NATURE LAB Educator Resources

BIOMIMICRY: WATER SECURITY INSPIRED BY NATURE

Subject Areas: Science: Engineering, Technology

Grade Levels: 9-12

Purpose and Overview:

Biomimicry is the design and production of materials, structures, and systems modeled on biological entities and processes. For millennia, humans have studied nature to design useful items in areas from transportation to entertainment. From using birdwings as inspiration for human flight machines, to modeling the nano-structures in the eyes of moths for anti-glare screens, we have looked to the wild to improve our lives.

In this lesson, students view a video that follows the journey of water from an area of rural Colombia to its capital city, Bogotá. They learn about a special ecosystem high above the city and some of the unique plants there that make it possible for Bogotá to have clean water year-round. Students will use these plants as inspiration for their own efforts at biomimicry.

Time: one to three 45-minute class periods

Essential Questions:

- How can natural structures be used to influence the design process?
- How can biomimicry enhance our ability to design efficient products?
- How can biomimicry be used to solve global challenges?

Themes:

An abundant supply of clean water is necessary for life. In areas where water is scarce, it may be useful to take a cue from nature on how to store water effectively so that it's available when needed.

Biomimicry can be used to solve the global challenge of water security. Using elements from nature to inspire the way we engineer solutions, we can more efficiently protect our water and our way of life.

Introduction:

Water scarcity and quality are growing problems worldwide. While many of us in the US do not face these issues, some, such as those living in the southwest, have experienced serious water shortages. In other parts of the world, people must deal with the lack of quality water on a daily basis.

Water security—access to clean and sufficient water—is fundamental to human well-being and is a clear priority for not only international development, but for ecosystem protection as well. See

http://www.unwater.org/publications/water-security-infographic/ (UN Water) for information and a useful infographic about water security.

Creative water capture and storage is one solution for increasing available water in areas where there is atmospheric moisture—fog, mist, or dew. In the ***Source of Life*** video, students learn about the frailejones and moss of the páramo, two examples of nature that work to capture and store water. These examples provide the basis for students to explore how biomimicry can inspire and inform design and engineering process in the effort to solve global challenges like water security

Objectives:

Students will….

- define and identify examples of biomimicry in product design
- design and create a prototype of a water harvesting product inspired by a frailejón
- engage in an iterative design and build process
- evaluate criteria and process
- define and propose a solution to a problem (drought)

Materials:

For teachers:

- computer and projector
- Internet connection
- Video: ***Source of Life***
- **Biomimicry Examples** PowerPoint

Items to have on hand for clean-up:

- cloth or paper towels
- paper towels
- sponges

Examples of materials that can be used for student designs.

For each group of students:

- notebook
- spray bottle filled with set amount of water
- graduated cylinder (to measure collected water)
- copy of **Biomimicry Evaluation Guidelines** handout

List of possible items for water collection device (materials below are suggestions):

Water collection at the base:

- small glass or clear plastic containers
- funnel

Fasteners:

- wire or twist ties
- tape
- hot glue
- toothpicks
- clay
- florist tape/painters tape

Water collecting materials:

- cotton balls or synthetic pompoms
- yarn
- tongue depressors or popsicle sticks
- scissors
- tubing or straws

- soft foam or sponges
- pipe cleaners
- overhead sheets or other type of plastic sheet
- foam florist balls, blocks
- produce/citrus net bag or other type of plastic netting

Standards:

Next Generation Science Standards:

Disciplinary Core Ideas:

- ESS3.A Natural Resources
- ESS3.B Natural Hazards
- ESS3.C Human impacts on Earth Systems
- ETS1.A Defining and Delimiting Engineering Problems
- ETS1.B Developing Possible Solutions
- ETS1.C Optimizing the Design Solutions

Crosscutting Concepts:

- Cause and Effect
- Systems and System Models
- Structure and Function
- Interdependence of Science, Engineering, and Technology
- Influence of Science, Engineering, and Technology on Society and the Natural World

Science and Engineering Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Construction Explanations and Designing Solutions
- Engaging in Argument from Evidence

Performance Expectations - High School

Students who demonstrate understanding can:

- HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Suggested Flow:

Engage

1. Present students with images of products modeled on nature or natural systems, such as Velcro, sharkskin swimsuits, and bullet trains. Show page one of the **Biomimicry Examples PowerPoint** for sample images. Have students spend a few minutes thinking about what the inspiration in nature

might have been for each product. Have them write their thoughts in a notebook and later share with the class.

2. Show pages two-seven of the **Biomimicry Examples PowerPoint**, revealing the models for the products. Ask students if they are familiar with the term "biomimicry". Guide them to a shared definition of the term: "an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies" (from The Biomimicry Institute - https://biomimicry.org/).

Explain

1. Show the video, ***Source of Life***.

2. Ask students whether they saw any potential models for biomimicry in the video. The *frailejón, and the moss are good choices]*. Ask students to describe the features that make them good water collectors (e.g., for the frailejón: the fine hairs, storage capacity of the stem, etc.; for the moss: its sponge-like quality).

3. Mention to students that the areas they saw in the video were not suffering from a shortage of water. You may want to show them images of drought-ridden environments that you find online. Also note that even in areas where there is enough rain, clean water can be a major health issue. Remind them that water security is about both quality and quantity. Nature helps to promote water security because nature can help to both filter and clean water and retain it.

Explore

Explain to students that the challenge is to design a product, modeled on the plants in the video, to capture and store water within a set of design constraints. They will engage in the iterative process of designing, testing, reflecting, redesigning, and retesting that is a critical part of the engineering and design process.

Option One

Students work in small groups to design and build a prototype of their product using a limited set of materials. They then share their group designs with the class in a gallery walk.

1. Set up the available materials for students to view prior to beginning the group work. Give them a few minutes to review them and make notes.

2. During the challenge, students should maintain a design notebook, clearly recording the following:
   a. an initial materials list
   b. their initial design
   c. each modification they make as they proceed, as well as the rationale for the modifications
   d. a final materials list
   e. design specifications so that someone else could replicate their design

3. Share with students the following design challenge constraints:

   a. Students must show their initial design and materials list to the teacher before they can collect materials. This is to discourage waste.

b. Each group will collect an initial set of materials before their first trial. They can collect additional materials for subsequent trials as they continue to be available. Note that since resources are limited, students can barter with one another for supplies as needed.

c. Each group will have one spray bottle full of the same amount of water to start. Stress that they need to control how they spray their prototype on each trial, for example spraying from the top each time.

d. Students should conduct as many iterations as possible in the time allotted (depending on class scheduling), to refine their design and improve their product with each iteration. Reinforce that the point of this activity is to design, build, test, reflect, reconfigure, and then test again.

4. Have students present their final prototype to the class. You may want to also have them record their final design specifications and material list on poster board. Groups can present individually or you can have them engage in a gallery walk (see Evaluate #3).

Examples of simple designs using straws, pipe cleaners, cotton, and sponges.

<u>Option Two</u>

If you don't have the time or resources to go through the entire design process, an alternate activity is to have individual or small groups of students do further research into examples of biomimicry used in product design. Ask them to choose a favorite and create a class presentation explaining their choice and describing how it is an example of biomimicry, as well as what problem it tries to solve.

Extend

Have students design another product that solves a different environmental challenge. Students can choose their own challenge or decide as a class which challenge to try to solve (e.g., food security, sustainability, etc.). See the education resources from The Biomimicry Institute (https://biomimicry.org/education/) for ideas.

Evaluate

1. Have each group of students complete the **Biomimicry Evaluation Guidelines** handout as a guide to review their product.

2. Ask students to write an advertisement of the product, as if for a web site, including the following categories:
    a. effectiveness (amount of water retained)
    b. feasibility of applying their solution on a large scale
    c. use of natural resources (does it take up space? use natural materials vs. plastics?)
    d. durability
    e. value (time to manufacture and cost vs. effectiveness)

3. Have students peer review one another's prototypes as presented in a gallery walk, using the **Biomimicry Evaluation Guidelines** handout as a guide for their peer reviews.

4. Whole class reflection on the content and process:
    a. how well did the group collaborate?
    b. how could your group improve the product having now seen other group's work?
    c. why is water storage and the use if biomimicry relevant in today's world? (severe droughts, water shortages)
    d. what was learned from "failures"
    e. what are the barriers to using water retainment systems? (money, time, materials)
    f. why is biomimicry a useful design tool? (nature invented the wheel for us, so why not start there)
    g. what questions did the process raise?

5. After students have completed their own designs and the review process, show them examples of how mist nets have been used in real-life to work as water collectors. There are several videos online, here are a few of our favorites:

    - Harvesting Water from the Sky in Arid Peru (Makeshift) – this video tells story of one family in Peru that is using nets to capture moisture. https://www.youtube.com/watch?v=bqZw1MqlSvM

    - Fog Catcher for Water (Mashable) – this video depicts the CloudFisher System https://www.youtube.com/watch?v=683iTtIxwOs

Additional Resources and Further Reading

- AskNature Resource Collection (The Biomimicry Institute) https://asknature.org/?s=&page=0&hFR%5Bpost_type_label%5D%5B0%5D=Resources&hFR%5Btaxonomies_hierarchical.resource-type.lvl0%5D%5B0%5D=Instructional%20Material%20%3E%20Curriculum%20Units&is_v=1#.WjPb7nfMzGI

- AskNature resources specific to managing water (The Biomimicry Institute) https://asknature.org/collections/managing-water/#.WohDPHfMzGI

- AskNature resources specific to biological strategies (The Biomimicry Institute) https://asknature.org/?s=&p=0&hFR%5Bpost_type_label%5D%5B0%5D=Biological%20Strategies#.WohC73fMzGI

- Biomimetics: Design by Nature (National Geographic Magazine) http://ngm.nationalgeographic.com/print/2008/04/biomimetics/tom-mueller-text

- 14 Smart Inventions Inspired by Nature: Biomimicry (Bloomberg News) https://www.bloomberg.com/news/photo-essays/2015-02-23/14-smart-inventions-inspired-by-nature-biomimicry

- How Biomimicry Is Inspiring Human Innovation (Smithsonian Magazine) https://www.smithsonianmag.com/science-nature/how-biomimicry-is-inspiring-human-innovation-17924040/

- Harvesting Water from Fog (MIT Mechanical Engineering)
  https://www.youtube.com/watch?v=h8vlzZ25vtg

- Janine Benyus: Biomimicry in Action (TED Talk)
  https://www.youtube.com/watch?v=k_GFq12w5WU

- How Biomimicry Works (How Stuff Works)
  https://science.howstuffworks.com/life/evolution/biomimicry.htm

- Learning from Nature: A Course on Biomimicry (Sustainability Leaders Network)
  http://www.sustainabilityleadersnetwork.org/2013/03/biomimicry-curriculum/

- Engineering Inspired by Nature Curriculum (The Center for Learning with Nature) - teachers can register for free
  https://www.learningwithnature.org/engineering-curricula/preview/#page2

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Biomimicry Evaluation Guidelines

Use the categories below to organize your review of your and/or your peer's biomimicry product. Make sure to include details from the design in your review. Use additional paper as needed.

For self and peer review:

a. efficient use of materials

b. effectiveness—water retained

c. feasibility of applying their solution on a large scale

d. use of natural resources (does it take up space? use natural materials vs. plastics?)

e. durability

f. value (time to manufacture and cost vs. effectiveness)

For self review only:

g. what was learned from "failures"

h. group collaboration