Gaia Hypothesis and explain how the Gaia Hypothesis relates to the stability of the earth's systems.

Assessment Evidence

Performance Task(s):

- Life Cycle Analysis (see appendix **Activity 4**)
- Environmental Ethics Collage (see appendix **Rubric 2**)
- *Performance Based Assessment:* Students must act as consumers to make a choice between a regular cotton t-shirt and an organic cotton t-shirt on an imaginary shopping trip. Each student must defend his/her choice using the concepts of life cycle analysis (see appendix **Activity 4** and **Rubric 1**) and ecological footprint studied in this unit. (Possible web sources for organic clothing include www.nau.com, missionplayground.com, www.gaiam.com)
- Student input to class discussions
- Unit Test

Learning Plan

1. Life Cycle Analysis: approximate class time: 5 class periods

The class will do a life cycle analysis of a commercially produced potato, using the short article provided (see appendix “French Fries” **Reading selection A**) as a reference. First, student will read the article and record a summary of a life cycle on the following table:

Stage of Product Life Cycle	Inputs (resources)	Outputs (wastes)
Acquisition of Raw Materials		
Manufacture and Processing		
Distribution and Transportation		
Use		
Recycling/Reuse		
Disposal		

After students have read and recorded their own ideas, the teacher will elicit responses from students to create a flow-chart style diagram on the chalkboard that depicts the biography of a French fry from beginning to end.

Following this example, students will choose a simple object and work in groups (3 – 4 students) to perform a life cycle analysis. Student presentations will incorporate any necessary research. (see attached assignment sheet and scoring rubric)

Following student presentations, the class will return to the original potato example. Students will read the additional articles (see appendix “Potato Grown Using Traditional Peruvian Methods,” **Reading selection B** and “Organic, Locally Grown Potato” **Reading selection C**) and record summary findings in tables like that used for the “French Fry” biography. A class discussion will compare the commercially produced potato to other growing methods. Questions will consider the following: What growing methods use the fewest inputs and generate the least wastes? Does this mean that this growing method is more efficient? Explain. Define efficiency. Why do you think the large-scale commercial growing methods are so widespread in the United States?

2. Ecological Footprint: approximate class time: 2 days

Note: For complete lesson materials on the Ecological Footprint, contact Creative Change Educational Solutions www.creativechange.net

Students will complete Feeding Yourself for a Year. (See appendix **Activity 1**.) By estimating the amount of resources they will consumer in a year, students will design an imaginary farm to supply the resources needed for one year of life.

Students will take the Ecological Footprint quiz at www.myfootprint.org and creating a bar graph to illustrate the concept of overshoot, students will participate in further discussion about the concept of sustainability.

Students will complete the activity, Lowering Your Ecological Footprint (See Appendix **Activity 2**) Students will use the questions as a template for generating possible action plans for change. A class discussion will allow students to share their ideas.

3. Human Societies: approximate class time: 3 periods

- Students will read a brief summary of three different cultural groups (see appendix **Reading selection D**): one hunter-gatherer society, one agricultural society, and one industrial society. They will then summarize this information in a table to compare the lifestyle, resource use, and ecological impact of these three different cultures. (See appendix **Activity 3**.)
- Students will work in teams of 2-3 to create definitions for several terms relating to lifestyle and culture: developed, undeveloped, wealthy, poor, educated, uneducated, technology, progress. Students will then view a segment of “*Ancient Futures: Learning from Ladakh*”¹¹. After viewing, students will return to their definitions to make revisions. Revisions will be shared as a brief class discussion. Students will view a second segment of the film depicting changes that have occurred in Ladakh as modern technology encroaches on this traditional culture. A second class discussion will address the issue that the traditional agricultural lifestyle is the only way to achieve sustainability. The conditions depicted in the second video segment are part of a larger progression of change. Change is continuous. What ways can modern industrial societies achieve sustainability?

4. Environmental Ethics Approximate class time: 4 periods

- As the “hook” to the lesson, ask students to brainstorm with a partner the major sets of rules in their households. What are their parents’ pet peeves? What rules are they most likely to get punished for breaking? Is it cleaning up after oneself? Is it hitting or otherwise tormenting your siblings? Then discuss what rules, if any, that all households have in common. These rules stem from a basic set of values that we all share.
- Introduce the following terms as a fundamental set of values shared by society: justice (the principle that equals? should be treated equally), sufficiency (the principle that all forms of life are entitled to enough goods to live on and flourish), solidarity (requires us to consider that we are related to all things and that we have an ethical obligation to care for them), and participation (points us toward

¹ *Ancient Futures: Learning from Ladakh* can be purchased at <http://greenplanetfilms.org>

how decisions are made in our society). Also discuss the concepts of absolute, intrinsic, and instrumental value?

- Using the principles listed above as a lens, have students discuss in groups the following questions:
 - Who are the stakeholders in the issue of endangered species?
 - What is the role of future generations in our decisions about the storage of nuclear waste?
 - What areas (and what organisms) might be affected by oil leaks that flow into Long Island Sound?
 - Do you think animals have absolute, intrinsic, or instrumental value?
The global café model will work well here.
- Introduce the *Frontier Ethic* and the *Sustainable Development Ethic*. The Frontier ethic is based on the primary assumption that humans are separate from nature; its key principles state that resources are unlimited and meant for human consumption, humans are separate from nature and not subject to natural laws, and human success is measured in terms of control over the natural world. The Sustainable development ethic is based on the primary assumption that we must meet current human needs without limiting the ability of future generations to meet their own needs; its key principles state that resources are limited and not all meant for human consumption, humans are a part of nature and are subject to natural laws, and human success is measured in terms harmony with the natural world.

To help students understand these sets of ethics, have several statements prepared to be placed on a spectrum from one extreme to the other. Have the students place them where they think is appropriate.

- Humans are a part of the ecosystem, no different from any other living organism.
 - Humans are separate from the environment and are different than other living organisms.
 - The earth is a set of resources for humans to use.
 - Humans should use resources and manufacture products with consideration for long-term impacts.
 - Progress is measured by the quantity of material goods produced.
- Discuss these two very different ethics in relation to the previous concepts of justice, sufficiency, solidarity, and participation. Which set of ethics is a more appropriate view, based on these concepts? Continue to use them as a lens.
- Ask students to consider which one of these sets of ethics is most reflected in the day-to-day life of the average American. Ask them to express their views by completing the attached collage assignment. (See appendix **Rubric 2.**)

5. Gaia Hypothesis Approximate class time: 1 period

- Students will participate in a PBL (Problem Based Learning Activity). They will be presented with a problem, and asked to brainstorm solutions in small groups. Each group will present their ideas to the class. Then, students will receive part 2 of the PBL with the actual answer to the problem. (see appendix **Activity 5: Part I & II**)
- After the PBL, the class will discuss the relationship between the Gaia Hypothesis and the idea that all living and non-living things are connected to those ideas that we have been discussing in class over the last several weeks.

Appendix

Reading Selection A: “French Fries”

From “Introduction to the Ecological Footprint,” a lesson from Creative Change Educational Solutions
www.creativechange.net

Cultivating and harvesting: The potato, a russet Burbank, was grown on one-half square foot of sandy soil in the upper Snake River valley of Idaho, on a one-crop farm. (In the early 1960s, Russet potatoes became the main source for French fries because they stay stiff after cooking.)
A harvesting machine, powered by petroleum-based diesel fuel, dug up my potato.

Fertilizer and pest control: Without a diversity of species to provide natural pest and disease control, one-crop or monoculture farms are more susceptible to these problems. To avoid blight, the potato was treated with fertilizers and pesticides. These were made with petroleum, and nitrogen—a key element of fertilizer—was obtained by extracting gases from the air. Among these were pesticides like Telone II (acutely toxic to mammals, and probably birds, through the skin or lungs) and Sevin XLR Plus (nontoxic to birds but highly toxic to fish). These chemicals accounted for 38 percent of the farmer's expenses. Some of the fertilizers and pesticides washed into streams when rain fell. The Environmental Protection Agency's tests of waters in the Columbia Basin found agricultural contaminants in every tributary, including the Snake River.

Water source: The potato required seven and a half gallons of water. The water came from the Snake River. The Snake River valley and its downstream neighbor, the Columbia Basin, produce 80 percent of U.S. frozen French fries. Dams along the river provide irrigation for the fields. Below Milner Dam, west of Pocatello, the riverbed is dry much of the year. As a result, eighty percent of the Snake's original streamside, or riparian, habitat is gone.

Processing/Storage: Processing my potato created two-thirds of a gallon of waste-water. This water contained dissolved organic matter and one-third gram of nitrogen. The waste-water was sprayed on a field outside the plant. The field was unplanted at the time, and the water sank underground. Half the potato's weight, mostly water, was lost in processing. The remainder was potato parts, which the processing plant sold as cattle feed.

After they were sliced, the potatoes were frozen. This required electricity, which came from a coal-fired power plant. The freezer also used hydrofluorocarbon coolants. Some of these coolants escaped from the plant. They rose 10 miles up, into the stratosphere. The coolants did not deplete the ozone layer, but they did trap heat, contributing to the greenhouse effect. (Other types of coolants, chlorofluorocarbons (CFCs), deplete the ozone layer, but these coolants are now banned.)

Transportation: A truck, powered by gasoline, took the potato to the processing plant. After processing, a freezer truck hauled the French fries to a grocery store or restaurant supplier.

And what about the frying? The oil for the French Fries is made from soybeans, corn, or cottonseed. In the US, the majority of soybeans for cooking oil are grown in the Midwest. After frying, wasted fat remains. Often, the liquid fat is poured down drains, where it hardens and can create blockages (just as it can in your arteries). The disposal of fat has become a problem in many cities. In London, for example, half of all sewer blockages are caused by fat.

Reading Selection B: Potato grown using traditional Peruvian methods

From "Introduction to the Ecological Footprint" Creative Change Educational Solutions,
www.creativechange.net

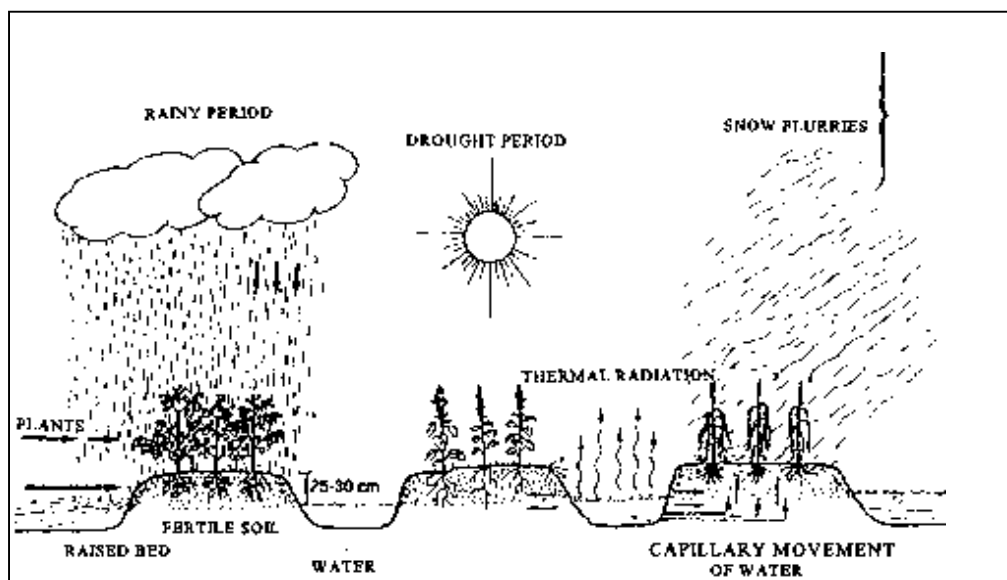
Scientists believe that potatoes grew wild in the mountainous regions of Peru as long as 13,000 years ago. The Inca civilization dominated the region from 1350-1533 and cultivated potatoes (which they called *papas*). The potato was not only a staple food; they were a part of the villages' medicine and spiritual rituals.

Scientists and farmers recognize the value of the Inca's agricultural knowledge and expertise. Today Incan farming methods are being revived to provide nutritious food using methods that maintain the health of the local ecosystem. The Incas developed more than 200 varieties of potatoes and developed new ways to increase production. Here are some of their techniques:

Cultivating and harvesting: To prepare the soil the Peruvian farmers developed a foot plow called *taclla* that used a person's weight as leverage to turn over the heavy sod. The Inca people depended on human power and hand tools to harvest crops.

Water source: Since potatoes are native Peru, they are adapted to the climate and little irrigation is needed.

To protect crops from flooding or drought, the Incas built a system of raised beds and canals, pictured right. The water in the canals also protected against extreme changes of temperature.



Pest management: Pests were controlled using natural predators, and there was no use of human-made chemicals.

Processing and storage: To prepare their potatoes for storage, the Incas left potatoes out over night to freeze, and in the morning they walked on the potatoes to remove the moisture. This process was repeated for 4-5 days. The resulting product was called *chuño* and could be stored for up to four years. This storage method insured that the tribe had food even in times of extreme weather and poor crop yields.

Transportation: *Chuño* was a staple food for the Incas. People traveled on foot between the highlands and lowlands to trade among villages. A network of paths helped promote trade and contact, and llamas were used as pack animals.

Sources for this reading: <http://collections.ic.gc.ca/potato/history/beginnings.asp>; <http://newton.nap.edu/books/030904264X/html/8.html>, Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation (1989) Office of International Affairs, Organization of American States. Picture retrieved from www.oas.org/dsd/publications/Unit/oea59e/p178.GIF

Reading Selection C: Organic, Locally Grown Potato

From "Introduction to the Ecological Footprint," a lesson from Creative Change Educational Solutions, www.creativechange.net

This potato, consumed by a student in southeast Michigan, was grown at a nearby farm in Ann Arbor (<http://www.communityfarmofaa.org/>).

Pest management and fertilizer: The potato was grown on land that was fertilized using compost and manure; the farm does not use any synthetic fertilizers or pesticides. The farm uses manure from their animals, and compost from plant matter and food scraps. Instead of using pesticides, the farm uses integrated pest management. Therefore, there is no contamination of waterways or surrounding animal habitat. Also, the potato was one of over a dozen crops. Having a diversity of plants, and rotating them year to year, helps control pests, disease, and increases overall soil fertility.

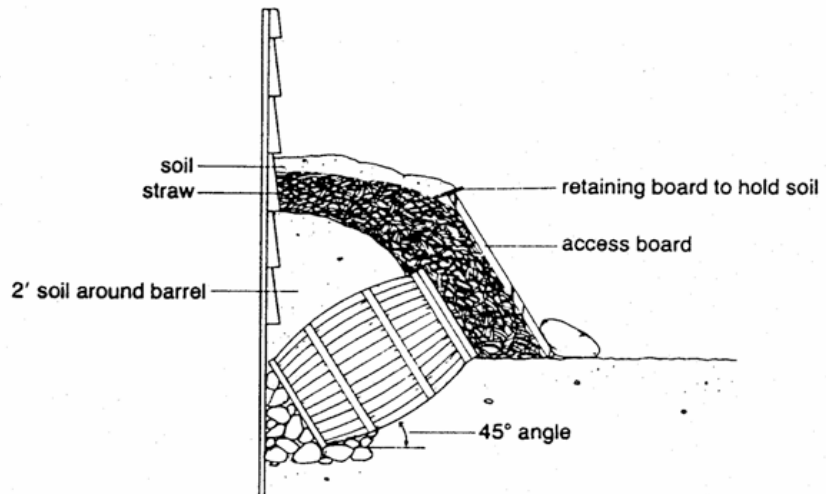
Watering: The farm has its own well, which taps into a groundwater aquifer, pipelines installed out to the fields. The farm uses sustainable watering practices, including drip irrigation (watering right around each plant). This consumes considerably less water than spray pipes because there is less water lost by evaporation and run-off.

Cultivating and harvesting: Due to the variety of crops grown at the community farm, all planting and harvesting is done by hand and there is no use of harvesting equipment. The potato is then sold, at the farm or at the local farmer's market.

Transportation: It takes less than a gallon of fossil fuels to get the potato from the farm to the local farmer's market. Because the farmer's market is located near the center of the city, many residents can walk, ride bikes, or take the bus to buy the potatoes. Some customers drive.

Processing and Storage:

The little time between harvesting the potato and the short trip to the local market eliminates the need for the potatoes to be frozen or even refrigerated. Once purchased, the potato can be best stored in a burlap sack in a dry, dark place where the temperature stays at 30-40 degrees Fahrenheit. Options include a refrigerator, or a storage barrel buried underground. The barrel will keep potatoes for 6-10 months without the use of added energy.



Activity 1: Feeding yourself for a year

From "Introduction to the Ecological Footprint," a lesson from Creative Change Educational Solutions, <http://www.creativechange.net>

Imagine that for one year, you will be responsible for growing all of your own food on your own self-contained farm. You will grow all the vegetables you eat, grow all your grains (such as rice or wheat for bread), catch all the fish you eat, and raise animals if you want meat. (You also have to grow whatever the animals eat, or have enough pasture land for them to graze). Finally, you need space to store the food, prepare it, and deal with all the wastes you produce over a year.

How much land would your farm take up? How much cropland would you need to grow everything? What about pasture land? How much water would you need, and where would it come from?

You also need to build your own shelter. On your farm, you have to grow all the trees (or other materials) you need for that. If you are in a climate with a cold winter, you also need enough firewood to stay warm. How many trees do you think you would need? What other materials would you need? How many acres would it take to provide all of that? (Note: An acre is the size of a football field.)

In this activity, you will create a map of your farm and try to estimate how much land it would take up.

Directions

1. Draw map that shows the layout of your self-contained farm, including your shelter.
 - Create a scale that shows how big the overall farm would be.
 - On the map, show areas of different types of land you will need, such as cropland, pasture lands for grazing animals, oceans and rivers for fish, forests for wood, and land with buildings on it.
 - Include a table or list of how many acres you'll need of each kind of land. This will only be an estimate.
2. Then, write an explanation of how you developed your response.
 - How did you calculate the amount of food you would consume?
 - How did you decide how much land it would take to grow it?
 - What other questions did you consider?
3. If you had trouble developing a response, tell why.

Activity 2: Lowering your Ecological Footprint

From "Introduction to the Ecological Footprint," a lesson from Creative Change Educational Solutions, www.creativechange.net

The role of individuals

There are many ways you can reduce your footprint and live more sustainably. Here are a few ideas:

Change in habit	Footprint reduction over in a year	Some reasons for the reduction
Eat six ounces less beef or fish.	20 square yards	Factory farming and irrigating feed grain is extremely water intensive. Just 2.2 lbs. of hamburger produced by a typical California beef cattle operation uses 5,432 gallons of water. About 38% of the global grain harvest becomes food for livestock.
Drive 100 miles less.	100 square yards	Driving is one of the largest contributors to a person's footprint because of the land used for roads, the fossil fuels burned, the carbon released into the atmosphere, and the resources needed to produce cars.
Shower 90 minutes less.	100 square yards	Fresh water requires energy and chemicals usage to pump, process, and clean it. Heating water also requires gas or electricity to warm it.

The role of society

While individuals have an important role in promoting sustainability, some of the most powerful ways to reduce our footprint can only occur at the societal level. Increasing the availability of renewable energy, for example, can only come about if communities, states, and the nation as a whole work for this. Strategies could include policies that promote renewable energy, tax incentives for research, education and career training, and incentives for individuals to adopt renewable energy in their homes.

Clearly, change must occur at the individual and societal level. In this activity, you will a strategy to reduce your footprint in terms of food, energy usage, or transportation. You will conduct research and identify changes at both the personal and societal level that can impact your footprint.

Directions for activity 2



1. Identify a proposed **personal** action for reducing your footprint in terms of food, energy, or transportation. For example, you could reduce your food footprint by eating more local foods or fresh foods.

2. Suggest a change at the community, state, or national level that could make it easier to reduce your footprint.

Example: I could buy more locally-grown food if our community had a farmer's market, or if our grocery store carried it.

3. Identify who the decision-makers are for these changes.

4. Identify who would be in favor of the change, and who might be against it.

5. Describe barriers to achieving the change.

6. Describe ways you and other students can advocate for the change.

7. Finally, identify steps you will commit to as an individual and as a citizen involved in shaping policies.

Reading Selection D



World Cultures



Chipaya – high plans farmers of Bolivia

Long ago driven to a salt flat by an enemy tribe, the Chipaya Indians have learned to siphon life from barren soil. Chipaya live in traditional round huts designed for withstanding the strong winds in the shadow of the Andes mountains. Most Chipaya families keep sheep that provide them with meat, cheese, and wool to keep or trade with outsiders. In the village of Ayparahui, the people depend on the sparse resources of sandstone, limestone, wild grasses, and wood. Families plant quinoa, the staple grain, in dry lake beds, and flood their fields to leech away salts. These people have made a living by farming harsh land for hundreds of years.

Penan – nomads of the Borneo Rainforest

They roam a rainforest invisible to us, every step snapping with promise: tools, food, remedies. Traditional Penan society is nomadic and survives by hunting and gathering. Until a few decades ago, thousands of Penan wandered through the forests of Borneo's interior. Today, less than 300 nomads remain. While most Penan now have permanent homes by the riversides, they continue to make long journeys into the forest to collect food, medicine, and other jungle products. The physical and spiritual well-being of all Penan, whether nomadic or settled, depends on the survival of the forest.

The Penan, like other nomadic hunter-gatherers, enjoy an egalitarian society. There are no social classes or hierarchies. There is no wealth or poverty, and all food is shared. Each band has a headman who acts as a spokesperson but wields no power. Outsiders who observe them are invariably struck by the complete absence of violence among the Penan.

China – a rapidly industrializing nation

China is rapidly industrializing, developing new coal-fired power plants, and new industries at incredible speed. The population explosion in China has prompted one of the most aggressive population control policies in the world. Tax benefits, advantages in schooling and preferential housing are just some of the benefits afforded to Chinese families if they choose to have only one child. The Chinese have also been incorporating culture from around the world.

For the past year and a half in Shanghai, for example, Chinese children have been tuning in to that American children's classic TV show Sesame Street. But here it's called Zhima Jie, and when you look closer, it's not simply the American show. The show's team of actors and educators has been collaborating to produce a program that promotes Chinese, rather than American, values. The kids are loving it.

The show incorporates many of the usual Sesame Street activities—teaching numbers, for instance—but instead of the alphabet they teach the origin and meaning of Chinese characters. They explain the history and customs of certain festivals. They describe certain ancient art forms. And they also teach sharing and cooperation.

McDonald's restaurants have also invaded China (and countless other countries across the world). Women in traditional cultures like to meet at McDonald's because there's no alcohol served, and they see it as a safe, socially acceptable place for a woman alone to go. And, far from being a place where you eat and run, many people, from the elderly to teenagers, see it as a spot where they can linger. In cities where space is at a premium, like Hong Kong, teenagers like it because it's somewhere outside their often cramped apartments where they can meet their friends—sometimes they even do their homework there.

Activity 3: Human Societies and the Environment

	Hunter-Gatherer Society	Agricultural Society	Industrial Society
Which culture fits in this group?			
What type of technology do they use? Give Examples.			
Describe the general health of these people.			
Do they use large or small amounts of natural resources?			
How much does the average citizen know about the environment?			
How much and what types of energy do they use?			
How much environmental impact do they have?			

Activity 4: Life Cycle Analysis

A life cycle analysis is a cradle-to-the-grave approach of looking at a product, its manufacture and the waste it produces. It measures energy use, materials inputs, and waste generated from the time raw materials are obtained, to the final disposal of the product.

There are **six** stages to be evaluated in the life cycle of a product:

- Acquisition of raw material
- Manufacturing and processing
- Distribution and transportation
- Use and reuse
- Recycling
- Disposal

The Assignment:

With your lab group, you must choose a product and perform a life cycle analysis. Once you have chosen the product, you will have 40 minutes to brainstorm and 40 minutes in the library research lab to complete a life-cycle analysis and design a visual presentation (poster). The first 20 minutes of the following class period will be devoted to finishing touches and preparation for your group presentation. The presentation should be approximately 3-4 minutes and each member of the group must speak.

Rubric 1: Life Cycle Analysis

Group:			
Name:			
	Points	Points Assigned	
Criteria	Available		Total
Group Participation <ul style="list-style-type: none"> • Staying on topic • Involved others, Did not dominate • Does fair share of work • Participated in presentation 	2		
Total for Group Participation	2		
Includes all 6 parts of life cycle analysis	6		
Uses researched facts to trace life cycle	1		
Poster is neat and professional	1		
Total for Poster and Presentation	8		
Final Score	10		

Rubric 2: Environmental Ethics Collage

Name:			
	Points	Points Assigned	
	Available		Total
<i>Collage</i>			
Collage includes at least one picture for each of the three key concepts of the chosen ethic	3		
Obvious time, effort and thoughtfulness are expressed in collage	1		
Visuals are clear and neat, indicative of upper grade level student (Pieces are completely and invisibly secured to background)	1		
<i>Reflection</i>			
One environmental ethic is clearly chosen and defined	1		
Reflection clearly relates materials on the collage to each of the three key concepts of the environmental ethic, exhibiting critical and creative thought	3		
Reflection is neat with no spelling or grammatical errors. There is an introduction, one paragraph on each of the three key concepts, and a summary.	1		
Final Project Score	10		

Activity 5:

PBL Part I: Earth's Atmosphere: The Mysterious Case of the (Non)-Disappearing Gases

When Earth first formed about 4.5 billion years ago, it was a fiery ball of molten rock. Eventually, the planet's surface cooled and formed a rocky crust. Water vapor in the atmosphere condensed to form vast oceans. And the atmosphere consisted of hydrogen, water vapor, ammonia, and methane.

From that time until now, the composition of the atmosphere has changed a great deal. Today, the earth's atmosphere is made up primarily of nitrogen, oxygen, and carbon dioxide, along with other trace gases.



The current composition of atmospheric gases on earth is in a state that shouldn't exist. Take, for example, the simultaneous presence of methane and oxygen in our atmosphere. In sunlight, these two gases react chemically to make carbon dioxide and water vapor. The rate of this reaction is such that to sustain the amount of methane always present in the air, at least 1 billion tons of this gas must be introduced into the atmosphere in addition to at least 2 billion tons of oxygen each year. Even nitrogen gas is out of place in the earth's atmosphere, for with the Earth's abundant oceans, we should expect to find this element in the chemically stable form of the nitrate ion dissolved in the sea.

How could the earth's atmosphere have changed from one made up of hydrogen, ammonia and methane, to an atmosphere that is 78% nitrogen and 21% oxygen? And how can such massive amounts of these gases remain in the atmosphere when spontaneous reactions should have used them up long ago?

Brainstorming

Consider the following questions as a group. **Brainstorm** and list your ideas on the paper provided.

- *What information is given?*
- *What prior knowledge could apply?*
- *State a hypothesis in response to the experimental question: How does the earth maintain oxygen, nitrogen, carbon dioxide and methane in the atmosphere?*
- *What information would you need to support or disprove your hypothesis?*

PBL Part II Earth's Atmosphere: The Mysterious Case of the (Non)-Disappearing Gases

The only possible explanation of the Earth's atmosphere is that it was being manipulated on a day-to-day basis from the surface, and that the manipulator was life itself. The first bacteria to frolic in earth's primordial ooze 3.5 billion years ago were unable to breathe oxygen. These were organisms that survived by anaerobic respiration.



At the same time, these organisms also gave off a waste product: carbon dioxide. With this new thing present in the atmosphere, blue-green cyanobacteria developed the ability to photosynthesize, using the carbon dioxide and adding oxygen into the atmosphere. Then organisms developed aerobic respiration, a much more efficient version of respiration requiring the use of oxygen gas.

The balance of atmospheric gases is maintained primarily by the life processes and chemical reactions that occur within the bodies of living organisms.

Over 30 years ago, *Dr. James Lovelock* considered these facts and in 1979 published his “Gaia Hypothesis”. According to Lovelock, the composition of the atmosphere is not what it should be and the concentration of gases is at an ideal for living things. Therefore he proposed that there was a larger force involved that was helping to make the earth livable. He called this force Gaia, after the Greek Earth Goddess.

The *Gaia Hypothesis* is the theory is that living organisms and inorganic material are part of a dynamic system that shape Earth's biosphere. The earth is a self-regulating environment; a single, unified, cooperating and living system that regulates physical conditions to keep the environment hospitable for life. The *Gaia Hypothesis* states that the earth functions like a single living organism that regulates itself in order to maintain life. The entire range of living matter on Earth from whales to viruses and from oaks to algae could be regarded as constituting a single living entity capable of maintaining the Earth's atmosphere to suit its overall needs and endowed with powers far beyond those of its constituent parts.

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