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# K-12 Partnership Lesson Plan

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# *Bringing Biology to Urban Design*

# *All Aboard the Poop Train!*

## Overview

There has been a significant shift in human populations toward urban areas, which in conjunction with the growing global population has increased the demand for resources like food and energy. In order to satisfy these demands, we must find ways to produce food and energy more sustainably and increase our energy efficiency. Some of the ways we try to accomplish these goals involve taking inspiration from biological systems. This two-part lesson will outline many of the ways that we have applied what we know about nature to make urban systems more sustainable, build in ways that reduce energy demand or increase efficiency, and manage our waste more effectively.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Explain why there is an increasing demand for resources in urban areas
* Explain biologically-inspired strategies for providing food sustainably
* Explain how biologically-inspired design can increase energy efficiency and reduce costs

**Length of Lesson**

This lesson can easily be split into two class periods:

40-60 minutes – Biological Urban Design

20 minutes – Radiolab Poop Train podcast activity (+ time for additional setup and discussion)

**Grade Levels**

Elementary, middle school

**Standards covered (NGSS)**

Disciplinary Core Ideas:

*Elementary*

* **4-ESS3-1**: obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
* **5-ESS3-1**: obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment

*Middle School*

* **MS-LS2-3:** develop a model to describe the cycling of matter and flow or energy among living or nonliving parts of an ecosystem
* **MS-ESS3-4**: construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems

Cross Cutting Concepts:

* Energy and matter in systems
* Structure and function

Science and Engineering Practices

* Constructing explanations and designing solutions

***Previous Michigan Standards Met:***

* **E.ES.E.4:** Natural Resources- The supply of many natural resources is limited. Humans have devised methods for extending their use of natural resources through recycling, reuse, and renewal.
* **E.ES.03.41:** Identify natural resources (metals, fuels, fresh water, fertile soil, and forests).
* **E.ES.03.42:** Classify renewable (fresh water, fertile soil, forests) and non-renewable (fuels, metals) resources. \*
* **E.ES.03.43:** Describe ways humans are protecting, extending, and restoring resources (recycle, reuse, reduce, renewal).
* **E.ES.03.44:** Recognize that paper, metal, glass, and some plastics can be recycled.
* **E.ES.E.5:** Human Impact- Humans depend on their natural and constructed environment. Humans change environments in ways that are helpful or harmful for themselves and other organisms.
* **E.ES.03.51:** Describe ways humans are dependent on the natural environment (forests, water, clean air, Earth materials) and constructed environments (homes, neighborhoods, shopping malls, factories, and industry).
* **E.ES.03.52**: Describe helpful or harmful effects of humans on the environment (garbage, habitat destruction, land management, renewable, and non-renewable resources).
* **L.EC.M.3:** Biotic and Abiotic Factors- The number of organisms and populations an ecosystem can support depends on the biotic (living) resources available and abiotic (nonliving) factors, such as quality of light and water, range of temperatures, and soil composition.
* **L.EC.06.31**: Identify the living (biotic) and nonliving (abiotic) components of an ecosystem.
* **L.EC.06.32:** Identify the factors in an ecosystem that influence changes in population size.
* **L.EC.M.4:** Environmental Impact of Organisms- All organisms (including humans) cause change in the environment where they live. Some of the changes are harmful to the organism or other organisms, whereas others are helpful.
* **L.EC.06.41:** Describe how human beings are part of the ecosystem of the Earth and that human activity can purposefully, or accidentally, alter the balance in ecosystems.
* **L.EC.06.42:** Predict possible consequences of overpopulation of organisms, including humans, (for example: species extinction, resource depletion, climate change, pollution)

**Materials**

* Biological Urban Design PowerPoint
* Radiolab Poop Train Descriptive PowerPoint
* Energy Efficiency Worksheet
* Radiolab Poop Train Worksheet (all materials available on the “Bringing Biology to Urban Design” lesson page on the KBS GK-12 website)

**Background**

Script to accompany “Biological Urban Design” powerpoint:

**Slide 3 [Moving to the City]:** We have seen a significant shift toward a more urban population over time. In 1910, only 2 out of every 10 humans lived in a city or urban location. In 2010, slightly over half of the population (55%) lives in cities. We estimate that by 2050, 70% of all people will live in an urban area. While the proportion of people living in cities has increased over time, the world’s population has also grown exponentially. This means that higher and higher numbers of people are living in cities, increasing urban population densities and putting an even greater strain on resources.

**Slide 4 [Thought Experiment]:** What things do we need to survive? Not things that you need to live a comfortable life, but survive? Food, water, shelter. If you live in a city, where does your food come from? It is not from a super market. Comes from farms that are spread out throughout the world. Fiji water? Really? What are some issues with getting food from far away? Sustainability issues, such as transporting the food from so far away. Is it sustainable to have bannanas shipped to us from South America? What ways can we make our food systems more sustainable? Local, local, local!

**Slide 5 [Urban Agriculture]:** Urban agriculture is popping up in all large urban settings. Here are some photos of urban farms. Pretty great to be getting food on your rooftop, or in the vacant lot next door, but do you think this approach will feed everyone in the city? No way!

**Slide 6 [Ecosystem Approach]:**  This illustrates a more sustainable approach to growing our crops and our protein sources (aka fish). Treating this as an ecosystem, we can recycle nutrients through the system into the crops from the fish waste, and then the clean water can feed back into the fish ponds.

**Slide 7 [Vertical Urban Farming]:** Super great idea, grow your food in the urban setting. Go up rather than out! This could address food desert issues, providing nutritious, local food to everyone within the city, rather than these individuals going to the local convenience store for processed foods.

**Slide 8:** More on vertical urban farms.

**Slide 9 [Some Design Ideas]:** Design ideas. None of these are real yet.

**Slide 10 [Energy within the city]:** Another resource in high demand in urban areas is energy. The energy we use comes from a variety of sources, sometimes renewable and sometimes not. If an energy source is not renewable, such as with oil or other fossil fuels, we will one day use it up and not be able to obtain any more. The fact that more people live in cities has caused the demand for energy to increase, which means we need to find ways to meet this demand more sustainably. Some of this is done by using renewable sources, such as wind or solar energy, and some of this is done by trying to conserve energy (reduce energy usage, as when we turn lights off when not in a room) or increase energy efficiency (finding ways to use less energy to meet the same needs, such as with newer styles of light bulb). There has also been a push to use biology and our knowledge of the natural world to build buildings that are more energy efficient.

**Slide 11 [Green roofs]:** One strategy currently being employed in many places is the use of green roofs, in which bare roofs are covered with plants. There are many benefits to these roofs; besides being nice to look at that, they can reduce surges in stormwater runoff and improve air quality. They can also have a big impact on energy efficiency. Typical black rooftops are some of the hottest surfaces in a city environment, so covering them with plants reduces the amount of heat absorbed. In addition, plants absorb light and use it, rather than having it be converted to heat energy. If the building does not absorb as much heat, not as much energy will be required to keep it cool.

**Slide 12 [Metal roofing]:** Another strategy that can save on energy costs is the use of reflective metal roofing. Typical asphalt roofs absorb energy and trap heat, while metal roofs reflect solar energy. In sunny, summer environments, these metal roofs can save up to 40% in costs used to cool the home. They may not be the most energy efficient strategy in a place like Michigan, where more energy would be necessary to keep the home warm in winter, but it can be quite effective in warmer places. This also illustrates the importance of keeping the local environment in mind when making smart engineering choices.

**Slide 13-14 [Algae building]:** A building in Hamburg, Germany has been constructed to be more energy efficient. The building has algae “sheets” lining the exterior of the building to help maintain constant temperatures within the building. The algae is also collected as it becomes dense and burned to produce electricity and hot water for the building. This is the first of its kind, but more are to come!

**Slide 15 [Experimenting with design]:** While many aspects of urban design can be difficult to experiment with in the classroom, there are some ways we can look at model versions. By using Lego buildings or shoeboxes or other smaller-scale structures, we can experiment with different biologically-inspired innovations and observe how the temperature in the building changes over time. If we can keep the building’s temperature from fluctuating too much as it is warmed by the “sun” (a lamp), and then cooled at “night” (turning the lights out), this represents an innovation that can save costs on energy.

[This point can be an opportunity to use the energy efficiency worksheet to draw conclusions based on data from a version of the experiment]

**Slide 16 [Lighting urban areas]:** Another area in which urban areas have a high demand for energy is keeping streets well-lit at night. This requires lots of energy and maintenance, and some areas experiment with keeping some of the lights off to save on these costs. Buenos Aires, a city in Argentina of 13 million people, has made the switch to LED street lights. While there are some start-up costs, they are more energy efficient and will be more cost-effective over time. What are some other strategies that might be used to reduce energy use, and potentially keep maintenance costs down?

**Slide 17 [Photo-luminescent road lines]:** A town outside of Amsterdam in the Netherlands has begun testing a new method of lighting roads at night. Rather than spending lots of energy on keeping street lamps lit, people there have painted marking on the road with a photo-luminescent paint. During the day, the sun shines on it, which allows the paint to glow at night. The method is still being tested, but if it proves effective and the lines actually glow the entire night, this will allow the town to move away from street lamps that use lots of energy (and reduce the amount and cost of maintenance that needs to be done).

**Slide 18 [Algae streetlamps]:** Researchers are investigating whether they can tap into the photosynthetic ability of algae to help charge batteries within these street lamps as algae are photosynthesizing during the day. This is becoming increasingly more tangible. Can you imagine any benefits coming from having these algae-lamps throughout an urban environment? They love to gobble up carbon dioxide so this technology could lead to reduced pollution/smog within cities, while saving electricity generation costs as well.

**Slide 19 [Radiolab Poop Train]**: We are going to listen to the Podcast of Radiolab. Start the Podcast at 2:30, not from the beginning. There is a single profane statement at the beginning, the rest of the podcast is appropriate for all ages. Hand out the worksheets now.

**Slides 20-23:** Just images to put on the board as the students are listening to the Radiolab episode for a visual guide.

### Activities of the session

1. [Class Period One] Go through Biological Urban Design powerpoint with students. This allows the class to address the reasons why innovation in urban design is important and expose them to several different strategies that have been implemented (or are being designed for potential future use).
2. [Class Period One] After slide 12 [experimenting with design], the Energy Efficiency worksheet can be used to help students draw conclusions about energy use and potential costs based on data collected by KBS fellows.
3. [Class Period Two] Introduce students to some basic concepts relating to waste management and why it is important to manage in sustainable ways. Introduce the Radiolab podcast on the Poop Train.
4. [Class Period Two] Have students fill out the worksheet with questions as they listen to the Radiolab podcast. If desired, they can look at visual aids on slides during the podcast. Discuss the answers (and any questions students still have) after listening to the podcast.

**Resources**

* Green Roof Benefits: <http://www.greenroofs.org/index.php/about/greenroofbenefits>
* Green Revolution: Green Roofs: <https://www.youtube.com/watch?v=vwpP3coXMwE>
* Glow-in-the-Dark Roads Now a Reality: <http://www.iflscience.com/technology/glow-dark-roads-now-reality>
* Energy Savings with Cool Metal Roofing: <http://www.metalroofing.com/v2/content/guide/costs/energy-savings.cfm>

**Extensions and Modifications**

* Have students actually build their own structures (using Legos, shoeboxes, etc.). Students can brainstorm their own ideas about biologically-inspired design and figure out how to translate them to their structures. Use a thermometer or temperature probe to monitor how the temperature fluctuates inside these structures, then use these data to draw conclusions about how effective this biologically-inspired design is.
* Essay on Radiolab

**Assessment**

Two worksheets are provided that can serve as an assessment option. These worksheets can also be incorporated into more formal assessment options (quizzes, exams, etc.).

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Class: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

The US Energy Information Administration says that almost 45% of all energy used in the average household is used to heat or cool the home. Many people spend a lot of money on heating in the winter and cooling in the summer, to keep the home at a constant temperature. Can sustainable design help save money?

This graph shows how the temperature changes over time inside two different homes. One is a regular home, while the second home has an aluminum roof. The aluminum roof is one strategy that could keep energy costs down in warmer climates, as it reflects light and keeps the roof (and home) from absorbing too much heat.

What differences do you see between the two homes in how the temperature changes over time?

If you wanted to keep each home at a constant temperature (such as 80 degrees), which home would require more energy (and therefore money) to keep cool?

Would an aluminum roof be a good way to reduce energy costs where it gets cold in winter? Why or why not?

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Class: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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What differences do you see between the two homes in how the temperature changes over time?

**Regular home temperature fluctuates a lot more, while the aluminum roof keeps the other temperature relatively constant.**

If you wanted to keep each home at a constant temperature (such as 80 degrees), which home would require more energy (and therefore money) to keep cool?

**Regular home. More energy would be required to bring the temperature back to 80.**

Would an aluminum roof be a good way to reduce energy costs where it gets cold in winter? Why or why not?

**Probably not – it is effective in a place like Florida, where it reflects heat energy instead of absorbing it and making the house warmer (requiring more energy to cool down). In a place like Michigan, this would make the house colder in winter and require more heating.**

Name:

**RadioLab’s Poop Train Podcast**

**Listening Activity: Answer these questions as you listen to the podcast [Cues for minutes of the answer].**

1. **What city is this taking place in [2:40]?**
2. **Where was most of the waste sent to prior to 1986 [4:00]?**
3. **What kinds of animals/bugs live inside this plant [7:20]?**
4. **How often does this plant make enough sludge to fill the entire Rose Bowl [9:10]?**

**5.) Are the “biosolids” that are leftover safe to use as fertilizer for our food [10:20]?**

**6.) Where does this leftover sludge get sent to finally? Ultimately called the “New York City Poop Train.” [12:40]**

**7.) Is it likely that you have eaten bread that may have been grown with biosolids [16:35]?**

**8.) Where are the biosolids going now, since the “poop train” has been stopped [19:30]?**

**9.) How much would it cost each New Yorker per month to send the biosolids back to Colorado [21:00]?**

**Some discussion questions:**

-Did you find it interesting to find out more about what happens after flushing the toilet?

-Is it a good idea to use human solid waste as a fertilizer?

-Does knowing that your bread may have been fertilized with human biosolids make you think differently about your food?

-Which is a better option, to send the biosolids to Colorado or putting it in landfills?

**Follow-up essay question: Is it a good idea to use human solid waste as a fertilizer? How does using human waste address some of the issues we have discussed about urban sustainability and large amounts of people living in cities?**