Making "Sustainable" Obtainable

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Introduction

Very few urban kids have a real connection to the natural world. In his book, *Last Child in the Woods: Saving Our Children From Nature-Deficit Disorder,* Richard Louv decries the lack of time spent outdoors by children and links that loss to behavioral problems, obesity, and lack of respect for the environment and the organisms in them. At the same time, we have come to the realization that we cannot continue to use and abuse the planet's resources as we have been doing. Yet without the connection to nature, who is going to care in the next generation?

I teach an ecology unit as part of the Biology I curriculum. The pacing guide allows me eight days to cover the basics of ecology and examples of human impact on the environment. I also have three days at the beginning of the semester to teach scientific method. I plan on using this time as well to introduce the concept of sustainability. The entire ecology unit will be based on the theme of sustainability—sustainable systems in the natural environment and how human impact interferes with that sustainability, and how we can reverse that trend in order to work with the environment and live more sustainably.

Very often science teachers are accused of presenting a liberal viewpoint about environmental issues. I believe that science should be objective and present the evidence and then let people decide for themselves. Most of my students will not become scientists, but they will be citizens who will help make decisions about the environment with their voices and votes, and also with their everyday actions. I want my students to connect with the environment in some way and also learn simple ways in which they can make a difference in how they leave it.

Background Information

At the time this paper was written, the world population was estimated to be 6,847787,606 souls and rising[1]. At what point will we reach the limits of our planet's resources to maintain such a population? At what point will the sheer numbers of people tip the balance between the demands on the resource of the planet and the availability of those resources?

The Environmental Protection Agency defines sustainability as "the satisfaction of basic economic, social, and security needs now and in the future without undermining the natural resource base and environmental quality on which life depends.[2]" Many of the world's problems seem overwhelming. The world's dependence on fossil fuels for use in our cars, factories, power plants, and even to grow our food, has led to increased levels of carbon dioxide in the atmosphere, and global warming. We continue to encroach on the habitats of other organisms, leading to a loss of biodiversity and extinction levels not seen for millions of years. Advances in technology have changed our lives, but last month's latest device is this month's newest addition to the growing problem of e-waste.

What difference will it make if we recycle, or conserve water by not letting it run while we brush our teeth? What impact will individual efforts on behalf of the environment have against such huge problems? My premise is that individual efforts do make a difference, if not to the global environment, then to the hearts and minds of the individuals who practice living sustainably, and who may be more likely to use their votes and voices in the establishment of policies that will have an impact on the environment. As part of this unit, students will explore the life cycle of a hamburger from the cow to the consumer, and how composting can not only reduce waste sent to a landfill, but also be used to grow food locally, reducing the carbon footprint of what we eat. They will learn what it means for a scientific paper to be peer-reviewed, and what data forms the basis for the conclusion that the current global warming trend is related to human activities.

Life Cycle Assessment of a Fast Food Hamburger

How many fast food hamburgers will an American eat in their lifetime? It's so cheap and easy to drive up and get one to go. But at what cost? The problem with many things we buy is that we pay for the cost of producing the item, but the environmental costs, present and future, are not added in to the price. However the bill will come in eventually. Dr. Joyce Smith Cooper at the University of Washington, has done a life cycle assessment of what actually goes into getting that hamburger into your bag. Starting with the bun, which is made from grain, there are the costs of planting the seeds—water, fertilizers, pesticides, and herbicides. Planting and harvesting the grain requires heavy machinery that uses fuel to operate. After harvesting, the grain is transported (using fossil fuels) to the mill to be ground into flour. Production of flour uses water and energy, produces pollutants, and creates wastes which are shipped to landfills. The flour is shipped to the bakery, which makes the buns, using energy, most likely from some fossil fuels to heat the ovens. More grain is grown and shipped to feed the cattle from which the hamburger will be made. The cattle produce wastes which pollute land and water. Methane gas, a greenhouse gas, is also produced. The cattle are then shipped to the processing plant where they are slaughtered, cut up, the meat packaged and cooled. The meat is then transported in refrigerated trucks to facilities where it is ground and re-packaged, and shipped out again to fast food restaurants, where more energy is used to store and then cook the meat. After cooking it is packaged once again in paper or Styrofoam containers, and then placed in a bag. These items have their own ecological costs.

Life cycle analysis of a product like a hamburger is a tool for determining the real cost of an item to the environment. By assessing and comparing the inputs in the creation of the item to the output inherent in the item, the differences can be used to track where any material or energy may have ended up if it was not in the final product[3]. To determine the life cycle of a product, an assessment must be made of (1) the raw materials needed, (2) the processing of those raw materials and any manufacturing activities involved along the way, (3) storage of the raw materials and the processed products, (4) transport of raw materials to processing centers and transport of products to their final destination, (5) costs involved in the use or maintenance of the product, and (6) the recycling, reuse, or disposal of the product[4].

One estimate, based on such a life cycle analysis places the total energy use for one cheeseburger at between 7 and 20 megajoules[5]. Based on the use of diesel fuel for transportation, and electricity for food processing and production, the carbon footprint of that cheeseburger is estimated at 250 grams to 500 grams of carbon emissions if the additional carbon costs associated with the restaurant and driving to the restaurant are included. Americans are estimated to eat an average of three cheeseburgers per week. If the methane produced by cows is included (one kilo of methane producing the equivalent effect of 23 kilos of carbon dioxide), then the carbon footprint of the cheeseburgers eaten in the U.S. equals that of 100,000 SUVs[6]. This is a pretty high ecological price to pay for our burgers.

"Quantity of grain needed for 4 hamburgers could feed someone in a developing country for more than a week"

"One quarter-pound hamburger requires10-20 times as much energy as grain"

"More energy goes into the production of the hamburger than is gained by the person who consumes it."[7]

Composting

In any large city, a great deal of solid waste is produced by households that must be disposed of. An average of 25% of this waste is organic kitchen and yard waste. Eighty percent of the weight of this kind of waste is water weight. So, in effect, 20% of all the waste produced in the home leaves as water[8]. It makes no sense to spend millions of dollars to haul water to landfills. Very little water evaporates out of the trash. When it is brought in, waste is placed in a deep trench, lined with a protective, waterproof layer to prevent water, and the toxins that leach into it, from escaping into the surrounding soil and groundwater. The contaminated water must then be treated—an additional expense associated with the disposal of organic wastes. In landfills, yard wastes do not decompose, because the waste gets covered and there is very little oxygen available to the aerobic bacteria and fungi to do their job. So rather than take organic wastes to landfills, people are asked to bag this type of waste material separately and it is picked up and transported to a composting site. There it is turned into compost that can be purchased, by the people who sent it there, for $25 a truckload. At least it is out of our landfills and is being put to good use. Over the years, however, the volume of compostable material collected has continued to increase, as well as the expenses involved in handling it. Cities across the country are now encouraging citizens to compost these wastes at home[9].

Composting has many benefits for the homeowner. It provides slowly releasing nutrients to the soil, and is much less expensive than commercial fertilizers. Composting improves the soil by increasing water retention and allows for healthy root growth. It acts as a buffer, moderating the pH levels of acidic or alkaline soils. The heat created during composting breaks down pesticides, and kills weed seeds, as well as disease-causing fungi and microbes. Compost attracts earthworms which aerate the soil and add nutrients as they burrow through it.

Composting can be done using several different methods. Some methods are more labor intensive, but produce faster results. Other methods are easier, but the process will take a lot longer. The easiest method of all is to let the leaves fall where they may and let them decompose.

If they fall onto the lawn, they can be mowed over with a mulching mower, adding important nutrients to the soil and reducing the amount of fertilizer one would have to purchase for the lawn. Passive piles can be created from leaves swept from patios and other areas, where leaving the leaves in place is not an option. These passive piles will take much longer to decompose, however and may not be an attractive option for some homeowners[10].

Hot batch composting is more labor intensive, but produces faster results. The heat created comes from the oxidation of organic compounds by decomposing organisms. Temperatures can reach as high as $170^{o}F$[11]. High temperatures have the added benefit of killing weed seeds and many pathogens. On the other hand, if the temperature stays high for too long, beneficial organisms may be killed. Frequent turning of the compost pile keeps the temperature at an optimal level.

Having the right mix of materials to be composted is important. Brown, carbon containing materials such as leaves, should be added in a 30 to 1 ratio with green, nitrogen-containing material such as grass clippings or kitchen wastes[12]. The materials should be chopped into smaller pieces if necessary, increasing the surface area for the decomposers to get at[13]. Enough water should be added to just moisten the material. Turning the compost pile every few days aerates the material so that anaerobic decomposition does not set in.

There are a variety of types of compost bins and pens that can be used. For my classes I will use simple wire pens made from fencing material. These require no stakes for support and can be easily moved. The compost materials are added to the pen and moistened with water. Every few days, the pile can be turned by lifting off the wire pen and moving it to one side. Using a pitch fork, the compost is then placed back into the pen in the new location, mixing and aerating it at the same time. For comparison, I will have one or two groups create garbage can compost bins, which don't hold as much, but which can be rolled to mix the material, rather than turning it with a pitchfork. These bins are created by drilling holes in the sides and bottom of a large trash can for aeration and drainage, and attaching the lid with cords to hold it on tightly when being rolled[14].

Vermicomposting

Vermicomposting uses earthworms to compost newspaper and kitchen scraps. The worms eat their way through the material, and out comes the earthworm poop, or castings, rich in plant nutrients and microorganisms that are beneficial to plants. This material is basically a type of manure, rather than compost. "Tea" made from steeping the castings in water can be applied to the soil to increase plant growth, or applied to leaves where the microorganisms present in the tea inhibit the growth of black spot fungus and powdery mildew. (worm castings and soil) To make a small vermicomposting bin, small plastic containers, like coffee containers can be used[15]. Quarter inch holes are drilled into the sides of the container to provide oxygen to the worms, and prevent anaerobic decomposition. Strips of newspaper are moistened with water and placed loosely in the container. A small amount of soil or coffee grounds can be added to the newspaper.

Red wriggler worms (*Lumbricus rubellus*) are added next. Vegetable and fruit scraps are added and mixed in with the paper scraps. Worms will eat many different kinds of kitchen scraps: coffee grounds and tea bags, fruit scraps, except for citrus fruits, vegetable peelings, except onion, garlic or hot peppers, eggshells, and bread, pasta, rice and cereal[16]. If the bin begins to smell, it is a sign that too much food is being added at one time[17]. The vermicompost can be collected in about four weeks. To separate the worms from the compost, pour out the bin contents onto a plastic tarp and pile them into a pyramid. After a while, the worms will move away from the light and move to the bottom of the pile. The top layers can then be collected and the worms returned to the bin. Earthworms are hermaphrodites and will breed and produce more worms, ensuring a continuous supply of workers for the compost bin[18]. Maintenance includes keeping the bin contents moist by spraying periodically with water, and feeding the bin with scraps several times a week as needed.

The Microorganisms of Compost Piles

The microorganisms so important to the decomposition in a compost pile include bacteria, and fungi which act as chemical decomposers because they change the chemical composition of the compost material[19]. A compost pile may include over 300 different strains of bacteria[20]. The most desired types are aerobic bacteria. They are the most abundant in a healthy compost pile, oxidizing organic molecules to use for energy and releasing heat as they do. They also release nitrogen compounds, phosphorus and magnesium as waste products—nutrients that plants just love[21]. The heat from this metabolic activity can build up within a couple of days if the conditions are right. Oxygen, moisture, temperature, and pH levels must be right or these bacteria will remain inactive or even die. Oxygen levels must be greater than 5%. If they drop below this, anaerobic bacteria start having the advantage and take over. Their metabolic wastes are not as beneficial and the nitrogen-containing organic acids and amines they produce smell like ammonia and are toxic and unusable by plants. Other gases are also produced: hydrogen sulfide, which smells like rotten eggs, cadaverine and putrescine, which are the smelly products from the breakdown of amino acids—especially if there are animal products in the compost[22].

There will be succession in the types of aerobic bacteria that appear as the temperature changes. At low temperatures, psychrophilic bacteria are most prevalent. They are most active at 55^{o} F to 70^{o}F. They give off very little heat as they oxidize the material, but enough to raise it so that mesophilic bacteria start to replace the psychrophilic bacteria. Mesophillic bacteria work best at 70^{o}-100^{o}F. They decompose the material more rapidly and produce acids, carbon dioxide and heat. Above 100^{o}F, they are replaced by thermophilic bacteria which thrive in temperatures of 113^{o}-160^{o}F. The heat given off by these bacteria can cause the compost pile to reach 130^{o} to 160^{o}F. At these temperatures, the thermophilic bacteria are going to break down a lot of the organic matter very quickly, using up their food supply, unless the pile is turned and mixed. If not, they will quickly die out, the temperature will decline and the mesophilic bacteria population begins to take over. In fact if the temperature gets over 160^{o} for very long, other decomposing organisms will be affected, which may be detrimental to the maintenance of the compost pile. It may also kill the microbes in the compost which have been shown to help fight fungal infections when the compost is added to soil. Turning the pile will release some of this heat and keep that from happening[23].

The Evidence for Global Warming

Every once in a while, I'll have a student who questions the conclusion that humans are the cause of recent increases in global temperatures, or that the consequences of increasing global temperatures will be as dire as many scientists are predicting. Their opinions are generally based on what they've read on websites which often have more of a political agenda than a scientific one. So one of my goals is to present students with the evidence that has been collected on global warming, and give them the chance to evaluate the evidence for themselves.

Global warming is caused when an excess of greenhouse gases—carbon dioxide, methane, nitrous oxides, and halocarbons--are released into the atmosphere, where they absorb and retain heat energy. As more evidence is collected every year, it has become more certain that human activity is behind the increased levels of these greenhouse gases, and that global climate is being affected[24]. Carbon dioxide levels have increased faster in the last ten years than at any time since measurements were begun in the 1950s and are 35% higher than pre-industrial levels. Evidence for this comes from analysis of gases found in air bubbles trapped in ice cores. These core samples also show that nitrous oxide and methane levels have also increased. Halocarbons are a new phenomenon, being mainly produced by humans for use as refrigerants and spray propellants[25]. Questions arise about the origins of climate change. Volcanic activity, forest fires, and solar activity all contribute to global warming, but these alone cannot account for the increasing global temperatures[26]. The smoking guns include higher concentrations of greenhouse gases over high population areas like North America, and isotope analysis of carbon dioxide and nitrous oxides that identifies the source of the emission as the burning of fossil fuels, and methane as coming from agricultural sources[27].

What is the evidence that global temperatures are increasing? In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) describes the increase in global temperature as "unequivocal," based on measurements of average global air and ocean temperatures, global average sea level, and snow cover[28]. The IPCC was established in 1988 to assess and publish reports on the most current scientific information on climate change. The lead authors who write these reports are selected because they are active in climate change research. Their reports are reviewed by hundreds of other experts in the field to ensure that the reports have credibility[29].

The IPCC's most recent findings are that global surface temperatures have increased twice as much in the last 50 years, as in the last 100 years[30]. In fact, tree ring analysis shows that the recent levels of warming have not been seen in the last 1300 years[31]. New measurements of the troposphere show that the temperature has increased similarly to surface temperatures. Ocean temperatures have increased, as oceans have absorbed as much as 80% of the heat in the atmosphere[28]. The result has been thermal expansion of the water and a rise in sea levels. Arctic sea ice has decreased since 1978 by an average of 2.7%, increasing to 7.4% in the summer months[29]. Melting of glaciers and polar ice sheets has continued, and adds to sea level rise, as well as reducing the availability of water for some communities[30]. From 1961 to 2003, average sea levels rose at a rate of about 1.8 mm per year, while from 1993-2003, the rate was 3.1mm per year. In addition, permafrost temperatures have increased up to 3°C. As a result of increased carbon dioxide levels, oceans have absorbed more, causing them to become more acidic[31].

Climate scientists have developed better models for predicting future climate trends, by using information from more areas around the world. By identifying more of the variables that affect climate change, such as the effects of atmospheric aerosols, how water and energy are exchanged between land and the atmosphere, and how sea ice fluctuates seasonally, scientists have been able to adjust their climate models in order to make better predictions about future climate trends. Predictions made ten years ago have proven the models to work very accurately, and clearly show the connection between human activities that produces greenhouse gases and climate change. If the models are run to only include "natural climate influences," the results do not match what we are seeing. However, if human impact is included in the model, the predictions more closely match what we are seeing happen. Based on these models, the 2007 IPCC report was able to say with 90% confidence that global climate change could be attributed to human activity[32].

Based on these models, the report predicts that there will be an increase in heat waves and droughts, coastal flooding and storms. Global warming will increase the incidence of infectious diseases, as parasites like malaria move into new habitats created by changes in climate patterns. One model predicts that by 2080, rising sea levels will leave coastal areas and small islands flooded[33]. Droughts could mean fewer crops and livestock.

Strategies and activities

The subject of sustainability will be introduced to students during the first week of classes. To bring home the idea that what we do each day can make a difference, students will read "Hamburger, Fries, and a Cola" from Facing the Future's "Buy, Use or Toss?" curriculum. They will use this information to complete a life cycle analysis poster for a typical "Happy Meal" showing the resources used and the potential impacts to the environment. The class will then complete a similar poster showing the life cycle analysis for a meal using locally grown foods, and the class will compare the results and discuss the potential impacts to the environment (and to our health!) that result from the simple choice we make about what we eat for dinner. This activity will be based on activities at http://www.monroecounty.gov/Image/LESSON11.pdf and http://www.facingthefuture.org/Curriculum/BuyUseToss/tabid/469/Default.aspx . I want students to begin thinking about where their food comes from and how that might impact the environment.

During this time, students will be introduced to the school garden as part of the unit on the scientific method. Most of my students have never grown anything. After completing the life cycle poster activity, I want students to learn how they might be able to grow some of their own food. I am planning this garden along with two other CTI Fellows from my school. Our hope is the garden will help students connect with the living, growing world around them, and make connections between the things they observe in the garden with the topics they are learning about in the classroom. We will each use the garden in different ways in our units. One teacher is using the garden to discuss how we can eat more sustainably. The other teacher will have her classes create ways to provide water for the garden, while at the same time conserving water resources, through the use of rain water collection systems and the use of "grey" water. I will have one of my two Biology I classes take on development of a compost pile to support the garden.

The first assignment related to the garden will be to read background information on composting for homework. The next day, the class will visit the garden site and I will demonstrate how to set up the compost bin, how to get a good mix of brown to green material, how much water to add, and how to turn the pile. I will show them a sample of completely composted material, so they can see what they are trying to aim for. Students will be divided into several groups to start compost piles, including hot batch piles in wire enclosures and in garbage can compost bins. We will brainstorm factors that might affect the rate of decomposition based on their background reading and the observations they make during the demonstration. Each group will design and conduct an experiment to test their hypothesis about a factor that might affect the rate of decomposition in their compost pile. Students will be able to observe which method produces compost the fastest. On day 2, the students will set up their compost pile, using the conditions they have decided to test. They will make decisions about the types of data they will collect and record initial measurements or observations of that data. Types of data that might be collected are internal temperature of the pile, height of the pile, relative sizes of material in the pile, and smell. In order to have enough leaves on hand to begin this activity, I will collect bags of leaves in the fall when they are set out by the street for collection. Students will also be encouraged to bring in bags of leaves from home. Wire bins and garbage can compost bins will also be pre-prepared for students to use in order to save class time.

It should be noted that composting is a slow process. It is important to tie this activity in with other things going on in the compost piles and in the garden. For example, I will have students use the compost pile as a source of bacteria and fungi for viewing under the microscope as we study the importance of decomposers in nutrient cycles.

Students in my second class will set up indoor vermicomposting bins. They will select a factor to vary in the bins such as type of food, size of container, or temperature, and observe its effects on the worms and their ability to turn the material into compost. Data to collect might include the weight and number of the worms (they will reproduce), the compostable material added in and the weight of earthworm castings collected. This rich source of compost can be used to start seeds indoors for the garden, especially during the early cold months of second semester. Later on, the earthworms will be used in behavior experiments for all classes. Students will test the earthworms' reactions to different stimuli such as light, temperature, moisture, and types of food—tests that may help students design better vermicomposting bins. See Activity 1 in the Appendix.

All classes will be asked to bring in compostable materials from home to add to all the compost piles. This might include some of the new "compostable" packaging materials, such as the new SunChips bags. I also hope to involve the cafeteria and our culinary arts classes in providing material for our compost piles. We will return the favor by providing herbs, grown using the compost, to the cafeteria and culinary arts classes.

Following the establishment of the composting experiments, I will then lead the students through an identification of the steps of the scientific method which they have just been using. Rather than teach the steps first, they will now be able to relate what they were doing to the steps as I describe collecting background information, identifying a problem, developing a hypothesis, designing an experiment and identifying variables, and collecting data. They will then use these steps again, this time with an awareness of what the steps are and how they are used, in developing the next experiment in the garden.

Students in both classes will use a section of the garden to compare the results of using compost to the use of commercial fertilizers on the growth and quality of plants. A control plot will be established which receives no nutrient enrichment of any kind. Initially, before our compost piles are ready, we will use compost from the city compost facility. Students will plant cool weather crops such as peas, broccoli, radishes, onions and lettuce, suitable for growing in the fall or spring. Students will sign up for regular watering and weeding duty to be done after school. Progress and results from each experiment will be shared with all classes as the data comes in. These will be fairly long term investigations, but will support other activities throughout the year. For example, the plants can be a source of cells to view under the microscope during the cell unit and onion root tips can provide cells undergoing mitosis. In addition, our hope is that the garden will produce enough food to share with local food pantries, providing a way for our students to reach out to the community.

Following the first unit on the scientific method, I teach a unit on biochemistry, which will prepare the students for understanding the nutrient cycles taught during the ecology unit. During this unit, the students will also do a qualitative analysis of the organic compounds in the "Happy Meal" and compare the nutritional information between that meal and a similar meal made from foods grown locally. They can then compare these results with their life cycle analysis diagrams for the two different meals. Hopefully they will begin to see what the better choice is, not only for the environment, but for their own health.

I will begin the ecology unit with a discussion of the human population growth curve and the biotic and abiotic limiting factors for our population. While discussing population growth, I'll show the world population clock (http://math.berkeley.edu/~galen/popclk.html) on the screen, so students can see how rapidly the population is growing. After students complete diagrams of the carbon, nitrogen and water cycles, I will divide them into groups and each group will read material I have collected on the human impact on one of the three cycles. This part of the assignment could be done as homework. After reading the material, the students will identify the different ways humans impact their cycle and students will work in small groups to create a poster that briefly describes one of the impacts on the cycle and how that impact might be reduced. The posters created by each group will be displayed around the room and students will then do a "gallery walk" to view and discuss what the other groups came up with.

Students will evaluate the evidence for human impact on global warming. The website Skeptical Science, at http://www.skepticalscience.com/argument.php, provides a good summary of the arguments being promoted that denounce the evidence for man-made global warming, and provides the scientific evidence that refutes those arguments. The information is presented at basic, intermediate and advanced levels, so students can select the amount of detail they want to dive into. Students will work in pairs and will be assigned one of the arguments to read about and discuss. They will then make a presentation to the class, where they role-play the two sides of the argument.

The National Geographic video "Human Footprint" provides a visual depiction of just how much trash one individual can produce over the course of their lifetime, the impact that waste has on the environment, and how important it is to reduce our consumption of material goods. This video is a good introduction to the next activities. One thing I want my students to do is to assess what portion of their household waste is being recycled and what they can do to increase what they recycle. I will bring in a speaker to describe how our city handles recycling and how reusing and recycling help reduce the amount of solid waste in our landfills. Our county recycling facility invites groups to come for tours, and it is very interesting to see how the recyclable material that comes in is sorted for distribution to various users. Because of the difficulty in scheduling field trips at my school, I offer my students extra credit to visit the facility with their parents and write a summary of what they learned.

This will lead to a class discussion on ways we can use these limiting factors in a more sustainable way—recycling, composting, and using alternative energy sources. Students will develop ways to make our classroom and school function more sustainably, and to take steps in their own lives to change how they impact the environment. After calculating their ecological footprint online using the footprint calculator at www.myfootprint.org the concept of sustainability will be reviewed and students will break out in small groups to brainstorm areas of their lives where they might be able to conserve resources and begin to live more sustainably. I will have them pick one or two things to do for thirty days that will have a positive impact on the environment. Students will keep a journal, called "30 Days of Green," in which they discuss their successes and failures at maintaining that behavior. See Activity 2 in the Appendix. During class, we will discuss some of the problems in following their sustainable behavior and have other students suggest ways the problems might be overcome. Big steps start with little steps and anything I can get my students to do to start living sustainably and caring for the environment will be a success.

Students will set up biodiversity plots on the school grounds as we study population ecology. The plots will be one square meter each, placed randomly on the school grounds. Pitfall traps can be placed in the ground to collect insect specimens. Plots will include grassy areas, as well as areas that are under trees and contain more leaf litter. Once the plots are established, I want to try to maintain them for use in following years, saving the time spent in establishing the boundaries of the plots, but also allowing for data to be compared over time. Students will count the number of individuals of each plant and animal species in their square meter. The results of all the plots from less disturbed areas and areas maintained by humans will be compared for number of organisms, as well as the diversity of species found. Students will reflect on how human disruption of an ecosystem can affect biodiversity and how that impact can be reduced.

As we study communities and food webs, I will have students collect samples from our compost pile and capture organisms using Berlese units to create a compost pile food web. They will observe the variety and kinds of organisms and develop a food web based on the community of organisms found there. After teaching about symbiotic relationships among the member of a community, students will examine the roots of legumes from the garden for signs of *Rhizobium* bacteria nodules.

Throughout the school year, I plan to set up a table at the back of the classroom where there will be rotating displays of real items from nature that I find or have collected, for students to look at before or after class, or when they finish an assignment early. This is something you often see in elementary classrooms, but rarely in high school. My hope is that seeing the variety of things I can find around the school or my home, students will start looking and bringing in items to use in the display. The point is to get them to start looking at the world around them, to appreciate the diversity of organisms in it and to consider their impact on that world when they make decisions about how they live their lives.

Notes

[1] "World Population Clock." UC Berkeley Department of Mathematics. http://math.berkeley.edu/~galen/popclk.html

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[3] "Life Cycle Assessment." UW Faculty Web Server. http://faculty.washington.edu/cooperjs/Education/LCApresentation/ppframe.htm

[4] Ibid

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[7] Gault, Meili. "The Life Cycle of a Hamburger and its Environmental Implications." http://greendesignetc.net. greendesignetc.net/Flows_09/Flows_Gault_Meili_paper.pdf

[8] Massad, George. Interview by author. Personal interview. Independence Public Library, October 4, 2010.

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[11] Pleasant, Barbara, and Deborah L. Martin. *The complete compost gardening guide: banner batches, grow heaps, comforter compost, and other amazing techniques for saving time and money, and producing the most flavorful, nutritious vegetables ever*, 122.

[12] Massad.

[13] Pleasant, *The complete compost gardening guide: banner batches, grow heaps, comforter compost, and other amazing techniques for saving time and money, and producing the most flavorful, nutritious vegetables ever*, 137.

[14] Ibid., 138-139.

[15] Massad.

[16] Pleasant, *The complete compost gardening guide: banner batches, grow heaps, comforter compost, and other amazing techniques for saving time and money, and producing the most flavorful, nutritious vegetables ever*, 137.

[17] Massad.

[18] Ibid.

[19] "The Science of Composting - Composting for the Homeowner - University of Illinois Extension." Untitled Document. http://web.extension.illinois.edu/homecompost/science.html.

[20] Pleasant, *The complete compost gardening guide: banner batches, grow heaps, comforter compost, and other amazing techniques for saving time and money, and producing the most flavorful, nutritious vegetables ever*, 137.

[21] "The Science of Composting - Composting for the Homeowner - University of Illinois Extension." Untitled Document. http://web.extension.illinois.edu/homecompost/science.html.

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[23] Ibid.

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[25] Ibid

[26] Ibid., 66.

[27] Ibid.

[28] "Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007." IPCC - Intergovernmental Panel on Climate Change. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html.

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Teacher Resources

In addition to the resources listed in the bibliography, the following websites may be helpful…

http://www.facingthefuture.org/Curriculum/BuyUseToss/tabid/469/Default.aspx --A complete unit on sustainability, that contains a hamburger life cycle activity.

http://www.visionlearning.com/library/module_viewer.php?mid=98 –Human impacts on the nitrogen cycle

http://www.visionlearning.com/library/module_viewer.php?mid=95
-- Human impacts on the carbon cycle

All of the following contain good info on human impact on the water cycle:

http://www.atlas.keystone.edu/edu/Teachers/basics/04humanimpacts.htm

http://www.sciencelearn.org.nz/Contexts/H2O-On-the-Go/Science-Ideas-and-Concepts/Humans-and-the-water-cycle

http://www.visionlearning.com/library/module_viewer.php?mid=99

http://www.purdue.edu/dp/envirosoft/groundwater/src/cycle.htm

Appendix

Activity 1.--Worm Behavior Lab

You have observed how the worms have been turning vegetable scraps and newspaper into rich compost. The question is, now how do we separate the worms from the composted material, without harming them, so the compost can be used in our garden? Is there something about the worms' behavior that might provide us a clue? Your task is to design an experiment to test how the worms respond to some stimulus that might be used later to solve our problem.

List the possible stimuli suggested during the class discussion:
____
____
____
____

Day 1--Individual Planning:
Select one of the stimuli above to use as your independent variable and design an experiment to test the effects of that stimulus on the worms.
Independent variable:____

How will you be measuring the effects of your independent variable on the behavior of the worms?
Dependent variable:____

What other stimuli that might affect the behavior of your worms will be controlled?

Constants: Why it must be controlled: How you will control it:____
1. ____
2. ____
3. ____

Describe the steps you will take in carrying out this experiment:____________________
____
____
____
____
____
____
____

In designing your plan, care must be taken to cause no harm to the worms. We want to be able to continue to use their composting services.

Turn in your individual plan by the end of class.

Day 2—Group Planning
Meet with other class members who selected the same variable and evaluate each other's experimental plan. Discuss what is good and what could be added to improve it. Come up with one plan that you will all use together, and record it in your lab notebook. Create a data table for your new plan—which you will use the next day in lab.

Collect everything your group will need for the experiment, making a list of these items as you go.

Day 3—Conduct the Experiment

Take a few minutes to test your plan and see if there are any adjustments that need to be made to the procedures that you did not think about while planning. Make a note in your lab book about any changes made to your group's plan. When you have worked out the bugs, start collecting your data.

Repeat the experiment as many times as you can.

Every member is responsible for leaving class with all the data, and the notes on the changes made to the plan.

Discuss with your group what the data means.

The Poster—Before you leave class, assign each group member one or more sections of the poster to prepare. Decide on a font type and font size to use. Use a large enough font that the writing is easy to read. You may add pictures if you like, but the important part is the information. Each person should come to class with their part of the poster complete and printed out. Share emails, phone numbers, etc. so you can call each other if you need help or have a question.

Day 4—Prepare and Review Posters
You will have a few minutes in class to put the poster together. On the back, list the group members' names and what parts of the poster they were responsible for.

Poster Rotation—Students will rotate to view all posters and evaluate them using the chart below:

Poster #:	Independent Variable	Dependent Variable	Conclusion	Rating: (1-10/Reason)

After viewing the results of the experiments, what stimulus tested might provide us with the method for separating the worms from the compost, and how would we do it? Do the results of any of the experiments suggest improvements we could make to improve the vermicomposting habitat for the worms?

Activity 2.--30 Days of Green Journal

After viewing Human Impact, and reading chapter 6 in your textbook, I hope you have started to think about the impact that your lifestyle might be having on the environment. It is so easy just to toss that soda can in the trash if there is not a recycling container handy, or trash that old cell phone just because we want the latest coolest version. And what effect are we having on the planet when we buy and eat food that was grown thousands of miles away and transported using the energy of fossil fuels?

I want you to pick at least one thing that you will do over the next 30 days that will reduce your environmental impact on the planet. Some ideas are: recycling more, reducing water use or conserving water, reducing energy use around your house. There are many websites with ideas for things to do around your home or at school. Be creative!

Keep a journal—separate from your lab book—in which you:

1. Identify what you want to accomplish and set a goal for yourself. (My goal is going to be to reduce the amount of garbage that leaves my house and classroom and goes into the landfills. I will recycle more, and start a compost pile at home. I'm hoping you will help me by catching me if I throw something in the trash that could be recycled.)

2. Document your efforts each day at keeping your pledge. Document any changes that your efforts have made.

3. Reflect on how you felt about what you did each day. Were you successful at keeping your pledge? Was it difficult to remember to do? Were there obstacles to keeping your pledge? What might make it easier to keep up with in the coming days?

Scoring:

15 points--The goal is clearly identified and steps the student will take are described. The goal will clearly reduce the student's impact on the environment.

4 X 15= 60 points--Documentation is provided in the form of entries made to the journal describing progress made, including dates. There should be at least 15 entries.

4 X 15= 60 points--The student reflects on their progress in a thoughtful and constructive manner, using complete sentences. There should be at least 15 dated entries.

Total Points:135 points

15 Bonus Points—A decorated cover reflective of the topic of the goal of the student's 30 Days of Green.

Implementing District Standards

This unit addresses the following North Carolina goals and objectives for Biology I:

Competency Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.--Students will use the scientific method to explore factors that affect the production of compost, and the behavior of earthworms. They will analyze and evaluate data on global warming.

Objective 5.01 Investigate and analyze the interrelationships among organisms, populations, communities, and ecosystems.--Students will identify the organisms in the compost piles and create a food web showing the relationships between them.

Objective 5.02 Analyze the flow of energy and the cycling of matter in the ecosystem.--Students will identify ways that humans impact natural cycles, including global warming.

Objective 5.03 Assess human population and its impact on local ecosystems and global environments.--Students will evaluate human impact on the environment by exploring the impact of producing a fast food hamburger meal versus locally grown food sources. They will compare foods grown using organic methods to foods grown using chemical fertilizers. Finally, they will evaluate the evidence for human activity related to global warming.