Biomimicry Design Challenge

Lesson 3: Exploring Nature's Solutions

Credit: Getty Images 153187546: Alvenmod: Bird Watcher Silhouette

SUMMARY

This three-part lesson begins with an outdoor experience in which students practice observing nature with a curious mind and begin speculating about the functions behind what they observe. In the second session, students view a presentation that introduces a method for translating design questions into terminology that can be used to search biology for applicable strategies. Then they participate in a game-show-style activity to reinforce their understanding. The session concludes with a homework assignment in which students work in their teams to apply what they have learned to translate their design question from the previous lesson into a "How does nature…" research question. In the third session, students learn about credible sources and methods for finding biological strategy information. Then they work in their teams to develop a research plan to investigate their "How does nature…" questions and begin finding biological models.

STANDARDS

Common Core State Standards (CCSS):
Grades 9–10: RI.9–10.1, W.9–10.1a–e, W.9–10.2a–f, W.9–10.4–8, SL.9–10.1a–d, SL.9–10.2–6, L.9–10.1b–d, L.9–10.2a–c, L.9–10.3a, L.9–10.4a–d, L.9–10.5a–c, L.9–10.6, RST.9–10.1, RST.9–10.3, RST.9-10.9, RH.9-10.1, RH.9-10.4, RH.9-10.5, WHST.9–10.1a–e, WHST.9–10.2a–f, WHST.9–10.4–10
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, RST.11-12.3, RST.11-12.9, RH.11-12.1, RH.11-12.4, RH.11-12.5, WHST.11–12.1a–e, WHST.11–12.2a–f, WHST.11–12.4–10

Next Generation Science Standards (NGSS):
High School Engineering, Technology, and Applications of Science: HS-ETS1-1, HS-ETS1-2, HS-ETS1-3

Cloud Education for Sustainability (EfS) Standards & Performance Indicators:
Grades 3–12: A5, C1, C3, C4, C6–12, C37, D2, G1, G4–7, H5, H6

Texas Essential Knowledge & Skills (TEKS):
Biology: §112.34.c.3.A,D, §112.34.c.8.A, §112.34.c.10.C
Environmental Systems: §112.37.c.3.A, D, §112.37.c.5.C

OBJECTIVES

Students will be able to …

- ✓ Explain how looking to nature for ideas is what makes biomimicry unique.
- ✓ Describe how to translate design problems into biology research questions and why that process is helpful.
- ✓ Describe how function and strategy link design and biology.
- ✓ Demonstrate how to identify biologically relevant functions and contexts within a design challege.
- ✓ Explore several methods for researching biological strategy information.
- ✓ Identify the function(s) their design needs to perform.
- ✓ Find relevant biological strategies on AskNature and/or other scientific resources.

ESTIMATED TIME NEEDED

Three 55-minute sessions plus group work outside of class

KEY VOCABULARY

Biomimicry, design, sustainability, function, strategy, biological model, characteristic, mechanism, process, taxonomy

TOPIC TAGS

Biomimicry, design, sustainability, function, strategy, biological model, characteristic, mechanism, process, taxonomy, design in nature, challenge, project

PREVIOUS SKILLS NEEDED

Ideally, completion of Biomimicry Design Challenge Lessons 1–2; listening skills, teamwork and collaboration skills, basic sketching skills

ATTACHMENTS

SESSION 1: OBSERVING NATURE

- Function Junction Search Cards

SESSION 2: BIOLOGIZE THE DESIGN QUESTION

- Biologize the Design Question Presentation
- Biologize the Design Question Teacher's Notes
- Biologize the Design Question Student Notes
- Biologize the Design Question Student Notes Sample Answers
- Ask Nature Game Cards
- Biologize the Design Question Worksheet
- Biologize the Design Question Worksheet Sample Answers

SESSION 3: LOOKING FOR NATURAL MODELS

- Explore: Looking for Natural Models Presentation
- AskNature Biomimicry Taxonomy handout (optional)
- Natural Strategies Reseach Documentation Worksheet

MATERIALS

SESSION 1: OBSERVING NATURE

- ❑ Notebook or sketchbook
- ❑ Colored pencils (optional)

SESSION 2: BIOLOGIZE THE DESIGN QUESTION

- ❑ Presentation equipment
- ❑ Bell, buzzer, or other noisemakers (optional)

SESSION 3: LOOKING FOR NATURAL MODELS

- ❑ Presentation equipment

BACKGROUND INFORMATION

The power of the biomimicry design process lies in effectively identifying analogies between what we want to do with our designs and the things that nature already does, which we can learn from. This activity is captured in the Explore step of the design process used in this module. In this lesson, students explore nature both physically—through outdoor observation activities that spark curiosity and creativity—and intellectually, by researching natural models and strategies that can inform their design projects.

IN ADVANCE

SESSION 1: OBSERVING NATURE

Make arrangements to conduct class outdoors in a natural area or garden, including securing permission from staff and parents as necessary. A large undisturbed area with native plants and animals is ideal.

If a visit to an appropriate natural area is not possible, you could have students do one or more of the nature-observation exercises on their own as a homework assignment. Ask students to keep a journal about their experience; then discuss students' observations in the next class period, using the guiding questions to facilitate reflection. Alternatively, if you can extend the amount of time students spend outdoors or wish to give students additional on-their-own work, see the Cross-Disciplinary Connection: Art on page 16 for numerous additional outdoor activities to enhance students' ability to observe nature.

Print the Function Junction Search Cards and laminate if possible. You may wish to put the cards in a hat or bowl to facilitate each team's picking one.

Credit: Getty Images 472126727: baona: book

IN ADVANCE, continued

SESSION 2: BIOLOGIZE THE DESIGN QUESTION

Review the Biologize the Design Question Presentation and corresponding Teacher's Notes. Set up and test the equipment needed to share the presentation.

Print and cut out the Ask Nature Game Cards; laminate them if possible for durability. Review the Implementation instructions for the Ask Nature Game and determine how you will arrange the class for the game show. If possible, put three desks at the front of the class with a bell or buzzer at each one. Consider having some fun with this activity by decorating the classroom and/or contestants' desks to look like a game show set. You may wish to put every student's name on a piece of paper and into a hat or bowl you draw from (with TV game-show fanfare) to select contestants. Alternatively, you could have a pad of paper at each desk and, using a timer, give each contestant the same amount of time to come up with a "How does nature…" question. Each contestant could write down his or her question and then have the studio audience determine the best "How does nature…" question.

SESSION 3: LOOKING FOR NATURAL MODELS

Remind students to bring their Biologize the Design Question worksheets with them to class. Review the Explore: Looking for Natural Models Presentation and corresponding Teacher's Notes. If students do not have access to the AskNature database for some reason, you may wish to work with a librarian to identify alternatives. The librarian can also help you come up with a list of local resources to help focus students.

Review the Biomimicry Taxonomy handout. The Biomimicry Taxonomy is a special classification system that is used by AskNature to organize biological strategies by function. The Taxonomy is organized into a hierarchy of functions, from simple to complex. The simplest, broadest functions are at the "group" level, followed by "subgroup," and then a specific function. Many teachers find the Taxonomy handout useful in helping students to frame questions around function and use AskNature effectively. However, if you think it might confuse students, you can skip it.

Set up and test the equipment needed to share the presentation and make sure students have access to the Internet and/or other research materials. Print several copies of the Natural Strategies Reseach Documentation Worksheet for each team. Instead of having students complete their research as homework, you could allow additional class time for teams to work together and/or visit the school library as a class.

Safety Alert

Encourage students to dress appropriately for outdoor activities and advise them of any hazards (e.g., poison ivy, stinging insects, etc.) in your area.

ACTIVITY BREAKDOWN, SESSION 1: OBSERVING NATURE

Time	Exercise	Description
5 min.	Introduction	Recap learning to date and introduce the Explore step and the focus of the session.
25 min.	Outdoor Observation	Students spend time outside observing nature on their own and then reflecting as a group on what they noticed happening.
20 min.	Function Junction Activity	Students form small teams to search for examples of specific functions in nature.
5 min.	Wrap-Up	Students return to the classroom.

ACTIVITY BREAKDOWN, SESSION 2: BIOLOGIZE THE DESIGN QUESTION

Time	Exercise	Description
5 min.	Introduction	Have students recall what they learned in the last session and introduce the focus for the day.
20 min.	Presentation	Show students the Biologize the Design Question Presentation while students participate and take notes on the corresponding Student Notes worksheet.
25 min.	Ask Nature Game Show	Give students an opportunity to practice what they learned by hosting a game show related to asking "How does nature…" questions.
5 min.	Wrap-Up	Facilitate a final synthesizing discussion and share with students their homework assignment.
Homework	Worksheet	Students work in their teams to complete the Biologize the Design Question Worksheet by the next class period.

Credit: Getty Images 599481142: H_Yasui: Scops-owl

ACTIVITY BREAKDOWN, SESSION 3: LOOKING FOR NATURAL MODELS

Time	Exercise	Description
5 min.	Introduction	Have students recall what they learned in the last session and introduce the focus for the day.
15 min.	Presentation	Show students the Explore: Looking for Natural Models Presentation.
30 min.	Team Research	Design teams meet to discuss research strategy.
5 min.	Wrap-Up	Teams share one element of their research progress with the class; review homework assignment.
Homework	Team Research	Teams share one element of their research progress with the class; review homework assignment.

Notes

IMPLEMENTATION, SESSION 1: OBSERVING NATURE

1. **Introduction:** Recap the previous lessons in which students received an overview of a design thinking process and dove into the Identify step to define their design problem. Tell students: Today we'll be talking about the next step, Explore.

2. Ask for a volunteer to share something he or she remembers about the Explore step. If necessary, suggest students refer to their A Biomimicry Design Thinking Process handout and notes. Remind students that in this step we explore how nature has solved similar challenges. Tell them that one of the best ways to learn what nature has to teach us is to spend time outdoors, carefully observing nature. While books and online resources contain a lot of great information, there's no substitute for experiencing nature with our own senses. Explain that in this lesson, students will complete some activities that are designed to focus their attention on seeing technological solutions in the natural world around them. Tell students that some famous examples of biomimetic design actually came about in just this way—when a curious person noticed something remarkable in nature and found a way to emulate it in a design.

3. **Outdoor Observation**: Instruct students to get a notebook and pen or pencil and leave phones and distracting digital devices behind. Take them outside to a natural area.

4. Tell students to split up and find a location in the natural area that interests them where they can sit quietly for 15 minutes. Students may be in visible range of each other, but they should not sit together or talk to each other or do anything other than observe the area around them, noting or making sketches in their notebooks about the plants and animals they see and any qualities about them that stand out.

5. After 15 minutes, direct students to join together as a group. Ask for volunteers to share something about their experience and observations. Facilitate a discussion using questions such as the following to guide reflection:

6. How did it feel sitting quietly and just looking at nature? Was it hard to do? Explain.

7. What did you notice that surprised you?

8. Give an example of a feature or behavior of an organism that you observed and what function (purpose) you think it serves for the organism. (Accuracy is not important here; the point is encouraging students to observe with a curious mind.)

9. Did you observe any patterns or common features among the different organisms in this area? What features of this habitat may have influenced those patterns or how common features may have evolved?

10. Did you identify any connections between what you saw and the design challenge you are working on?

11. **Function Junction**: Tell students that next they will be participating in an activity called Function Junction. Divide the class into teams of 2–3 students.

IMPLEMENTATION, SESSION 1: OBSERVING NATURE, continued

12. Explain that you are going to give each team a card with a word or phrase on it that represents something that both people and the rest of nature do (i.e., a function). A *function* is the purpose of something; in the context of biomimicry, function refers to the role played by an organism's adaptations or behaviors that enable it to survive. Function can also refer to something you need your design solution to do.

13. Either give each team one of the Function Junction Search Cards or have a member of each team draw a card from the stack or a hat.

14. Tell students that now they have 10 minutes to find an example in nature of the given function. After 10 minutes, they can get back together as a class to discuss what they found.

15. After 10 minutes, call students back together and ask a volunteer to share what their function card said and what they found. When a volunteer speaks up, ask that team to lead everyone to the example they found and to explain how the biological element they identified meets the listed function. The level of detail of the explanation or its accuracy is not important here; the point is for students to develop an ability to see and speculate about function in nature. Ask questions such as the following: How do you think this example meets your function? How would you go about finding out if your hypothesis is correct? *(Ask a biologist/naturalist, research the organism online, etc.)* Are there any other functions you can think of that your example might meet? Encourage all students to chime in with their observations.

16. Next, ask if any of the other teams found something nearby. Go to that next location and discuss what students observed. Continue until as many teams as possible within the time frame have had an opportunity to share.

17. **Wrap-Up:** Discuss the experiences of the day as students walk back to the classroom.

Credit: Getty Images 534197541 fotokostic: Bee on a yellow flower

IMPLEMENTATION, SESSION 2: BIOLOGIZE THE DESIGN QUESTION

1. **Introduction:** Have students recap highlights from the previous session, in which they used outdoor observation to begin looking for examples of functions in nature.

2. Explain that today we are going to focus on finding specific strategies in nature that meet functions related to a design challenge we are trying to solve. Doing so means that first we have to translate our design challenges into biologically relevant terms.

3. **Presentation**: Share the Biologize the Design Question Presentation with students, using the corresponding Teacher's Notes to guide discussion. To help students organize and summarize their learning, give each student a copy of the Biologize the Design Question Student Notes, and ask them to answer the questions as they view the presentation.

4. Give students a few minutes to work alone or with a partner to complete the Biologize the Design Question Student Notes.

5. As a class, review students' responses to the Student Notes, and answer any lingering questions students have.

6. **Ask Nature Game Show**: Tell students that we are now going to transform the room into a game show to help them practice creating "How does nature…" questions. Explain that you will be the game show host and you will need three contestants and a studio audience.

7. Ask for three volunteers to play the contestants, and direct them to take their seats at the front of the room.

8. Explain that you are going to read aloud a simple design problem. The contestants are to respond by identifying the essential function related to the design problem and phrase it as a "How does nature [function]." question. For example, the design problem might be: Light bulbs waste a lot of energy in the form of heat. The "How does nature…" question might be: "How does nature produce light?"

9. Tell contestants they should ring, buzz, or raise their hand (depending on how you've set up the game) as soon as they think they have a good "How does nature…" question.

10. Explain that you will read one of the design problems from the Ask Nature Game Cards aloud. The first contestant to ring, buzz, or raise his or her hand gets to try answering first.

11. The studio audience (students who are not contestants) will then get to determine if the contestant's "How does nature…" question is suitable for the given design problem (i.e., it identifies a function relevant to that problem). If the consensus is that the question is a good fit, that contestant can remain in the game.

12. If the consensus is that the question is not a good fit for the given design problem, another contestant can try to "steal" the show by offering his or her own question.

IMPLEMENTATION, SESSION 2: BIOLOGIZE THE DESIGN QUESTION, continued

13. Whoever has the best question gets to stay and play again. However, the other two contestants must leave the "stage" and join the studio audience.

14. Then you will call on two new contestants from the audience to replace those who have left. You may wish to have all students' names in a hat and randomly draw to replace contestants each round. (Or you could have only those students who wish to participate add their names to the hat.)

15. You could call on an assistant to write each function on the board, as well as the winning "How does nature…" question and the initials of the person who came up with it.

16. Play several rounds, so that as many students as possible get a chance to participate in the game show. You are likely to run out of time before all students have had a chance to participate. You may wish to choose (or have the class choose) a winner by determining who had the best question.

17. **Wrap-Up:** Wrap up the class by inviting students to share their thoughts about what they learned today. Facilitate a discussion with questions such as: What does it mean to "biologize" something? *(It means to translate it into biologic terms.)* How does framing a design problem as a "How does nature…" question help us biologize the problem? *(It gets us focused on function and thinking about how nature does things as opposed to how we might do things.)*

18. Hand out the Biologize the Design Question Worksheet. Instruct students to work together in their teams and use what they learned today to complete the worksheet and bring it with them to the next class session.

IMPLEMENTATION, SESSION 3: LOOKING FOR NATURAL MODELS

1. **Introduction:** Have students share their thoughts about the previous session, in which they learned how to "biologize" their design question and practiced creating "How does nature…" questions in the Ask Nature Game Show. Tell students they will be using the homework they completed later in this lesson.

2. Introduce the topic for today's class by telling students: Today we are going to talk about how to begin the research process to find answers to those "How does nature…" questions and to uncover specific natural models (biological strategies) that can inform your design solutions.

3. **Presentation**: Share the Explore: Looking for Natural Models Presentation with students, using the corresponding Teacher's Notes to guide discussion.

4. After the presentation, share with students some helpful community resources for researching their design questions, such as a science library or academic or professional experts who could be helpful.

5. If you think students will find it useful, give each team a copy of the Biomimicry Taxonomy or project it on a screen for students to reference.

IMPLEMENTATION, SESSION 3: LOOKING FOR NATURAL MODELS, continued

6. **Team Research:** Instruct students to gather together in their design teams and get out the Biologize the Design Question Worksheets they completed as homework.

7. Direct students to use the methods discussed in the presentation and their "How does nature…" research questions and function and context keywords from their worksheet to guide their research.

8. Pass out several copies of the Natural Strategies Research Documentation Worksheet to each team (or give students electronic copies to complete). Review the worksheet together and emphasize the importance of teams using the worksheet to track their sources. Encourage teams to find several strategies (five or more) for each function or biologized question they research. The more examples and variety they have, the greater opportunity for inspiration. Direct teams to split up the research tasks so the work can be shared fairly. Then give teams time to come up with a team research plan with specific tasks for each team member.

9. Individually check in with teams to monitor progress and answer questions as they work. Students can organize their research plans in many ways. Some may want to divvy up search terms and work independently at first. Others may want to explore together. You can determine the amount of flexibility you give students based on your needs and the class size. Guide students to select their search terms and keywords carefully and to try various synonyms and variations of the word representing the function of interest (e.g., compress, compression, and compaction; or filter, strain, and filtering). When looking for information about a specific organism, students may need all or part of the common or scientific names for that organism. Encourage teams to explore sources other than AskNature as well. Suggest they make a list of resources and people they could talk to. It can be especially beneficial for students to speak with a biologist or naturalist if they have questions or get stuck. The Biomimicry Institute offers a list of References for Biology Research on the Biomimicry Toolbox website (full reference below).

10. **Wrap-Up**: Before the class period ends, ask each team to share one element of their research plan with the rest of the class.

11. Direct students to continue on their own time working with their teams to execute their research plans. Ask them to find several strategies for each of their research questions and bring them to the next class.

Credit: Getty Images 533767955: Hill Street Studios: Students and teacher talking on park benches

ADDITIONAL TEACHING TIPS

SESSION 1: OBSERVING NATURE

Nature Observation: Sitting quietly and observing nature takes patience. After about 10 minutes, students may get restless and want to move on to something new. Acknowledge this struggle and encourage them to push past that urge and remain in place. Our brains are used to labeling and naming things based on past experience, so during the first several minutes it's easy to miss details. But with time, we begin to see new things like patterns, behaviors, and relationships. It's remarkable what this deeper state of observation can reveal. And it's this deeper level of observation that leads to new insights and questions that can really facilitate learning from nature. If you have time, try extending the observation period to 20 or 30 minutes.

Function Junction: Play several rounds of Function Junction in sequence, if time allows. After the first round or two, it can be fun to give all students the same function (e.g., "stabilize") without them knowing it. This tends to illustrate how nature can achieve the same function in many different ways.

SESSION 2: BIOLOGIZE THE DESIGN QUESTION

Ask Nature Game: Good responses refer to simple functions that can be found in nature and not in human-made things. The "How does nature…" question should make sense, so that it will be possible to search biology for answers to that question. There can be more than one correct response to each design problem because often there is more than one function involved. If a student provides an answer not listed on the game card, ask for a fuller explanation and accept the answer if it makes sense.

SESSION 3: LOOKING FOR NATURAL MODELS

AskNature Biomimicry Taxonomy: Students may devise functions that don't directly match those within the Taxonomy—either because their functions could be further simplified or because they just used different vocabulary to describe the same idea. This may initially cause frustration when using AskNature, but often with some critical thinking they will be able to find one or more matches in the Taxonomy. Encourage students to keep their original function statements, as these may be useful when using other research tools or talking with biologists.

REFLECTION QUESTIONS

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

SESSION 1: OBSERVING NATURE

- Describe how the Observing Nature activity is similar to or different from your "usual" experience of nature. *(Sample answer: I enjoy nature, but I am usually hiking or running or moving very quickly through natural areas. This experience was very different for me because I was so still and focused. Honestly, it was uncomfortable at first because I didn't know what I was doing. But then I started noticing things, and it became very fascinating. The time ended up passing very quickly.)*

- What do you think is the value in slowing down to observe nature? *(Sample answer: I think people start to feel more connected to nature when they really notice it. We begin to see that so much more is going on in nature than we realize and that it is really fascinating. It's going to be impossible to learn from nature unless we really slow down and observe natural organisms! We know that natural organisms have developed many strategies that we can learn from to solve human problems. We have to really look and study what we see in order to begin that process of discovery and learning.)*

- Is sitting quietly and observing nature easy for you to do? If so, explain. If not, what strategies could you try to make the experience easier for you? *(Sample answer: No, it is not. I think bringing a sketchpad and colored pencils will help me because it helps me sit still and focus on what I'm seeing. I also think it might help if I looked at it like a game—like I'm trying to find something unique and then capture as many details about it as possible because those will help me make progress in the "game" later.)*

SESSION 2: BIOLOGIZE THE DESIGN QUESTION

- Was the Ask Nature Game difficult or easy for you? Explain. *(Sample answer: The game was difficult for me at first because it was hard for me to get out of the human experience of things. It became easier as I practiced more, though, and now I find myself thinking about everything as a function that has a correlation in nature!)*

- Why is it helpful to translate a design problem into a biology research question? *(Sample answer: Because in order to find inspiring biological strategies that relate to my design problem, I need to be able to describe what my design needs to do using concepts and terms that are likely to appear in biology journals and on AskNature. It gets me thinking about correlations in nature and sets me up to learn from nature.)*

- How do function and strategy link design and biology? *(Sample answer: Everything we design has a function. So we can link design to biology by comparing human-made objects and systems to natural systems and organisms and looking for common functions and strategies.)*

- Are you confident that you can now identify biologically relevant functions and contexts within your design challege? Explain. *(Sample answer: It's not exactly clear to me what those connections will be, but I do think I understand how to make the connection, so I'm looking forward to giving it a try!)*

REFLECTION QUESTIONS, continued

SESSION 3: LOOKING FOR NATURAL MODELS

- Why might it be a good idea to use several methods to research biological strategies? *(Sample answer: With each resource we gain a different perspective, which can lead to our forming new insights and new ideas.)*

- What function(s) have you selected to research for your design challenge? *(Sample answer: We are looking at compression and compaction.)*

- Which part of your research plan do you think will yield the most helpful information? *(Sample answer: I know somebody who teaches biophysics. I think he will really be a helpful resource for us to contact about looking for biological examples of compression and compaction.)*

- Do you have any concerns about your research plan? Explain. *(Sample answer: No. I actually think we have a very detailed and doable plan. Each member of our team has a specific topic to research and I think we will all find good information. We've set up a wiki so we can share what we learn as we go.)*

- Why is it important to keep track of your research sources? *(Sample answer: Because we may want to go back for more information later or answer questions people have about our resource. Listing our resources also helps us get very clear about where the research is coming from, which can help us make sure it is a reliable, current, and nonbiased source.)*

DIFFERENTIATION

SESSION 2: BIOLOGIZE THE DESIGN QUESTION

During the Ask Nature Game Show, some students may feel intimidated about needing to come up with a properly worded question quickly. Alternatively, you could have a pad of paper at each desk and, using a timer, give each contestant the same amount of time to come up with a "How does nature…" question. Contestants could write down his or her question and then have the studio audience determine the best "How does nature…" question.

Credit: Getty Images 565976339: Jeremy Woodhouse: Close up of piles of dyed thread

ADDITIONAL INFORMATION

COMMUNITY CONNECTIONS

You could turn Session 1 into a full or half-day field trip by arranging for students visit a local nature center or preserve. If staff naturalists are available, have them give a presentation or tour focused on what is distinctive about the local ecosystem and its flora and fauna. See also the Cross-Disciplinary Connection: Art for more ideas about how to extend and enhance the outdoor observation activity. You can also extend the Function Junction activity by giving students more functions to look for and more time to explore.

To support the Session 3 homework assignment, arrange for or encourage students to visit a research library (e.g., at a college or university) where they can access a wider variety of scientific publications and consult with a research librarian.

CROSS-DISCIPLINARY CONNECTION: LANGUAGE ARTS

- You can extend this lesson with an activity or assignment emphasizing good research skills (evaluating the credibility of a source, citing sources correctly, etc.) and/or reading comprehension for science and technical literature. Have students summarize what they learn by writing 1–2 paragraphs on how and why it's important to evaluate the credibility of information they find.
- Share with students the following poem about observing nature:

Adirondack Morning

I took a word with me into the woods
that seemed the sum of all its being: *green*.
From fir to fern it stirred in all its moods—
blackwatch, chartreuse, and every shade between.
Emerald moss set off the sage of lichen,
and overhead the somber oak leaves swayed
translucent lime in sun, their outlines broken
by shadow shards of hovering leaves in jade.

But as I sat in stillness by the brook,
the rocks and tree trunks and leaf litter spread
a field of grayish brown throughout the nook,
where at a quiet lapping I turned my head
and saw, so close until it felt my stare,
an otter, the only other there.

—Suzanne Noguere

Then suggest students either write their own poem describing their experience of observing nature or write 1–2 paragraphs comparing this poet's experience of nature with their own.

Credit: Getty Images 545120500: Norbert Lochner: Fischotter

ADDITIONAL INFORMATION, continued

CROSS-DISCIPLINARY CONNECTION: ART

Art can be a valuable tool for tapping into our senses to experience nature in a powerful way. In addition, many of history's greatest scientists and naturalists were also artists (e.g., John James Audubon, Ernst Haeckel, Leonardo da Vinci) who used drawing and painting to document what they were learning about the natural world. The following are some activities you can share with students to enhance or extend the Observing Nature activities in Session 1 (and to enhance their artist's eye).

Blind Drawing

Background: Sketching helps us forget what we already know and forces us to reconcile what we think we see with what is actually there. A sketching habit enhances observation skills.
Instructions: Pick an organism in your environment. This could be a leaf, a mushroom, a tree—anything you see. Draw a quick sketch of the object, and don't worry if you "can't" draw. Now draw the organism or artifact again, but this time look only at the object, not at your paper, while you draw. Try to make your pen follow the path that your eyes take. Then compare the two drawings—did you discover anything new the second time?

Sound Map

Background: Our sense of sight tends to dominate our other senses. Closing our eyes and listening can actually help us make fresh new observations about the world around us.
Instructions: With your journal or paper in front of you, mark an "X" at the center of the page to represent yourself. Then close your eyes and listen. Make a map of the sounds you hear all around you, in all directions, and note whether they are human-caused. Create a symbol to represent each sound that you hear. Are the sounds related or responsive to each other?

Zooming In

Background: This activity allows us to explore what we can see when we observe at different scales.
Instructions: Use a length of string, a few sticks, a large embroidery hoop, or other materials to mark off an area of ground. Look at the marked area from a standing position for five minutes. Notice what you see. Now kneel and observe the space from that vantage point for five minutes. Take note of the things you missed while standing. Next, lie on your belly or lean closer to explore the area in detail. Look at it as if you were an astronaut on a strange planet. If you find something that captures your attention, such as an insect, worm, or plant, observe it as long as you want, then explore another portion of your space. Keep up the exploration for at least 10 minutes.

Systems Map

Background: This activity helps facilitate systems thinking.
Instructions: Make a sketch of the environment around you. Now map one of the unseen systems affecting this environment using arrows and notes such as you might find in an engineering drawing. For example, you could map the system of energy or nutrient flows in the environment, or map relationships between organisms.

ADDITIONAL INFORMATION, continued

CROSS-DISCIPLINARY CONNECTION: SCIENCE AND WORLD LANGUAGES

The science of classifying life is called *taxonomy*. Biologists name and identify organisms, grouping and categorizing them into a nested hierarchy of taxonomic ranks (domains, kingdoms, etc., down to genus and species) based on evolutionary relationships. Today the word *taxonomy* is also starting to be used to describe any system of classification. Have students study the Biomimicry Taxonomy and one or more taxonomies used in other disciplines, and then devise their own taxonomy for organizing and classifying a field of information that interests them. For example, students could create a taxonomy to organize their favorite video game characters or action film heroes. Second-language learners might want to use this opportunity to create a taxonomy of terms and associations that are helpful for their design challenge or other school projects or areas of interest.

CROSS-DISCIPLINARY CONNECTION: SOCIAL STUDIES

Share with students the following quotation from Janine Benyus:

> "What will make the Biomimicry Revolution any different from the Industrial Revolution? Who's to say we won't simply steal nature's thunder and use it in the ongoing campaign against life?
>
> This is not an idle worry. The last really famous biomimetic invention was the airplane (the Wright brothers watched vultures to learn the nuances of drag and lift). We flew like a bird for the first time in 1903, and by 1914, we were dropping bombs from the sky.
>
> Perhaps in the end, it will not be a change in technology that will bring us to the biomimetic future, but a change of heart, a humbling that allows us to be attentive to nature's lessons. As author Bill McKibben has pointed out, our tools are always deployed in the service of some philosophy or ideology. If we are to use our tools in the service of fitting in on Earth, our basic relationship to nature—even the story we tell ourselves about who we are in the universe—has to change."
>
> —Janine Benyus, *Biomimicry: Innovation Inspired by Nature*, p. 8

Conduct a Think-Pair-Share activity to help students process the passage. First, students could freewrite about what they think the passage means and why it is important to think about. Then they could find a partner and discuss their thoughts. Finally, have a class discussion for students to share their thoughts about the passage.

ASSESSMENT OPPORTUNITIES

Use a checklist to monitor students' participation in group activities. Suggest students augment their Portfolio with photos of any group work they are particularly proud of, such as the sketches they created during the Nature Observation activity or a collection of "How does nature…" questions they brainstormed. You could check participation by evaluating each student's Biologize Presentation Student Notes and check team participation and progress by evaluating the Biologize the Design Question Worksheet. Collect and review team research material to assess team progress and understanding. You may also wish to develop a rubric or checklist for teams to monitor the effectiveness of their research plans. The Reflection Questions on pages 13–14 also provide an excellent opportunity to check students' understanding of key topics. The Cross-Disciplinary Connections offer further opportunities to reteach, extend, and check each student's progress so far.

ADDITIONAL INFORMATION, continued

TECHNOLOGIES

Introduce advanced students to a full-text primary literature database (e.g., InfoTrac; many university libraries subscribe to these services) to search for journal articles on the organisms/phenomena they are researching for their challenge. Suggest students use an online tool such as a wiki or Google Docs to share their research findings.

RESOURCES/LINKS

For a variety of related resources, please see the Resource Bank for this grade level and theme. In addition, the following resources were cited in this lesson or relate specifically to this lesson:

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ScienceNews. [2016.]. [Home page]. Retrieved from https://www.sciencenews.org/