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Biomimicry: linking form and function to evolutionary and ecological principles

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Engaging with biomimetic design encourages students to explore the principles of form and function in relation to evolutionary adaptation.

Introduction

With students spending so much time on computers, this lesson offers the opportunity to look at nature and get creative. Through thinking about design, students will apply many scientific skills, such as observing, inferring, measuring, experimenting, researching, analyzing data, and forming evidence-based hypotheses, as well as engineering skills, such as design and prototyping. Students will develop their creativity and collaborative skills in this lesson.

Evolution is central to courses in life sciences. When evolution is treated only as a single unit, many students fail to see the connection to evolution as a driving principle. This activity explores evolution and related concepts of natural selection, fitness, and competition through the lens of biomimicry. It also is an excellent topic to reinforce themes such as 'form and function', to describe the relationship between adaptations and ecological niches, with parallels to biomimicry through design.

Activity 1

This activity introduces students to the concept of biomimicry through an inductive approach, in which they construct a definition from examples. It is preferable not to have the class share their initial definitions, but instead let it be a personal development. This activity lasts 10–15 minutes.

Materials

- Activity 1 student handout
- Activity 1 teacher handout

Procedure

1. Give each student a copy of the student handout.
2. Look at the pairs of pictures. Each is an example of biomimicry.

Sample pair of biomimicry pictures Permission for non-commercial use

3. Looking at each pair of pictures, think about the following:
   a. What do they have in common?
   b. How do you think the two are related?
   c. What is similar about their forms, shapes, or physical characteristics?
   d. What is similar about their functions?
4. Use information from the teacher handout for Activity 1 to help students.
5. Instruct students to write one or two sentences to define biomimicry.

Activity 2

This activity encourages students to think about biomimicry solutions with action cards as prompts. Action cards include movement, waste removal, cleaning, filtering, adhesion (see example below), communication, carbon storage, and water flow. This activity requires 15–30 minutes.

Procedure

1. Assign each pair or small group of students one or two action cards which they will use for the following steps.
2. Read the card to understand the action and example provided.
3. Think of ways that nature solves the problem on the assigned action card(s).
4. With a partner or in a group, research another organism that performs this action.
5. Share with the class the following:
   a. Assigned action and a description
   b. Example or hint provided
   c. Name of organism researched
   d. Brief background of the organism, its habitat, and ecosystem.
   e. Describe the features of this organism that allow it to solve the action you have been assigned.

Sample pair of biomimicry pictures Image courtesy of Stephanie Toro/Permission for non-commercial use

Materials

- Activity 2 student resources; the slides can be printed as handouts (two slides to a page), printed and made into two-sided cards, or distributed digitally
- Computer or tablet with internet connection for research

   f. Explain how these features mean that the organism is adapted to the required function (connect form and function).

6. During the class discussion, the teacher should reinforce the ideas of form and function, adaptations that can improve fitness and success in competition, and the

importance of evolution to create the best designs in nature.

Activity 3

During this phase, students will apply their understandings of principle biological concepts of adaptation, evolution, form, and function to the concept of biomimicry through a design challenge assigned by the teacher. This activity requires 45 minutes.

Materials

- Activity 3 student resources

Design challenge options

- A building in an area of low rainfall, which will collect rainwater and store it for future use
- A building that houses an indoor city garden, which will yield enough food for 100 families, use less water, and does not require fertilizers
- A contraption that will assist clean up of an oil spill in the ocean, which will capture oil to prevent it spreading and utilize it afterwards
- A waterfront building that will withstand hurricane-force winds, waves, and shifting sands
- A new car model with improved speed and fuel mileage because it is more aerodynamic
- A product that prevents animal growth on the bottom of ships and is natural, non-toxic, and effective for use in the ocean
- A building in the tropics that does not require air conditioning to keep it cool
- A wind turbine blade that moves in smoother, tighter circles and requires minimum wind levels to operate
- A bridge with greater strength in the main body and supporting structures
- Something that will 'sequester' carbon
- A new hairdryer that take less time to dry hair, is smaller, easier to pack in a bag, and uses less energy
- A sunscreen that is natural, waterproof, and reflects the sun for hours
- A building/structure that can withstand flooding
- Nail polish that doesn't chip, is long-lasting, and forms a thin layer

Procedure

1. Assign each pair or group the design challenge.
2. Students complete the table on the student resource handout in their groups through research online. The table includes the following tasks for students to work through:

   a. **Identify the function:** What does an organism utilize or do well? For example, move, store water, catch food, or capture rainwater. You can use the Biomimicry Taxonomy to help.

   b. **'Biologize' the question**
      - What are nature's best ways of solving the function?
      - Write a question for your function.
      - Examples: how do organisms move; how would nature store water; how do organisms catch food; how does nature capture rainwater?

   c. **Find nature's best practices**
      - Use observation skills, research, field trips, technology like microscopes or magnifying glasses, etc.
      - Take notes on how the organism(s) observed accomplishes the goal of the function chosen and answer the question from b.

   d. **Generate product ideas**
      - Using what you have learned from investigations, what new product ideas can you think of?
      - Draw/design your ideas – use the materials provided or permitted by your instructor.
      - Explain how your product addresses the following criteria:

        A. Sustainability
        B. Performance
        C. Energy efficiency
        D. Production costs (cut material costs)
        E. Redefine and eliminate waste

Discussion

After the lesson, have a discussion with students based on the following three reflection questions:

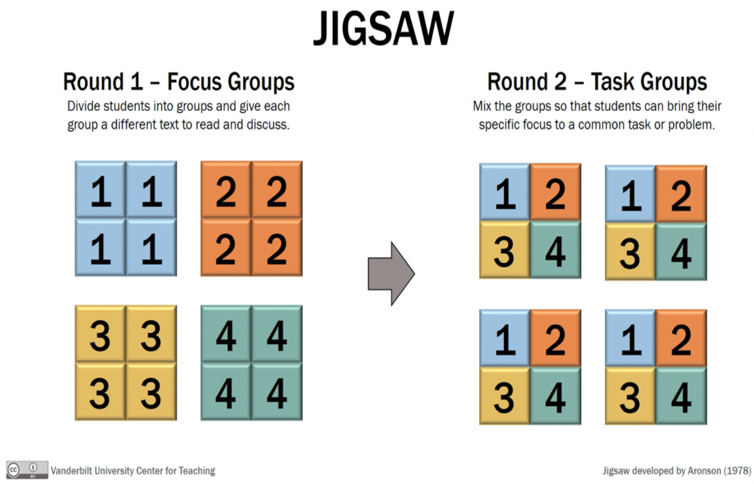
- How does form impact function (and the reverse) in nature?

- How has nature, through evolution, created adaptations that are most suited for their environment?
- Why should we look to nature for models in our own design processes to solve human problems?

Modifications and extensions

Depending on time constraints or the level of the students, this activity can be done with one specific design challenge for the whole class, different challenges for different groups, or no specific challenge is provided and the assignment is open-ended. When the entire class has the same challenge, you can structure the activity more and provide specific resources and examples to help students. However, allowing students to pick their own challenge adds a motivational factor by allowing choice.

There are also other modifications and extensions, such as allowing students to build physical models, time permitting. Additionally, using a jigsaw debrief method (see below for a summary) can increase student accountability and participation during presentations of designs. See the additional resources for more details.



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Resources

- Learn more about this topic from the Biomimicry Institute.
- Explore teaching resources from the Biomimicry Institute on the Ask Nature website.
- Watch a video that defines biomimicry with examples.
- Read about how shark skin inspired designers and engineers: Wegner C, Dumcke R, Tönnesmann N (2017) Design inspiration: the secrets of shark skin. *Science in School* **41**:19–23.
- Watch a video on useful technologies inspired by nature.
- Design and build a model of a flood-proof home with this Teach activity: Brown J (2015) Beat the flood. *Science in School* **32**:47-52.
- Watch a video on how the sticky feet of geckos have inspired new nanotechnology.
- How have animals inspired robot design? Find the answer in this video.
- Read an interesting article on the history of biomimicry.

Author biography

Dr Stephanie Toro has over 18 years of experience teaching science in the secondary and tertiary classroom. With a PhD in instruction and curriculum, she currently works in a consulting role with her non-profit, The Teacher's Toolbox, to customize professional development opportunities for STEM teachers/professors in secondary and tertiary schools and universities to transform instructional practices with sustained impacts. She also engages in passion projects that combine her love of marine science and marine science education.

Review

The presentation of the Biomimicry' topic in this article is useful to understand interconnections between pure science and applied science. The text contains different innovative ideas for High School classes work, observations and reflections about the relationship between form and function of different living and not leaving structures, also realizing scientific image education. The article proposes analytical sections for teachers and dynamic and interactive sections for students that allows the teachers to design didactic learning by doing activities for groups of High school students that have knowledge of basic elements of chemistry and biology, analyzing some historical aspects of technological discoveries and inventions. In the itinerary of this article, the old science is interconnected with new biology and chemistry science, important aspects to realize in an innovative way systematic learning methodology with contamination between different disciplines and to realize modern teaching activities working also about Energy, sustainability and ecological concepts for environmental education. Innovative and engaging STEM activities of this article could be used at different levels of complexity by science teachers also to project original didactic itineraries about water and to project cultural itineraries about cycles of matters with interesting interdisciplinary approaches.

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