

GARDEN LESSON PLAN: LIVING SYSTEMS

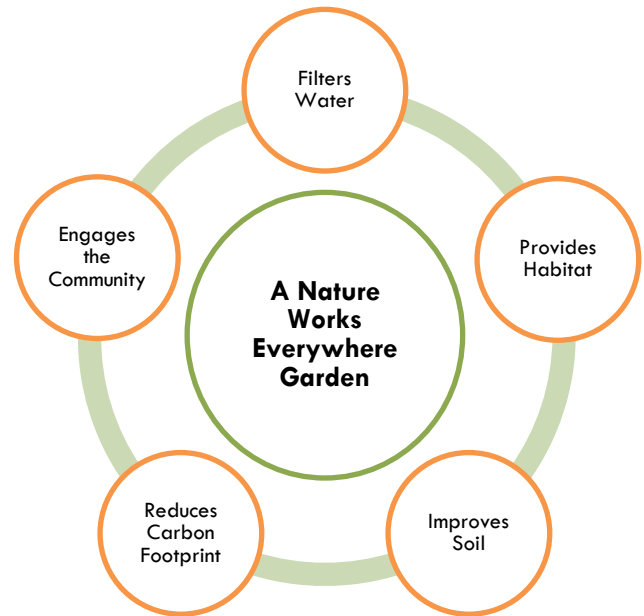
Many elements are interconnected and function together to create the natural and productive living system that is your garden. The purpose of this activity guide is to teach students the ecological functions found in any natural system and model how these functions are performed by a natural area like a garden.

Subject Area: Gardens, General Science

Grade Levels: Geared toward 6th-8th grade, but can be tailored for all grades

Essential Question:

How does a garden model a natural living system?



Purpose and Overview

This guide can be used on its own or as a foundation for participating in the *Nature Works Everywhere: Gardens* program. While all of the other Gardens Activity Guides require a garden or some type of natural area to use as an outdoor classroom, this Activity Guide can be used as a traditional lesson plan in the classroom that uses a virtual garden to model the same principles and concepts. **If you have no natural space or garden, this is the perfect guide for you!**

In Part 1 of the guide, students learn about and model natural systems that function to filter rainwater, provide habitat, reduce carbon dioxide in the atmosphere, improve soil, and produce food. In Part 2, students use the Nature Works Everywhere garden design tool at https://www.natureworkseverywhere.org/gardens/#garden_design to map a natural area and create a virtual garden that performs and models the ecological functions they have learned about.

Time:

This activity guide is part of an extended learning experience that engages students in creating and maintaining a school garden.

- Part 1: one 45-minute class period.
- Part 2: two to three 45-minute class periods.

Materials and Resources

Materials for teacher

- Computer with Internet connection

Materials for each student or group of students

- Garden Notebook
- Computer with Internet connection
- Poster board and markers (optional)
- String or yarn, paper name tags or similarly-sized slips of paper, tape
- Tape measure or other form of measurement
- Calculator
- Handouts listed below can be found here:
<https://www.natureworkseverywhere.org/resources/activity-guide-living-systems/>
 - a. Living Systems Field Report
 - b. Living Systems Evaluation

Nature Works Everywhere videos supporting this activity guide

- Nature Works – Global Gardens (<https://vimeo.com/77792707>)
- Nature Works – To Make Clean Water (<https://vimeo.com/77811268>)
- How Dirt Works Overview (<https://vimeo.com/77792712>)
- Pollinators — Putting Food on the Table (<https://vimeo.com/77811127>)
- Coral Reefs — Feeding and Protecting Us (<https://vimeo.com/77811130>)
- Reforestation: Impact on Climate (<https://vimeo.com/77792711>)

Gardens How-to Video Series:

- Planning Your Garden (<https://vimeo.com/91446626>)
- Building a Garden in a Day (<https://vimeo.com/91445078>)
- Caring for Your Garden (<https://vimeo.com/92520693>)
- Fears (<https://vimeo.com/92531513>)

Objectives:

Evaluation

- Define concepts such as ecological function, watershed, habitat, carbon sequestration, and pollination.

Synthesis

- Construct an argument to show the ecological benefits of transforming a natural space into a cultivated ecosystem.

Analysis

- Design a virtual garden within a natural space that optimizes the ecological productivity of that space.

Application

- Measure and diagram a natural space to identify physical features, structures, and plant life that set parameters for its ecological productivity.

Comprehension

- Describe or model how the components of a garden ecosystem — organisms, water, soil, air, and sunlight — interact to perform the garden’s ecological functions.

Knowledge

- Describe four ecological functions of a garden ecosystem: rainwater filtration, habitat provision, atmospheric carbon reduction, and food production.

Next Generation Science Standards:

Disciplinary Core Ideas:

- LS2A Interdependent Relationships in Ecosystems
- LS2.B Cycle of Matter and Energy Transfer in Ecosystems

Crosscutting Concepts:

- Patterns
- Cause and Effect
- Stability and Change

Science and Engineering Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

Performance Expectations:

Middle School

Activities in this lesson can help support achievement of these Performance Expectations:

- LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
- LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Common Core Standards:

6th-8th Grade Science and Technical Subjects

- CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks.

Vocabulary:

- **Carbon Cycle:** The series of processes by which carbon compounds are recycled in the environment, chiefly involving the incorporation of carbon dioxide into living tissue by photosynthesis and its return to the atmosphere through respiration, the decay of dead organisms, and the burning of fossil fuels.
- **Carbon Sequestration:** The process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliage, and roots) and soils.
- **Ecological functions:** Natural processes that benefit humans, such as food production and water filtration. Also called ecological services.
- **Ecosystem:** A community made up of living organisms and the nonliving components of their environment that interact as a system and are linked together through nutrient cycles and energy flows.
- **Food Web:** A representation of the feeding connections or consumer-resource relationships in an ecosystem. A *food chain* represents these relationships as a linear sequence beginning with species that are called producers and ending with species that are called decomposers.
- **Habitat:** The natural home or environment of an animal, plant, or other organism.
- **Permeable/Impermeable:** Allowing fluid to pass through/Preventing fluid from passing through.
- **Watershed:** An area of land where all of the water that is under it, or drains off of it, flows to the same river, basin or sea.

Background:

In this two-part lesson, students first investigate some of the ecological functions of a garden ecosystem and describe or model these functions to show how they operate and cooperate to form a living system; students then use a digital design tool to assess the ecological productivity of a natural area and design a virtual garden within the area to enhance its ecological productivity.

Engage

1. Begin by viewing the [Global Gardens](https://vimeo.com/77792707) video (https://vimeo.com/77792707 - about 4 minutes), which describes the benefits of an urban garden.
 - a. Ask students, What makes a garden “a complete mini-ecosystem” (at 0:24-0:26)? Students should recognize that, like any ecosystem, a garden is a community of organisms — plants, animals, and microbes — interacting with their environment and each other.
 - b. Have students give examples of some interactions they saw in the video: plants growing in the soil and producing food; butterflies, hummingbirds, and bees feeding on and pollinating flowers; earthworms burrowing in the soil.
 - c. Ask them to describe some interactions they could not see: for example, plants absorbing water, sunlight, and carbon dioxide for photosynthesis; bacteria breaking down organic matter in the soil; beetles and other insects feeding on plant leaves and vegetables; birds and other animals feeding on the insects and earthworms in the garden.

- d. Guide students toward the understanding that a garden is not just a place to grow flowers and vegetables. It's really a living system made up of many different organisms all growing together, and all sustained by the soil, water, air, and sunlight of their environment.
2. Remind students that the video also described the garden as a “mini-farm” and a “mini-watershed” (at 2:28-2:49). Discuss the following questions as a class:
 - a. How does a garden function as a “mini-farm?” Students should recognize that gardens can produce food with the help of gardeners who care for the plants and pollinators who make it possible for the plants to reproduce.
 - b. How does a garden function as a “mini-watershed?” Students should recognize that gardens filter rainwater that seeps through the garden soil and flows eventually to rivers and the ocean. To help with this concept, students can view the [Nature Works — To Make Clean Water](https://vimeo.com/77811268) video (<https://vimeo.com/77811268>).
 - c. What other functions does a garden perform that we saw in the Global Gardens video? Students should recall that a garden functions as a “mini-habitat” for the many different kinds of organisms that live there. A garden also functions to reduce carbon dioxide (CO₂) in the atmosphere through the elimination of many CO₂-producing steps in the food production and delivery process.
 3. Guide students toward understanding that each of these functions involves a set of interactions between components of the garden ecosystem. In other words, each is a separate ecosystem component within the larger living system of the garden.

Explore

Use this activity to help your students make connections between the ecological components of a natural system (and/or a garden) and brainstorm how relationships and interactions happen in an ecosystem.

For younger students, it may be helpful to start with the information provided in the Explain section below and follow that with this activity to apply what they have learned. If your students are already familiar with natural and ecosystem processes, they can begin here and confirm and extend their knowledge below.

1. Divide the class into four groups and have each group create a diagram or develop a description of one of the garden's ecosystem components: food production/carbon reduction, water filtration, habitat, or soil. Students should identify how these components are themselves systems and explain how parts interact to perform their functions.
 - a. Reassure students that their diagrams and descriptions can be very general or very specific. Explain that they are simply using what they already know about ecosystems and biology to map basic relationships between parts of the garden — enough to show that food production or water filtration, for example, doesn't “just happen” but is a result of ecological and biological interactions.
 - b. It may be helpful to provide or have students make name tags for the basic components of the garden ecosystem — plants, animals, micro-organisms, soil, water, air, and sunlight. These are the building blocks and the interactions between them form processes (such as

photosynthesis, pollination, and decomposition) through which the garden performs its different functions. Students can arrange the name tags to work out a basic diagram of the processes underlying the function they are exploring, then create additional or more specific name tags (e.g., roots, bees, bacteria, carbon dioxide) to explain in more detailed terms how the components work.

2. Provide the class with string or yarn and name tags to plot out and label the interactions and inter-relationships between the many constituent parts of this living system — the food webs within its surface and sub-soil habitats, the natural processes that absorb CO₂ from the atmosphere and prevent impurities from entering the watershed, the combination of biological and ecological processes that produce plant life we use as food. While it is unlikely that students will be able to represent all the complexity of this living system, their efforts will demonstrate that all components of a natural system are densely interconnected and must work together for nature to be productive.
3. Allow time for each group to present its analysis of the processes and interactions for its assigned area (water, soil, habitat, carbon/food) through which the garden performs its different functions. Encourage students to add or correct details in one another's presentations.
4. Conclude by taking a show of hands as you ask: Does the garden component your group analyzed depend on plants? on animals? on micro-organisms? on soil? on water? on air and sunlight? Students from every group should raise their hand each time, demonstrating that all these sub-systems are interconnected and interdependent, working together to make the garden a productive living system.

Explain

After groups have re-convened and shared their ideas about how habitat, water, soil, and carbon and food work together as a system, explain to students that you are going to take a closer look at each of the garden functions they have analyzed, in some cases by visiting a different ecosystem to see that function operating on a larger scale.

This section uses a lot of video content and information from across the *Nature Works Everywhere* curriculum to bring these ideas together with students. Use these as much or as little as you see fit, with the objective in sight to teach students about how the natural world (and your garden) functions as a living system that produces our food, water, the stuff we own and the air we breathe. This should confirm and extend the observations about ecological relationships your students explored in the Explore section above.

1. **Habitat:** For a large-scale perspective on the garden's function as a habitat, show students the video [Coral Reefs — Feeding and Protecting Us](https://vimeo.com/77811130) (https://vimeo.com/77811130 - about 4 minutes), which examines the relationships between organisms that inhabit this undersea habitat and how the habitat is being threatened by human activities around the globe.
 - a. Ask students to draw analogies between the coral reef habitat and a garden habitat. They should recognize that both are home to a diverse assortment of plants and animals that all have their special niche — a living space within the habitat to which the organism has adapted, whether it is the space near a sea anemone for a clownfish (at 1:07) or space near insect-attracting flowers for a garden spider. They should also recognize that

interactions among the organisms in both habitats can be described by a food web, which extends from plant life through many forms of animal life to predators like sharks in the coral reef and insect-eating birds or bird-eating cats in the garden.

- b. Students may also note that both of these habitats are useful to humans. The coral reef is a source of food (fish) and medicines. The garden, too, produces food, and for thousands of years gardens were also our main source of medicines. Despite this similarity, however, students should recognize that the coral reef is a natural habitat, whereas the garden is a cultivated habitat — created, shaped, and maintained by humans for a specific purpose. It functions through and models natural processes for us, similar to the functions and processes present in any ecosystem.
 - c. Optional: To further explore biological interactions and relationships in ecosystems using the coral reef as an example, download [The Need is Mutual: The Importance of Biological Interactions](#) lesson plan for use in your class.
2. **Water:** For background on the garden’s function as a “mini-watershed,” show students the [Nature Works — To Make Clean Water](https://vimeo.com/77811268) video (https://vimeo.com/77811268 - about 4 minutes), which explains how full-size watersheds filter impurities from rainwater and shows how rainwater that falls on hard surfaces instead of soil runs unfiltered into our water sources, carrying pollutants picked up along the way. The video also shows a “rain garden” mini-watershed at work.
- a. Have students give examples of impermeable surfaces in your community that are contributing to the unfiltered runoff of rainwater. They could name sidewalks, roadways, parking lots, roofs, driveways — any structure that prevents the soil or land from absorbing rain water. Discuss how, as shown in the video, gardens and other natural areas provide a way to create a balance between hard surfaces and soil — that is, between *impermeable* and *permeable* surfaces — in a community, and can even divert some rainwater from hard surfaces back into the soil. A garden acts as a mini-watershed because it serves the same function as a forest or other natural area - it absorbs, slows, and filters rain water as it enters an ecosystem. This is good for people and nature, to keep our drinking water and waterways clean and productive.
 - b. Ask students what role organisms play in the garden’s rain filtration system. They should recall from the [Reforestation: Impact on Climate](#) video that plant roots are important for holding soil in place (at 1:55-2:00), and from the [Global Gardens](#) video that plant roots absorb water from the soil (at 2:32-2:45), helping to slow the flow of rainwater into the surrounding watershed. They may also recall from this second video that garden soil has organisms and decayed organic matter mixed into it (at 1:50-2:15), which also helps slow the flow of rainwater. In other words, as in other garden sub-systems, organic and non-organic components of the garden ecosystem work together to make the garden a mini-watershed.
3. **Soil:** You can’t talk about water in the garden or in nature without exploring soil as well. Use the [How Dirt Works Overview](https://vimeo.com/77792712) video (https://vimeo.com/77792712 - about 4.5 minutes) to provide additional background on this important component of the garden and ecosystems, especially the segment (at 1:25-2:07) that shows how soil is in itself a habitat for a wide array of organisms whose interactions form a food web that extends from bacteria and other microbes to earthworms and millipedes, which can become part of the garden’s surface habitat when they are eaten by birds.

- a. Ask students how soil might be the building block of any natural system? What do we use every day that requires soil? The answer to this can be quite surprising for students – most things in fact require soil! You can trace the origins of practically any product, food or other resource to soil. For example, the t-shirt you are wearing? If it's made of cotton, that cotton grew in soil. What about a cheeseburger you ate for lunch? The bread comes from wheat which grows in soil. The lettuce, tomato and onions also grow in soil. And the burger and cheese itself – both are or come from a cow, which eats grass, which grows in soil!
 - b. You can ask your students to challenge you with any object, product, etc. that doesn't originate from soil. See if they can think of things that aren't dependent on soil – plastic for example - this doesn't seem to originate from soil. But plastic is a petroleum product that is produced from oil deposits. Those deposits of oil are results of many millennia of geologic processes acting on dead organic matter – plants and animals from long ago. Those plants grew in soil and those animals' food chains start with soil!
 - c. You may even have clever students who challenges you with sea food – that doesn't come from soil. But, it does. As with any food chain, the bottom of the food chain starts with plants that grow in soil or very small organisms that eat or are dependent on soil. It's all about the nutrients – soil provides the nutrients that make any food system possible, even in the ocean, much the same way that the sun provides the energy that is the basis for natural systems.
4. **Carbon and Food:** Next, for a large-scale perspective on carbon reduction in the garden, you can show students the video [Reforestation: Impact on Climate](https://vimeo.com/77792711) (at <https://vimeo.com/77792711> - about 3.5 minutes), which explains the carbon cycle — how trees and other plants absorb CO₂ from the atmosphere (called *carbon sequestration*) and then release oxygen back into the atmosphere (at 1:13-1:28). The video also shows how these, and other benefits of planting trees helps improve our global environment.
- a. Ask students to draw analogies between carbon sequestration by forests and by gardens. They will likely point out that, while the process is the same, forests are much larger than gardens and therefore can absorb more CO₂ and have a bigger impact on CO₂ levels in the atmosphere. Keep in mind that plants in a garden are not huge sequesters of carbon, unless you plant an orchard or include trees in your garden designs. Remind students, however, that — as they saw at the end of the [Global Gardens](#) video (at 3:23-32) — when you multiply the small impact of a single garden by the number of gardens around the world, it adds up to a very big impact as well.
 - b. Ask students where the real carbon savings might occur in a garden – how is the carbon cycle-related to what happens in a garden? Prompt students to recall that gardens can reduce CO₂ by eliminating CO₂-producing steps in the food production and delivery process (as explained in the [Global Gardens](#) video at 1:30-1:50 and the *Gardens Activity Guide: Food and Carbon*). Have students compare the CO₂ emissions generated by purchasing a tomato at the supermarket with those generated by picking a tomato from a backyard garden. It takes farm machinery, packaging machinery, transport trucks, and an air-conditioned supermarket, plus your own transportation to and from the supermarket, to put a purchased tomato in your kitchen, and the farther that tomato must travel from a farm, the more CO₂ it will generate. By comparison, a garden-grown tomato is almost CO₂-free, depending on how it is grown.
 - c. Ask students which of the garden's sub-systems is working to reduce CO₂ in this indirect way — by reducing the amount of CO₂ we must generate in order to eat? Students should recognize that, in this case, it is the garden's food production system that is reducing CO₂

in the atmosphere, providing us with a good example of how the garden's sub-systems all work together to create a living system that functions in many different ways.

- d. For a closer look at the garden's function as a "mini-farm," show students the [Pollinators — Putting Food on the Table](https://vimeo.com/77811127) video (https://vimeo.com/77811127 - about 3.5 minutes), which examines the crucial role that pollinators like ants and bees play in plant reproduction, which is the source of fruits, vegetables, and most other foods.
- Ask students what other components of the garden ecosystem, besides pollinators, are crucial to food production. They should recognize that soil, water, air, and sunlight are also vital parts of the food production sub-system (as previously discussed). And they might also point out that this sub-system functions in cooperation with other sub-systems: the garden must provide a habitat for pollinators before they will come to play their part in food production (as mentioned in the video at 2:06-2:10), and the garden's soil must provide nutrients and a filtration system that slowly releases water into the watershed for plants to get the water they need to grow. Remind students that you have already seen how food production indirectly increases the garden's capacity to reduce CO₂ in the atmosphere, which means that all four of the sub-systems you are examining interlock and work together as a single living system.
 - Conclude this review by asking students what part humans play in the garden's ecology. Remind them that a garden is a cultivated habitat, a place designed to function as a part of nature. Humans choose the plants that will grow in the garden, and in that way determine what kinds of organisms will live there and what kinds of food the garden will produce. Humans also choose the soil for the garden, and in that way determine how well the garden will function as a mini-watershed. And humans are crucial to the garden's capacity to reduce CO₂ in the atmosphere by eliminating CO₂-producing steps in the food production and delivery process, for if no one picks that tomato in the garden, its CO₂-saving potential will be wasted. In other words, unlike most other natural areas — forests, coral reefs, African grasslands — a garden is a living system that functions in cooperation with humans. Like the pollinators, we are an essential part of this "complete mini-ecosystem."

Extend

For a different perspective on the garden ecosystem, have students write an autobiographical account of life in the garden from the point of view of a seed planted in the soil. This story would begin with the seed's reaction to the organisms of the sub-soil habitat and the water filtration capacity of the soil, then follow the seed as it sprouts and becomes part of the garden's surface habitat, where it will interact with pollinators, and continue to draw on the soil for water and nutrients to produce what those who planted the seed call food. Remind students as they plan their seed autobiographies that, in a garden as in nature, humans are also part of the living system and should figure into every episode of the story.

Evaluate

Use these questions and scoring key to evaluate what your students have learned.

1. Identify four ecological functions of a garden.
2. Describe how a garden can benefit the watershed.
3. Identify five organisms you might observe in a garden habitat.
4. Describe how a garden can help reduce the level of carbon dioxide in the atmosphere.

5. Describe the role of pollinators in a garden ecosystem.

Scoring Key for Evaluation

1. A garden filters rainwater, provides habitat, reduces carbon dioxide in the atmosphere, and can provide food to humans.
2. The garden's soil is a permeable surface that allows rainwater to flow underground to the watershed. The garden's soil also removes impurities from rainwater as it flows through and slows the flow of rainwater so that it enters the watershed gradually.
3. Answers will vary, but students should identify both plants and animals as organisms that inhabit a garden habitat.
4. Gardens can reduce atmospheric carbon dioxide levels by providing a local food source that eliminates some carbon dioxide producing steps in the food production and delivery process.
5. Pollinators facilitate plant reproduction by transferring pollen from the male to the female organs of flowers, and thereby contribute to food production in the garden ecosystem.

Part 2 – The Virtual Garden

Engage

Suggested Flow of Activities:

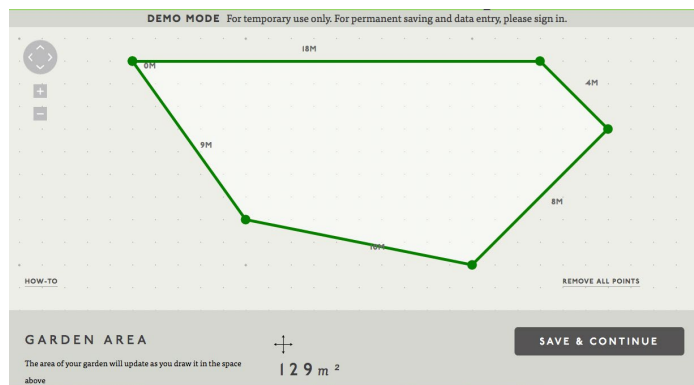
Having explored how a garden functions, they will now have an opportunity to put that knowledge into practice by creating a virtual garden online using the *Nature Works Everywhere* Garden Design Tool. Ideally, you have a natural space or garden already available to take the concepts explored above home with your students. If you don't however, your students can still use the virtual garden design tool to apply the knowledge they have gained about how a garden and how natural systems work. Use this tool to create a virtual garden and continue the exploration of the garden as a natural living system.

Note that students (and you) can try the basic “Demo Mode” version of the garden design tool without needing to sign up for the *Nature Works Everywhere Gardens* program. To access this version of the design tool, click the “Garden Tools” button to the right on the NatureWorksEverywhere.org website, then scroll down and click the “Try It Now” button below the description of the garden design tool on the left.

Follow the steps below to demonstrate the garden design tool for your students. You can also click “How-To” in the lower-left corner of the page, then click the “Take a Tour” button for step-by-step directions. Note that you can operate the design tool while the step-by-step directions are on-screen — that is, you can demonstrate how the tool works as you walk students through the design process.

Step 1: Draw Your Garden

The garden design tool provides a dot-grid on which to draw the outline of your garden. If you need more room, click the minus sign at the upper left of the screen to zoom out. You can click the plus sign to zoom back in. You can also move your outline up, down, left, or right with the directional arrows above the zoom controls.



To start your outline, click the cursor on any dot, then click on any other dot to create a line between the two dots. The design tool displays the length of the line in meters. Continue to click dots to create lines showing the perimeter of your garden plot, which can be any shape consisting of straight lines. To complete the outline, you must click the dot where you started.

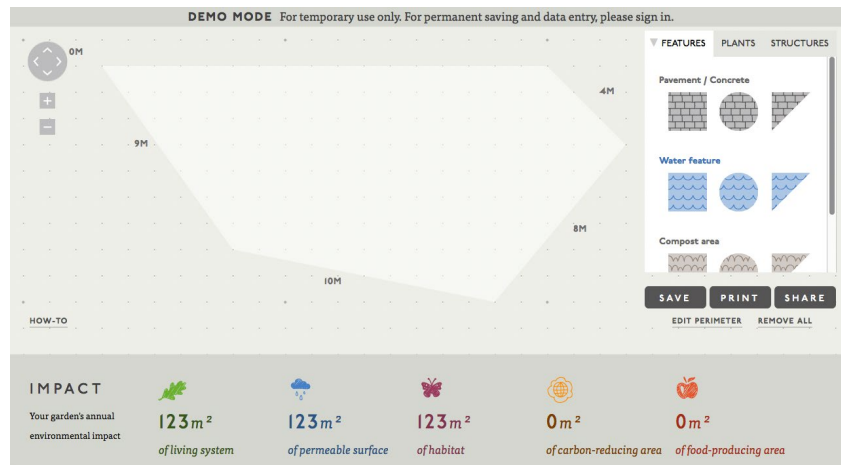
Rather than count and click dots to make your outline, you can draw lines on the grid by clicking on a dot and holding the mouse button down as you drag the cursor in any direction. The design tool displays the line's changing length as you stretch it; release the mouse button when you have reached the length you want. The endpoint of the line will automatically position itself on the nearest grid dot and show a white center. Click and drag on this white center to create the next segment of your garden outline and continue in this way until you complete the outline by returning to the dot where you started.

If you make a mistake, you can erase a line by clicking the red minus sign, or you can click "Remove All Points" at the right side of the screen to start over. You can also adjust the shape and size of your garden plot after you have completed your outline by dragging any of the green dots marking the endpoints of your lines.

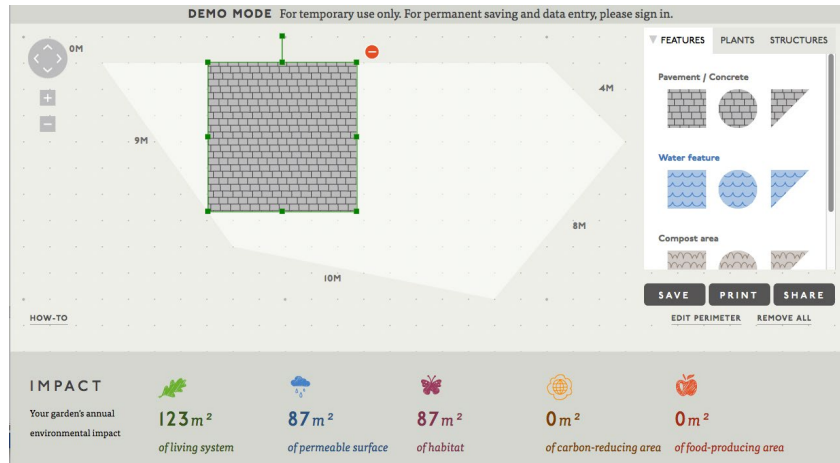
Once your outline is complete, the design tool calculates and displays the total square meter area of the garden plot. This measure is used to calculate the garden's environmental impact.

Step 2: Design Your Garden

Click the "Save & Continue" button to see your garden outline with the length of each side labeled. You can still change this outline by clicking "Edit Perimeter" on the right side of the screen, which will take you back to the Draw Your Garden page.

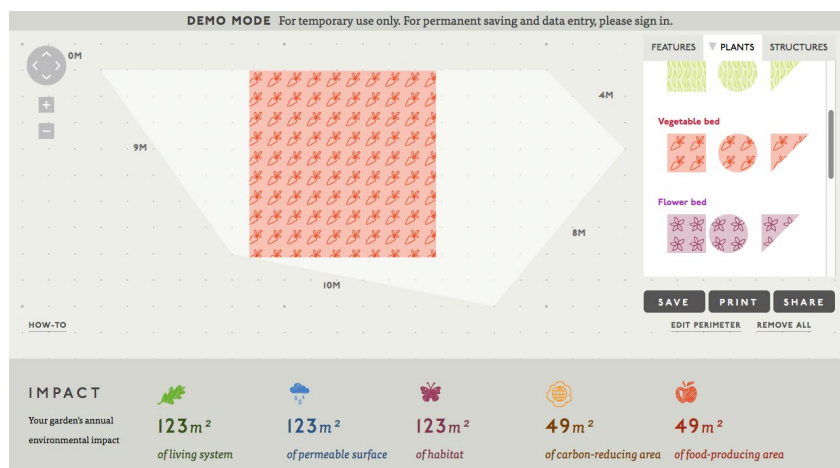


Otherwise, scroll down to see five measures of the garden's environmental impact, based on the ecological components and functions of the garden explored above. These measures show how much of the garden area supports a living system, how much is a permeable surface that will filter rainwater, how much is available for habitat, how much contributes to carbon reduction, and how much can produce food. At this point, because the garden is presumably bare soil, the design tool shows the total area as a permeable surface that supports a living system and provides habitat — that is, the living system of organisms within the sub-soil habitat. Similarly, the measures for carbon reduction and food production are both zero, since the design tool calculates these based on how much of the garden area has been planted.

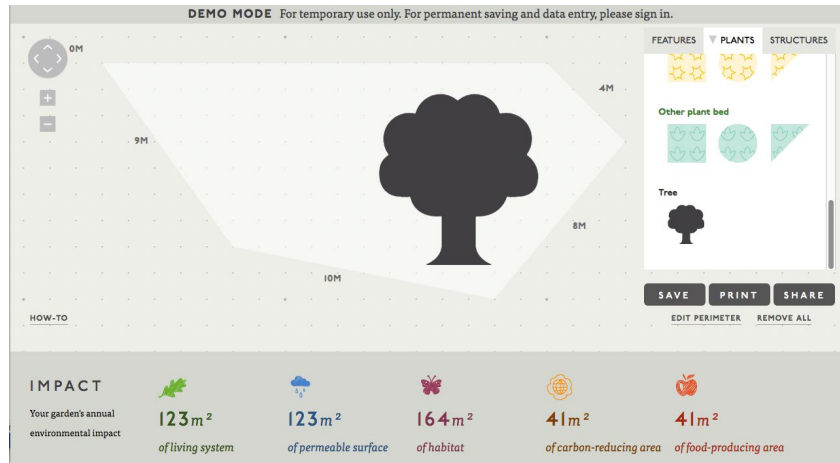


All these measures will change as you begin to add Features, Plants, and Structures to the garden plot. Note that the living system metric does not change – it reflects the total size of your garden as this is the living system you have created.

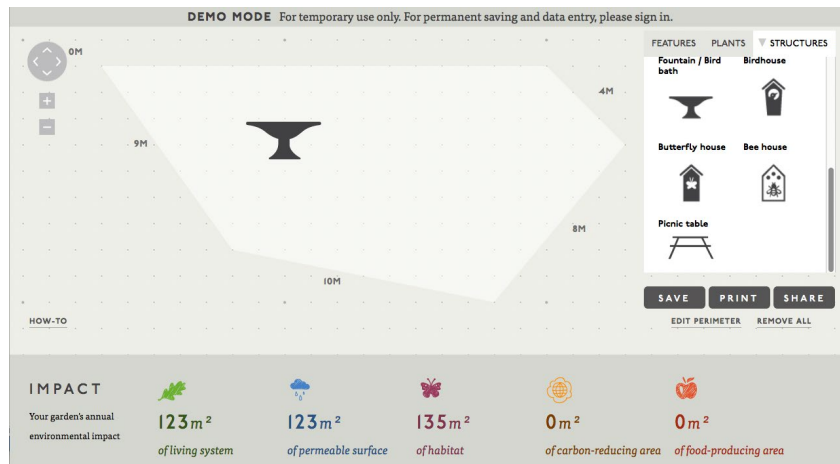
To demonstrate for students, left-click and drag one of the Pavement/Concrete icons from the Features panel on the right into the garden outline. Once placed, the icon is surrounded by small green squares. Left-click and drag any of the corner squares to make the icon larger, so that it covers more of the total area of the garden. As the icon expands, note how the measures for permeable surface and habitat both decrease. Have students explain why these measures are changing. (Answer: Pavement covers the permeable soil with an impermeable hard surface and deprives both surface and sub-soil organisms of habitat.)



Continue your demonstration by clicking the red minus sign to delete the Pavement/Concrete icon, then click the Plants tab and scroll down to the Vegetable Bed icons. Left-click and drag one of these into the garden and use a corner green square to make it larger. Note that the measures for carbon reduction and food production both increase while the measures for permeable surface and habitat remain unchanged. Have students explain why. (Answer: Vegetables are food that can reduce CO₂ in the atmosphere by eliminating CO₂-producing steps from the food production and delivery process, but vegetables do not change the total area of permeable surface or habitat within the garden perimeter.)



Now click the red minus sign to delete the Vegetable Bed icon, scroll down farther in the Plants panel, and drag the Tree icon into the garden. Use a corner green square to make the tree larger and note the effect on your measures of environmental impact. Habitat, carbon reduction, and food production all increase. Have students explain why these measures increase while permeable surface remains the same. (Answer: A tree's leaves, branches, and trunk increase the total area of habitat within the perimeter of the garden but do not increase the amount of permeable surface. Trees also increase carbon reduction and food production because trees sequester carbon and can produce food, such as apples or peaches.)



Last, click the red minus sign to delete the Tree icon and click the Structures tab, then scroll down to the Fountain/Bird Bath, Birdhouse, Butterfly House, and Bee House icons. Drag one of these into the garden design and use a corner green box to make it larger. Note that only the measure for habitat increases. Have students explain why. (Answer: All these structures add habitat space beyond that provided by the vegetation within the garden's perimeter.)

To complete your demonstration, show students how they can make icons taller or wider by dragging the green squares centered on the icon's sides, and how they can rotate an icon clockwise or counterclockwise by dragging the green square above the icon. Also show students how they can Print their virtual garden design or Share it by downloading an image that can be attached to an email or text or uploaded to a website.

Explore: Garden Design Lab

Suggested Flow of Activities:

1. Have students work individually or in pairs (depending on in-class computer availability) to experiment with the garden design tool. To provide a control factor in these experiments, have all students design gardens with the same total area — for example, 100 m². This will allow students to compare the environmental impact of their different designs based on the measures of permeable area, habitat area, carbon reduction area, and food production area.
2. As a warm-up, have students use the garden design tool to answer these questions:
 - a. What garden design will maximize all measures of environmental impact?
Answer: Two large trees covering the entire garden will raise the measures of carbon reduction area and food production area to 100% of the garden's total area and raise the habitat area measure to 200% of the garden's total area. These same measures can also be achieved by covering the entire garden with vegetable beds and installing a birdbath/fountain, birdhouse, butterfly house, or bee house that also covers the entire area.
 - b. What garden design will minimize all measures of environmental impact?
Answer: Covering the entire garden with pavement/concrete will reduce all measures except living systems to zero.
 - c. Other than trees, what combination of plants will maximize the garden's environmental impact?
Answer: Covering the entire garden with vegetable beds will raise all impact measures to 100% of the garden area. No other plants (except trees) alter any of the measures of environmental impact.
 - d. What combination of structures will increase the garden's environmental impact?
Answer: Installing a birdbath/fountain, birdhouse, butterfly house, or bee house that covers the entire garden will increase the habitat area measure to 200% of the garden's total area. No other structures alter any of the measures of environmental impact.
3. Now have students create realistic garden designs that combine Features, Plants, and Structures that appeal to their sense of what this cultivated part of nature could be. Encourage students to balance the environmental impact of their choices with what could be called the "human impact" — that is, what will make the garden interesting to people? what will draw people into this natural space? what will help the garden function as a community center, as shown toward the end of the [Nature Works — Global Gardens](#) video (at 2:50-3:10).
4. When they have completed their virtual garden designs, have students print them out using the Print button, or, if you are signed up and logged in, use the Share button to download an image that you can display on a computer screen or digital whiteboard. Plan time for students to present their designs, explaining the ecological, practical, and personal reasons for their choices. Encourage all students to ask questions about each design and to suggest/explore options for enhancing its environmental impact.

Explain: Garden Design in Practice

Suggested Flow of Activities:

To conclude this activity, they will be using the virtual garden design tool to develop plans for increasing the environmental impact of a natural area on or nearby your school campus. You can use the design tool to design and build an actual garden at your school. Use the *Gardening How-to Videos* series to help plan, prepare and execute a successful school garden.

To prepare for this part of the activity, choose an area that makes sense to build a garden on your campus, that your students can visit, and that may include some of the Features, Plants, and Structures found in the garden design tool. For example, you might choose a natural area that already has trees, lawn grass, a picnic table, and paved walkways, or an area along a stream with meadow grass, benches, and flowers in containers. Try to find a natural area that includes some items that students will have to incorporate into their design — a tree or stream — and others that they can redesign.

1. Distribute copies of the Living Systems Field Report reproducible (at the end of this guide), which students will use to measure and sketch the natural area you have selected. Alternatively, students who have access to a tablet or smartphone can use the online design tool in the field to measure and sketch the site. As a class, visit the area and have students work in teams to measure and record its total area (so that they can easily transfer these measurements to the design tool). Then have students work independently to sketch the Features, Plants, and Structures already on the site, using the design tool icons (which are shown on the Field Report sheet).
2. When they have completed their Field Reports, have students work individually or in pairs (depending on in-class computer availability) to transfer their field notes to the garden design tool if they have not done so already. (Students should access the design tool with the “Try It Now” button to begin with a fresh design workspace.) Ask students to Print an image of their map of the existing natural area for before/after comparison.
3. Allow time for students to redesign the natural area you have selected into a cultivated ecosystem. They should work to promote those ecological functions reflected in the design tool’s environmental impact measures, creating a living system that is a combination mini-watershed, mini-farm, mini-habitat for diverse types of organisms, and “mini-decarbonizer” that works to reduce CO₂ in the atmosphere. At the same time, they should aim to create an environment that will function as a community center — accessible to those with special needs, designed to attract and engage visitors, with features and structures that make this cultivated ecosystem easy to maintain.
4. Have students present their ideas for designing your garden to the whole class, showing their before and after garden maps and explaining the rationale for their design decisions. Then have the class vote on the best design proposal or work collaboratively to combine aspects of several different designs into a consensus vision for making this an area where nature works as productively as possible.

Evaluate

Use these questions and scoring key to evaluate what your students have learned.

1. Describe the environmental impact of impermeable surfaces like walkways in a garden design.
2. Describe the environmental impact of trees in a garden design.
3. Give two examples of structures that can increase the area available for habitat in a garden design.
4. Present an argument for shaping a natural area into a cultivated ecosystem through garden design.
5. Give an example of how garden design can strengthen the connections between nature and the human community.

Scoring Key for Evaluation

1. Impermeable surfaces reduce a garden's capacity to filter rainwater.
2. Trees increase the area available for habitat in a garden and can increase food production as well.
3. Answers will vary; some examples are a birdbath, fountain, birdhouse, bee house, and butterfly house.
4. Answers will vary; students should provide evidence or examples to demonstrate that garden design can increase the ecological productivity of a natural area by shaping it into a cultivated ecosystem.
5. Answers will vary; some examples are that a garden brings people together within a natural setting; engages them in working with nature to increase ecological productivity; and educates them about the ecological processes that preserve the health of our ecosystem.

Extend

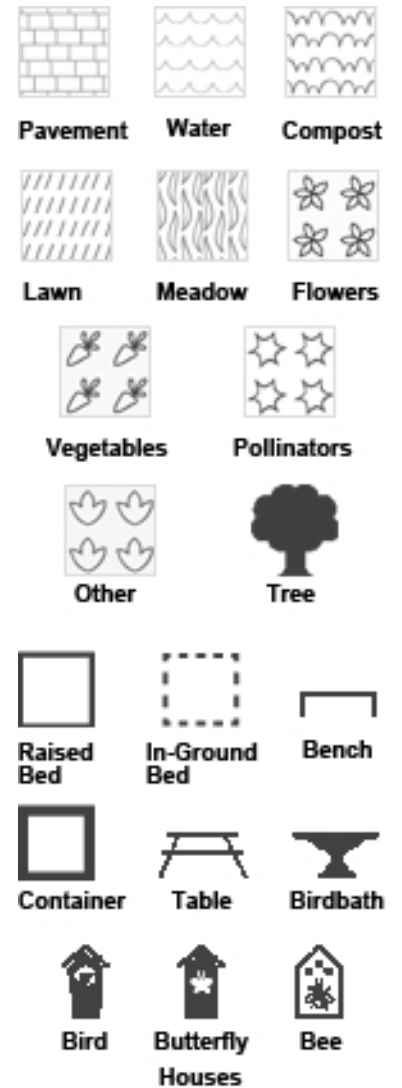
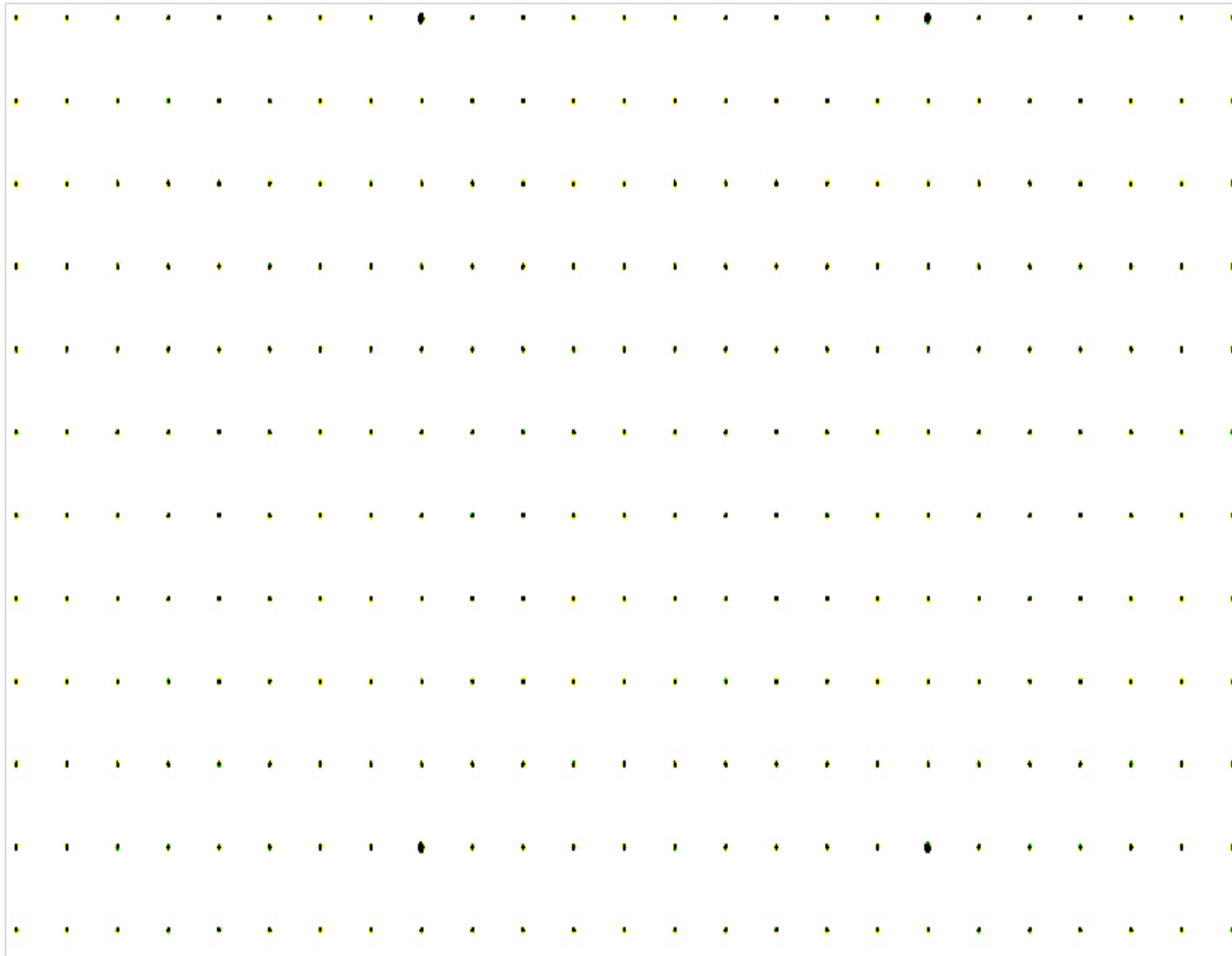
1. Turn your students' garden design inspirations into reality by participating in the *Nature Works Everywhere Gardens* program. Visit NatureWorksEverywhere.org and click Gardens to see how schools participating in this program have already made nature more productive at sites across the country. Then scroll down further and see the "Get Involved" section for a link to sign up.
2. When your school is registered, and your garden is planted, your students will be able to measure its growing environmental impact by collecting and reporting data on the garden's key ecological functions. As part of this program, students:

- Monitor rainfall to calculate how much rainwater your garden has filtered.
 - Conduct a species census to estimate how many different types of organisms are living in your garden habitat.
 - Weigh and count the fruits and vegetables they harvest to gauge the garden's productivity as a mini-farm.
 - Calculate how much CO₂ the garden has kept out of the atmosphere by serving as a local food source.
 - Stage a community outreach event at the garden and track the number of family members, friends, and neighbors who gain a new perspective on nature by sharing the garden's benefits.
3. The *Nature Works Everywhere* website provides videos and standards-based activity guides to help you integrate your school garden into your science curriculum. Activity guides tie-in with the program's data collection tools, with lessons that deepen students' understanding of all facets of the garden's ecology through hands-on investigations and projects.
 4. To get started, view the videos in the *Nature Works Everywhere* Gardening How-to video series, with links at the beginning of this guide.

Living System Field Report

Name: _____

Use this sheet to map a natural area that you will redesign to create a garden ecosystem.



Scale: one square = _____ m²