CITY PLANNING FOR BIODIVERSITY AND OUR FUTURE

TGR FOUNDATION

MIDDLE SCHOOL AND HIGH SCHOOL

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LESSON OVERVIEW

In this lesson students will define biodiversity and brainstorm about how cities can have an impact on the biodiversity in an area. They will then calculate a biodiversity index and discover why a high biodiversity index is important for an ecosystem. Finally, they will take on the role of city planners to create and present a unique model of a city that that is laid out in a manner that meets the needs of people and encourages biodiversity in each of the required zoning areas—residential, commercial and industrial.

THIS LESSON FOCUSES ON

ENGINEERING DESIGN CYCLE	21ST CENTURY SKILLS
• Defining the Problem • Designing Solutions • Creating or Prototyping • Refine or Improve • Communicating Results	• Collaboration • Communication • Critical Thinking • Creativity

THIS LESSON FOCUSES ON

Students will be able to:

- Define biodiversity and examine how a city may affect biodiversity.
- Calculate a biodiversity index using data.
- Design and create a model of a city that includes elements that encourage biodiversity.

MATERIALS

Per group

- Teacher Resource: City Planning
- Constraints (1 card per group)
- Bag of candy or colored paper
- Piece of large butcher paper
- Pencils
- Rulers
- Protractors
- Compasses

Each student will need

- Candy Ecosystem Biodiversity Index student capture sheet
- Brainstorming and Ranking City Features student capture sheet

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HAVE YOU EVER WONDERED...

Why your city is laid out the way it is? Who planned where all the elements of your city were built, and what factors go into those decisions?

Cities are designed in three distinct zones—residential, commercial and industrial zones. These three zones provide important services for the residents who live there and it is essential that those involved in planning a city take both the needs of the people and the environment into consideration when deciding what and where things will be located in a city.

How do cities affect wildlife?

Although you may not realize it, there are many species of plants and animals that call your city home! Having a large number of different species in an urban area is important—not just for those species, but for you as well. Green spaces and natural areas where wildlife can thrive in a city environment has a number of benefits that can result in cleaner air, cleaner water and a greater well-being for all the organisms that live there.

MAKE CONNECTIONS!

This section captures how this activity connects to different parts of our lives and frames the reason for learning.

HOW DOES THIS CONNECT TO STUDENTS?	HOW DOES THIS CONNECT TO CAREERS?	HOW DOES THIS CONNECT TO OUR WORLD?
It is important for students to understand the value of biodiversity in urban areas. City planning that encourages a high biodiversity in a city not only provides a place for living things to thrive, but it also improves the quality of life for the residents of the city by improving the air, the water and the land.	**Urban Planners** develop land use plans and programs that help create communities, accommodate population growth and revitalize physical facilities in towns, cities, counties and metropolitan areas. **City Council Members** work as part of the city council, a common form of local government in the United States. A city council is an elected legislative body with the authority to pass municipal ordinances and budgets, make appropriations and even set local tax rates in many cases. **Conservation Planners** are the bridge between developers, environmental groups and government, handling the joint and differing interests on conservation. They will be the first port of call for environmental planning and policy development. Essentially, their role is to determine the environmental value of a packet of land—typically for ascertaining whether or not developers can or should build on the land, or whether it is particularly worthy of special protection. **Landscape Architects** design parks and the outdoor spaces of campuses, recreational facilities, businesses, private homes and other open areas.	With the steady increase of urbanization around the globe comes a greater consumption of nonrenewable resources, higher levels of pollution, and less natural habitats for living things. As we face climate change, it is important to understand that a high biodiversity in cities can help to mitigate these effects by improving air quality. Including elements such as green spaces and community and rooftop gardens into city planning encourages biodiversity, which has been shown to have positive effects on the environment.

BLUEPRINT FOR DISCOVERY

WHOLE GROUP (5 min):

Teacher Preparation:
On an index card, write down the category "biodiversity" and list ten key words or phrases that are important for students to know and remember. Do not share these with students yet. Words and phrases may include: variety of life, makeup of life, ecosystem, specialized species, balance, genetics, species, traits, population and diversity.

1. Show the video segment to students.

2. Next, set a timer for one minute. Tell students the category you've identified, biodiversity, and ask them to try to read your mind and list the ten words you have on your list. This could be done as a whole group, with students sharing words verbally, or, with older students, you could ask them to write as many words as they can. If needed, replay the video segment or allow students another opportunity to look at the images.

3. Finally, when time is up, have students share their words and compare against your list.

4. If you and your students want to increase the competition, teams of students could compete to see who can correctly identify the most words listed on your card. You could also create a class scoreboard to track scores over time.

5. Explain to the students that it is important to be able to determine the biodiversity of an area. It is not simply the total number of organisms that creates a healthy ecosystem, but also the number of different species in that ecosystem. Species fill niches, or play important roles, in their ecosystem. When species are not present in an ecosystem, it is similar to a factory without workers filling the jobs that need to be done, or a chain that is missing important links and falls apart.

6. We can use data on the number of different species and the total number of animals or plants in an ecosystem to determine its basic biodiversity index. We can compare the biodiversity index of different areas to determine which have a higher or lower biodiversity. If there is a low biodiversity index, we can look for solutions to help increase the biodiversity of an area to improve the overall health of the ecosystem.

SMALL GROUP (10–15 min):

Teacher Preparation:
A diversity index helps us quantify the biodiversity of a habitat and is represented by a decimal number between 0 and 1. The closer the diversity index is to 1, the more the habitat is diverse and healthy. A value of .5 indicates a relatively diverse habitat. A value closer to 0 indicates little to no diversity. In order for students to practice this calculation in the classroom, you can simulate the number and abundance of species in an ecosystem using tokens. Prepare bags ahead of time and include different combinations of candy or colored pieces for each group. If you choose to use the nine species recommended in this lesson, limit the total number of candies in each bag to 18. If you want an ecosystem to have a low biodiversity, include 0–7 different colored candies in the bag. If you want an ecosystem to have a high biodiversity, include 8–9 different color candies in the bag.

As an alternative, instead of setting-up different environments where students measure biodiversity, you can set-up a high biodiversity with predators. Then, ask students to remove the predators and have prey fill up the population numbers, resulting in a lower biodiversity.

For Example:
Prepare each bag with two of each color (2 brown, 2 green, 2 red, 2 orange, 2 yellow, 2 purple, 2 blue, 2 pink and 2 black). Calculate biodiversity and you will get 9/18 or 0.5. Then, ask students to remove two predators, Redtailed hawk and Red fox (remove all red and orange candies from the bag). Add four yellow candies to show the prey increased when you removed predator. The biodiversity for this environment is now 7/18 or 0.38. This will allow students to make connections that threatening key species, such as top predators, decreases the biodiversity of an ecosystem and can potentially threaten the balance of the ecosystem.

1. Assign students into partners or into small groups for this activity. Give each group or pair a bag of different colored candy (skittles, M&M's, etc.). This bag represents an ecosystem, each color of candy represents a

species, and each individual candy represents an individual organism in that ecosystem. (Teachers may also use bags of different-colored paper or other materials if they choose not to use candy.)

2. Distribute the Candy Ecosystem Biodiversity Index student capture sheet. In this activity, students will use the key on the sheet to identify and count all the "species" in their bag of candy. They should record their data in the data table and use the formula to calculate the basic biodiversity index for their ecosystem.

3. Ask groups to share the biodiversity index they calculated from their bag. Example guiding questions include: Which ecosystems had the highest biodiversity index? Which had the lowest? Why do you think it is important to compare the biodiversity between different areas? What happens to biodiversity if predators are removed?"

WHOLE GROUP (30-40 min):

1. Ask students to think about how cities might impact biodiversity. Have students discuss their ideas with peers sitting next to them. Ask students to share these ideas and record them on the front board or overhead screen. **Optional**—show the following video clip to students to encourage thinking: University of Minnesota: American Urban Landscapes Lack Plant Biodiversity

2. Lead a discussion with the whole group about residential, commercial and industrial zones using FAST FACTS. Not only do they need to think about how the layout and facilities in a city are designed to help the people living in it, but that it should also benefit the ecosystem and encourage biodiversity.

FAST FACTS

Residential zone—an area of land set aside for housing

Commercial zone—an area of land set aside for for-profit businesses like office complexes, shopping malls, service stations and restaurants

Industrial zone—an area of land set aside for factories and warehouses

3. Divide students into groups. Each group is a separate city planning commission responsible for all zones to be placed to design a balanced city.

4. Distribute Brainstorming and Ranking City Features student capture sheet to each group. Instruct students to collaborate in their groups to brainstorm which city features they need in their city. These should be recorded in the City Features column on Brainstorming and Ranking City Features student capture sheet. Students may want to list out places they visit in their community or locations they wish were in their community. As students' brainstorm, it is suggested the teacher(s) in the room walk around and prompt student thinking with the following guiding questions:

    - Where do people in your city go to school?
    - Where do people in your city work?
    - What do people in your city do for fun? Where do they go?
    - Where do people in your city live? Is there a variety of homes?
    - What natural recreational spaces are available?
    - Where do people in your city go to buy food? Get gas for vehicles?
    - Where are most people in your city employed?
    - Where do people park their vehicles or methods of transportation?

    After a few minutes of brainstorming, stop students and ask them to think and discuss with their group if there is anything that they would add to their list to encourage sustainable solutions (i.e. solar panels, rooftop gardens, recycling centers, community gardens).

If students are having a difficult time coming up with ideas, show the following video clips for inspiration:

The Trust for Public Land

AmericanRivers

If students have a device (laptop, iPad, etc.), encourage them to look up examples of green cities to get ideas for ways to improve their models.

5. Instruct groups to rank the city features on their list in order of importance in the Rank column on Brainstorming and Ranking City Features student capture sheet.

6. The first step in the design process, after brainstorming, is to sketch a scaled drawing of their city. Pass out paper, pencils, rulers, protractors and a compass and provide time for students to start sketching. Alternatively, students may use a sketch application on a mobile device or tablet. Give each group a piece of butcher paper to sketch out their design.

7. Stop students to introduce a twist! They will need to incorporate an important environmental constraint to their city planning. Remind students that with city planning, it is important to maintain or increase the biodiversity of an area to improve the overall health of the ecosystem. All of their cities have a living organism that may be negatively impact by their current plans.

8. Distribute one of the City Planning Constraints Cards to each group at random. Ask students to revisit their initial design and using the information on the card, address the environment constraint in their design.

   Scenario 1 is the most challenging constraint for students to incorporate. Teachers may want to review the cards ahead of time and assign to groups accordingly.

9. Encourage each group to look at the other cities being developed. This can be done as a free-flowing process throughout the creation of city plans or as a gallery walk at the end.

   Optional:

   - Next, students will use one of the following 3-D modeling software programs to design their city in threedimensions. Each site includes tutorials that can guide students to transferring their sketch into the software.

   Examples of 3-D modeling software programs:

   Sketchup:
   https://www.sketchup.com/

   Tinkercad:
   https://www.tinkercad.com/

   Autodesk123D:
   https://autodesk-123d.en.softonic.com/

   Autodesk Fusion 360:
   https://www.autodesk.com/products/fusion-360/overview

   FreeCAD:
   https://www.freecadweb.org/

10. Once each group creates their desired city, they should prepare a 1-minute formal presentation on the benefits of their cities and what features they have added to encourage and support biodiversity based on their environmental constraint. Allow for questions and answers after each presentation.

11. After viewing all cities and hearing presentations, instruct students to discuss what considerations affected the location of their city features for both people and for wildlife. Remind students to think about things such as pollution, noise, traffic, accessibility for everyone, visual appearance and services provided.

12. Take a picture of each group's map and have them submit their brainstormed lists/tables and presentation notes.

TAKE ACTION!

EXTENSION ACTIVITY:

1. Have students conduct research on what LEED (Leadership in Energy and Environmental Design) is, what green construction is, and how buildings and communities qualify for LEED.
2. Ask them to choose one feature (building, neighborhood, etc.) from the city they designed that they could improve to make greener or more sustainable.
3. Have students create a PowerPoint or google slide presentation, write a proposal or create a blueprint that could be submitted to LEED to qualify that structure or neighborhood as green.

Helpful Links:

https://www.usgbc.org/articles/how-leed-changing-city-planning

https://www.usgbc.org/articles/transform-your-community-leed-cities

NATIONAL STANDARDS

Next Generation Science Standards

MIDDLE SCHOOL

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing Explanations and Designing Solutions Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.	**LS4.D: Biodiversity and Humans** Changes in biodiversity can influence humans' resources and ecosystem services they rely on.	**Systems and System Models** A system can be described in terms of its components and their interactions.
Developing and Using Models Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	**ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.	Influence of Science, Engineering and Technology on Society and the Natural World The uses of technologies and limitations on their use are driven by individual or societal needs, desires and values; by the findings of scientific research; and by differences in such factors as climate, natural resources and economic conditions.

HIGH SCHOOL

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Obtaining, Evaluating and Communicating Information Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually and mathematically.	**LS4.D: Biodiversity and Humanss** Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth.	**Systems and System Models** A system can be described in terms of its components and their interactions.

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Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Constructing Explanations and Designing Solutions Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria and tradeoff considerations.	**ETS1.B: Developing Possible Solutions** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.	Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter and information flows—within and between systems at different scales.

RECOMMENDED LINKS

http://e360.yale.edu/features/urban_nature_how_to_foster_biodiversity_in_worlds_cities

https://www.amnh.org/explore/curriculum-collections/biodiversity-counts/plant-ecology/how-to-calculate-abiodiversity-index/

http://www.mapei.com/US-EN/leed-calculator.asp

https://link.springer.com/chapter/10.1007/978-3-319-56091-5_10

https://www.bls.gov/ooh/architecture-and-engineering/landscape-architects.htm

https://www.environmentalscience.org/career/conservation-planner

http://www.fishwildlife.org/files/ConEd-Schoolyard-Biodiversity-Guide.pdf

http://eu.montana.edu/climb/lessons/exploring/docs/exploringecosystems_lesson3.pdf

CANDY ECOSYSTEM BIODIVERSITY INDEX STUDENT CAPTURE SHEET

Calculate the biodiversity index (or how diverse and healthy an ecosystem is) of a bag of candy. Each color of candy represents a different species in your ecosystem. The number of each colored candy represents the population size of that particular species.

Species Key

Candy Color	Species	Candy Color	Species
Brown	White-tailed deer	Purple	Garter snake
Green	Leopard frog	Blue	Blue jay
Red	Red fox	Pink	Woody Plant
Orange	Red-tailed hawk	Black	Grains
Yellow	Field mouse		

Directions:

Count how many different colors of candy you have. Record the name of each color in the first column. Record the total number of colors in the last box of the first column. Count how many of each color candy you have. Record that number in the second column. Count the total number of candies. Record that number in the last box of the second column.

CANDY COLOR (Species)	# OF CANDY FOR EACH COLOR (Population)
(a) Total # of Colors:	(b) Total # of Candies:

Calculate the biodiversity index for your candy: (a)/(b) = BIODIVERSITY INDEX _____

BRAINSTORMING AND RANKING CITY FEATURES

City Features	Rank (1=most important)

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CITY PLANNING CONSTRAINTS

Scenario 1: River

Predictive modeling has shown that your current city plan may lead to sewage and storm-water waste to flow into a nearby river. The river is up-stream of the city's drinking source and nutrients flowing into this source may contaminate the water making it more difficult to use for drinking water. Excess nutrients have caused algae blooms which have lowered the oxygen content of the water. This had led to the decline of several species of native fish.

How could you include a sewer system to collect sewage and rain-water preventing them from flowing into the river?

Be sure to include the river and how the sewer will redirect water and prevent most of the runoff from entering the river before it is treated by the waste water treatment facility.

Scenario 2: Green Space

The use of dark and non-reflective surfaces can make a densely populated city much hotter than the surrounding area. Concrete and asphalt are examples of materials that can lead to an increase in the local, average air temperatures.

How could you include trees and vegetation to help cool your city? Where could you add shade to buildings or pavement?

Be sure to include the use of native plants that will work well with your city's climate.

Scenario 3: Forest

There is a larger forest near your city that is home to the spotted owl. Early building plans show a need to cut down parts of this forest, threatening the breeding grounds of this owl.

How can you modify your design to protect the forest as you build?

Be sure to indicate plans that prevent future builders from cutting down the trees in the spotted owls habitat.

Scenario 4: Swamp

Building plans show your city has gotten too close to a swamp that is an important habitat for the Red Headed Woodpecker.

How can you modify your design to maintain the swamp environment that is home to the Red Headed Woodpecker?

Be sure to indicate the swamp on your city planning map and illustrate how you will protect this habitat as you build your city.