The Nature of Robots

OVERVIEW

In this lesson, students learn that, contrary to many examples from movies and pop culture, most robots do not look like humans. They see how, rather than simply trying to make exact replicas of organisms, many modern roboticists observe strategies and structures that have evolved in nature and use them as a starting point for their own designs. Students explore several specific examples of bio-inspired robots and consider how studying the form and function of organisms has helped roboticists address human challenges. Then they apply the biomimicry design process to design their own bio-inspired robot that will solve a specific personal or societal challenge.

Co-authored by the Biomimicry Institute.

KEY OBJECTIVES FOR STUDENTS:
- Define a robot and describe ways in which robots can assist with human activities and endeavors.
- Describe several examples of robots that mimic structures or strategies observed in nature.
- Closely examine features of an organism and describe how those features are or could be integrated into a robot design.
- Outline a personal or societal problem that could be addressed by a robot whose design mimics a structure or strategy found in nature.

ESTIMATED TIME NEEDED (MINUTES):
- 60 minutes

GRADE LEVELS:
9, 10, 11, 12

PRIMARY SUBJECTS:
Environmental Education, Science

SECONDARY SUBJECTS:
Biology, Career Technical Education (CTE), History, Language Arts, Physics

TOPICS:
Biomimicry, biomimic, biomimetics, sustainability, design in nature, bio-inspired, nature-inspired, robot, robotics, roboticist

METHODS:
Brain-Based Learning, Design Thinking, Multi-Disciplinary, Multiple Intelligences, Real-World Application, Technology Integration

SKILLS:
Collaboration, Communication skills, Creative problem solving, Critical Thinking, Systems thinking

VALUES:
Curiosity, Mindfulness, Resilience
BACKGROUND INFORMATION FOR TEACHERS:
Robots serve many different functions in industrial, military, space, and household settings. Most robots are designed with specific features and programmed to autonomously and efficiently complete specialized tasks, often tasks that are too monotonous or dangerous for humans to safely and effectively perform. Because of this specialization, robots usually do not mimic the general form of humans or animals, though a robot might mimic the movement of a human arm or the running form of a cheetah in order to serve a particular function. In fact, robotic designs are increasingly inspired by nature, such as space robots with gecko-gripper technology that allows them to scale the exterior of the International Space Station, or the Bionic Handling Assistant®, a flexible gripper robot arm inspired by the trunk of an elephant. Unlike most robots, the Bionic Handling Assistant is compliant, responsive, and gentle, making it safe for human-technology interaction.

PREVIOUS SKILLS NEEDED:
Cooperative learning skills, listening skills

IN ADVANCE:
Make one copy of The Nature of Robots Design Activity Worksheet and The Nature of Robots Quiz for each student. Review the lesson and presentation in advance and determine whether you want to include any videos demonstrating robots in action, such as the Bionic Handling Assistant videos referenced on page 12 of the presentation. Test your presentation equipment and Internet connection to ensure you can show students the presentation and the optional video. If possible, bring examples of robots to class or ask students to bring examples from home.

MATERIALS NEEDED:
- Presentation equipment
- Colored pencils, sketch paper, rulers, etc. for sketching designs
- Thumbtacks or tape for displaying sketches

KEY VOCABULARY:
biomimicry
biomimic
bio-inspired
nature-inspired
robot
robotics
roboticist
ACTIVITY OUTLINE:

<table>
<thead>
<tr>
<th>Time</th>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 min.</td>
<td>Presentation</td>
<td>Show students The Nature of Robots Presentation, using the Teacher’s Notes to guide discussion.</td>
</tr>
<tr>
<td>5 min.</td>
<td>Individual Brainstorming</td>
<td>Give students time to independently consider personal and societal challenges and what we might learn from nature about those challenges.</td>
</tr>
<tr>
<td>20 min.</td>
<td>Design Activity</td>
<td>Students design a bio-inspired robot to address a specific challenge.</td>
</tr>
<tr>
<td>10 min.</td>
<td>Gallery Walk</td>
<td>Have students hang their sketches on a wall; then conduct a “gallery walk” so students can review and provide feedback on the designs.</td>
</tr>
<tr>
<td>5 min.</td>
<td>Wrap-Up</td>
<td>Stimulate a final, synthesizing discussion.</td>
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IMPLEMENTATION:

1. **Presentation**: Show students The Nature of Robots Presentation, using the accompanying Teacher’s Notes to guide discussion.

2. **Brainstorming**: The last slide of the presentation prompts students to take out a blank piece of paper and spend a few minutes thinking about challenges that they or society face. This activity is designed to be a no-judgment brainstorming session, where students simply record whatever comes to mind. You may wish to circulate to help any students who look stuck by asking questions about products that irritate them or processes they find challenging or annoying.

3. After students have finished this initial brainstorming, challenge them to begin isolating key challenges and thinking about how other organisms might address those or similar challenges.

4. **Design Activity**: Have students choose a partner or form a small group.

5. Give each pair or group a copy of The Nature of Robots Design Activity Worksheet, and direct students to choose one of their specific personal or societal challenges and work through the worksheet together to design a bio-inspired robot to address that challenge. Remind students that their robot need not resemble a particular animal; rather, it should be inspired by or borrow a specific feature or behavior from an organism that exists in nature.

6. **Gallery Walk**: Have students hang their sketches on a wall. Then conduct a “gallery walk” in which students review the designs and provide constructive feedback using self-adhesive notes.

7. **Wrap-Up**: Guide students to share what they got out of the design experience and use the Reflection Questions to lead a final, synthesizing discussion.

**ADDITIONAL TEACHING TIPS:**

This lesson makes great fodder for a capstone project. Students could start from scratch or build upon an idea in class as the focus of their capstone. See the Biomimicry Design Challenge Module for ideas and tools for managing a capstone project and for entering the Biomimicry Institute’s Biomimicry Global Design Challenge.
REFLECT

REFLECTION QUESTIONS:
Use the following questions to prompt critical thinking and guide students to reflect about the lesson:

- Why is it useful to consider that the technical meaning of the word robot is different from popular representations of robots in media and society? (Sample answer: If we broaden our thinking about what robots can do and how they should look, we are likely to find a far greater range of potential designs and uses for them.)
- Why are scientists and engineers increasingly looking for inspiration from nature when designing robots to solve industrial, military, medical, and research challenges? (Sample answer: Different organisms navigate and move through their environments in a variety of ways, and unlike most robots, their power source (metabolic energy) and motors (muscles) are all self-contained. They tend to be much more maneuverable than most robots, and often have complex sensory and motor systems that automatically control movement. So studying how these organisms move can help in the design of robots that are more functional in a variety of challenging situations.)
- Which of the designs in the gallery walk were the most compelling, and why? (Encourage students to share the specific functional, design, or bio-inspiration that made the design compelling.)

ASSESSMENT OPPORTUNITIES:
You can use a checklist to monitor student participation in group discussions and the design activity. You could also ask students to evaluate their self and group participation in the design activity. The Nature of Robots Quiz provides an opportunity to measure student comprehension. You may wish to share The Nature of Robots Quiz Sample Answers with students so they can grade their own work. The Reflection Questions on the Assess Tab also present an excellent opportunity to assess students’ comprehension of the material—whether you do so via a checklist in a group discussion, or use the questions as an oral or written quiz. In addition, the material on the Extend Tab is useful for further checking student comprehension as well as for reteaching and extending key ideas from the lesson.

STANDARDS ASSESSMENT:
This lesson, with all components included, is linked to the following standards:

Common Core State Standards (CCSS)
Grades 9–10:
Grades 11–12:
- RI.11–12.1, W.11–12.1a–e, W.11–12.2a–f, W.11–12.4–8, SL.11–12.1a–d, SL.11–12.2–6, L.11–12.1b–c, L.11–12.2a–c, L.11–12.3a, L.11–12.4a–d, L.11–12.5a–c, L.11–12.6, RST.11–12.1–4, WHST.11–12.1a–e, WHST.11–12.2a–f, WHST.11–12.4–10

Next Generation Science Standards (NGSS)
Middle School:
- Engineering Design: MS-ETS1–1, MS-ETS1–2
High School:
- Engineering Design: HS-ETS1–1, HS-ETS1–2

Cloud Education for Sustainability (EfS) Standards & Performance Indicators
Grades 3–12:
- A7, A8, C1, C4, C13–15, C18, F7e,f, G1, G5, H7, H9, H11, I37, I38

Texas Essential Knowledge & Skills (TEKS)
Physics: §112.39.b.1, 3–5; 112.39.c.3.A, B, D, E

Estándares Secretaría de Educación Pública (México):
Secundaria:
- Español: LIT.SE.1.1, 1.2, 1.4, 1.7, 1.8, PTE.SE.2.1–2.11, PTOECO.SE.3.1–3.6, FUL.SE.4.1, AL_CE.5.2–5.7, 5.10, 5.11
- Ciencias: CC.SE.1.12, ACT.SE.2.1–2.5, AC.SE.4.1–4.3, 4.6, 4.7

Estándares Secretaría de Educación Pública (México):
Bachillerato:
- BA.CG.1.1, 1.2, 1.3, 2.4, 3.5, 3.6, 4.7, 5.8, 6.9, 6.11
- BA.CDB. CO.4.1, 4.3, 4.4, 4.5, 4.6, 4.7, 4.9, 4.12
- BA.CDE.CE.1.1,1.9, 1.12, CO.2.1, 2.3, 2.7, CS.3.3
COMMUNITY CONNECTIONS:

- Encourage students to do research to see if there are any companies in your area that might be creating robots, especially bio-inspired robots. They could also investigate whether any relevant research is being done at a local university. Then have them organize a classroom visit to interview a representative about their work and how their observations of nature have inspired robot designs. Be sure students prepare for the visit in advance by developing a list of questions; then suggest they summarize what they learned in the form of an article for a school newspaper or newsletter. Alternatively, students could conduct phone or e-mail interviews and then summarize what they learn in an article to share with the class/school.

- Suggest students take a “nature walk.” This would involve taking a blank notebook and walking very slowly and silently down a forest path; sitting on a park bench; quietly observing a neighborhood yard, courtyard, or other area; or even visiting a zoo, botanical garden, conservatory, or other space where they sit and quietly observe living systems. Encourage students to simply pay attention to the environment until a plant or animal captures their attention; then they can focus on how that particular organism operates within its environment. Students could take notes or sketch features of an organism’s structure or detail a process they observe the organism undertaking. Encourage students to keep an open mind—something as simple as an ant crawling up the stem of a blade of grass or the way a vine has woven its way over other plants and structures might seem fascinating when observed carefully. Then students could consider how the features or habits of the organism they are observing can be interpreted into a robotic feature to solve some sort of personal or societal challenge. Encourage students to summarize their experience with words, photos, and sketches that describe the organism and how it could inspire a robot design that would solve a human challenge. Have students share their results with the class.

DIFFERENTIATION:
You may wish to predetermine groups in order to balance students’ strengths and weaknesses for the open-ended lab activity.

CROSS DISCIPLINARY CONNECTIONS:

Engineering
Suggest that students use upcycled materials to create a 3D model of their bio-inspired robot design. If possible, the 3D model should be functional and able to carry out a specific task on a scale that is either similar to or smaller than the intended use of the robot. This could be part of a long-term capstone project in which students use design thinking to ideate and create a working robot. See the Capstone module for more information and a plan that students could follow.

Language Arts
- Have students write a grant proposal to solicit funding to develop and build their bio-inspired robot. They can do online research to identify actual grant opportunities and then either fill out a generic form such as this Grant Proposal Template, use a generic format such as this one from Dartmouth College, or complete the specific form from the organization that would award the grant. Suggest students keep a Wiki or other record of their efforts toward planning for and building their robot.

- Suggest students read the short story “I, Robot” in the collection of short stories of the same name by science fiction writer Isaac Asimov. In that story, Asimov describes “Three Laws of Robotics:”
  - A robot may not injure a human being or, through inaction, allow a human being to come to harm.
  - A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
  - A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

- After students have read the story, have them discuss these laws of robotics and whether they are useful in the “real world” of robotics and bio-robotics today.

History
Have students research the history of the word robot. (The word robot— from the Czech word robata, or “forced labor”—was coined by Josef Capek for his brother, Karel Capek, an early-twentieth-century Czech playwright. The term first appeared in Karel’s play, Rossum’s Universal Robots, which opened in Prague in January 1921.) Suggest students conduct research on the origin of the word and how its meaning evolved throughout the twentieth century, as technology and cultural understandings of robots evolved. The following are great introductory resources on the history of robots:

- Introduction to Robotics, by Ken Bowles
- Robotics FAQ, by Kevin Dowling

Encourage students to find a creative way to share what they’ve learned with the class, such as an interactive slideshow, an animated short video, homemade miniatures of various robots over the years, a letter from a modern robot to an early robot, etc.

TECHNOLOGY:
• You can enhance The Nature of Robots Presentation by showing students videos of the Festo Bionic Handling Assistant. The Bionic Handling Assistant page on the company website includes several videos illustrating the motion of the robotic structure, which can help students better visualize how the structure operates like an elephant trunk.

• Encourage students to bring to class any examples of robots they have. Your school may also have a robotics class—if so, invite the robotics instructor or students from the class to share examples of robots they have built, especially any that are bio-inspired.