



# Biology STEM Unit 1 Project

## Rooftop Garden

### Student Project Materials

**NGSS Standards:** HS-LS2-7, HS-ESS2-4, HS-ESS3-2, HS-ESS3-4, HS-ETS1-1, HS-ETS1-2, HS-ETS1-3

#### Background:

Human activity is constantly impacting Earth and Earth's systems. As we clear land to plant agricultural crops, build new buildings, or use nonrenewable energy sources, we impact water and air quality, decrease biodiversity, increase the concentration of greenhouse gases in the atmosphere, and increase the urban heat island effect. One way to help reduce the impact of human activity on Earth's systems is to build rooftop gardens, or *green roofs*.

Rooftop gardens have many positive environmental impacts. One main benefit is the reduction of storm water runoff. Rapid runoff from roof surfaces can create or worsen flooding and increase rates of erosion. When a rooftop garden is present instead of a conventional roof, it can absorb storm water and release it more slowly over time. Rooftop gardens can also provide a layer of insulation, which helps keep buildings cooler in the summer. Rooftop gardens can also reduce air pollution and reduce building material waste as green roof membranes do not need to be replaced as frequently as conventional roof materials.

When native plant species are used, rooftop gardens can increase biodiversity and provide a habitat for native wildlife. Gardens can be a refuge for certain populations of organisms that may be struggling to survive. When planned to work in conjunction with other gardens and green spaces, certain species can use rooftop gardens as stepping stones as they migrate to existing natural areas. In this project, you will design a rooftop garden to support native species of plants and animals.



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#### Key Question:

**How can a rooftop garden help reduce the impact of human activities on Earth's systems?**

#### **ENGINEERING DESIGN PROCESS**

The Engineering Design Process is the idea of an orderly, systematic approach to a desired end to a problem or need. Keep in mind that design projects may enter the design process at any step. It is a cyclical process, differing from the scientific method, a linear process. Engineers may have to repeat some steps or may skip steps at times.

#### **ENGINEERING DESIGN PROCESS: DOCUMENTATION**

In engineering design, documentation is the formal method of recording and communicating the steps of the process. This begins with the creation of initial sketches based on the information in the design brief, and continues through the creation and testing of prototypes, and finally concludes with the completion of a set of working drawings that describes the design solution. Complete documentation should be an integral part of each step of the design process, not just at the end.



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#### Identify and Define the Need or Problem

Outline Concepts | Ask Questions | Summarize Challenges

#### Outline Concepts:

The need or problem should be clearly defined, so that the parts of the system in question are evident. Research the benefits of rooftop gardens, including how they can increase biodiversity, reduce greenhouse gases, and improve water and air quality. Research rooftop garden design, including possible types of containers, growth media, storage units, and other materials needed. Research the plant hardiness zone you live. Research native plants that would grow well on a rooftop garden.

#### Ask Questions:

Research and outline important concepts related to this topic using the following questions as a starting point:

- In which plant hardiness zone do you live? What other abiotic and biotic factors, such as the amount of light, soil type, nutrients, insect pests, weeds, and disease, will you need to consider as you design your rooftop garden?
- Which species of native plants would grow well in a rooftop garden in your area?
- How will your rooftop garden reduce the impact of human activity on the environment? Consider how your rooftop garden can reduce runoff, improve water quality and air quality, conserve energy, reduce greenhouse gases, increase biodiversity and habitat for wildlife, and decrease the urban heat island effect.
- Which species of wildlife will your rooftop garden support?
- How will nutrients, such as carbon, nitrogen, and phosphorus, cycle through your rooftop garden?
- What are some potential food chains and food webs that involve your rooftop garden?
- Which building(s) in your area would support a rooftop garden?
- What types of containers, growth media, storage units, and other materials will you need to build a prototype of your rooftop garden?



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#### Summarize Challenges:

Criteria are the desirable characteristics of a solution. Criteria may be quantitative or qualitative. Identify the criteria for your rooftop garden. Constraints are limitations or boundaries that contribute to the challenges of the engineering design process. It is critical to the success of any project to define the criteria and constraints early in the process. It is also important to be as detailed as possible. Consider the following statements and questions as you identify your criteria and constraints:

- Your rooftop garden should consist of all native species of plants.
- Do you need any permits to build a rooftop garden in your area?
- How will you prioritize safety for accessing the rooftop?
- What is the maximum weight the roof can hold?
- Is there proper drainage from the rooftop?
- Is the roof shielded from the wind?
- How much will the garden cost to build and maintain?
- What might you need to do to prepare the garden for winter?

Summarize the main challenges associated with developing a rooftop garden on the building that you identified.



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#### Research, Brainstorm, and Develop

Design Considerations | Preliminary Development | Choose Solutions

#### Design Considerations:

Research successful and unsuccessful rooftop gardens that support biodiversity within an ecosystem, referencing relevant and scholarly resources in your design. Engineers use this research to ensure that they do not repeat past design mistakes. Research any outstanding questions determined by your group. In developing your ideas, consider the following factors:

- Sun Exposure: If the roof of the building gets substantial sun or shade, adjust your design accordingly.
- Wind Exposure: If the roof is not naturally shielded from the wind, consider adding windbreaks.
- Water Availability: Plan a site for a water supply for rooftop plants in case of extended drought.
- Plant Selection: Select the most appropriate native plants for your garden based on your research about the area.
- Container Types: Select the most appropriate container types for your plants. Consider root growing depth, drainage, and other important factors you have identified.
- Planting Medium: Select the best growth medium for your plants, potting soil, or other medium if appropriate.

#### Preliminary Development:

Brainstorming is a process by which team members attempt to quickly generate as many ideas as possible. In structured brainstorming, each person is given a turn to provide one idea. The cycle continues until all team members have provided all their ideas. Brainstorm all possible ideas and designs for your rooftop garden. If the brainstorming session does not give adequate results, conduct more research to help focus the group. Record your ideas in your engineer's notebook including notes, sketches, and any procedures.

#### Choose Solution:

An initial analysis of ideas produced in brainstorming should be completed to determine which solutions could be discarded. Choose the best of your alternate possible solutions. How will your chosen design increase biodiversity and positively impact the local environment? What evidence can you provide to support the claim that your design is good for the area?



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#### Execute, Evaluate, and Share

Design Proposal | Evaluate and Share

#### Design Proposal:

Design a plan for the layout for your rooftop garden, including an estimated cost for implementing the project. Identify and label the following areas in your plan:

- Location, size, and shape of the rooftop
- Plan for safely accessing the rooftop
- Containers
- Growth medium
- Plant species and the configuration in which they will be planted
- Plan for water and nutrient delivery, if needed
- Plan for drainage, if needed
- Plan for pest and/or disease control
- Storage area
- Safety barriers

Have your teacher approve your plan. Choose and/or obtain the materials you need to make a prototype of your solution. Construct your prototype garden. Record the materials you use and the procedure you followed. Allow the plants to grow and record their progress. Record how you met or addressed your criteria and constraints in your notebook. Consider using a video camera to record your progress in building your prototype and as the plants grow.

#### **CAUTION: Follow all safety directions given by your teacher.**

- **Do not eat any of the materials or chemicals used in the project.**
- **Wear appropriate skin, eye, and clothing protection while working with the growth medium and the plants.**



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#### Evaluate and Share:

Within the evaluation, your group should first consider each constraint to ensure that all were met. Time should be spent documenting the successes and failures of your prototype. Once the constraints are reviewed, the prototype should be evaluated against each of the criteria.

Present your prototype to your class. During your presentation discuss the following:

- Project goals
- Main challenges
- Other designs you considered
- Why you choose one solution to test over others
- Your analysis of your prototype
- Improvements you would make to your prototype before implementing your solution on a rooftop
- How your rooftop garden reduces the impact of human activity on Earth's systems