Nature as a Problem Solver: A STEAM Curriculum
Teacher’s Guide for 3-4th Grade

Curriculum Overview
Nature as a Problem Solver: A STEAM Curriculum connects science and design solutions through observation, questioning, building arguments and models, and a new scientific process called biomimicry. Through a series of hands-on, minds-on activities, students not only prepare for a trip to the Desert Botanical Garden, but they are exposed to a new way of problem solving inspired by nature. These activities are designed as options so that they integrate well into your classroom. A concluding design challenge brings together all elements of learning into an engaging and thought-provoking group project that aligns with Common Core standards.

Materials
- Video of an art exhibit installation (links provided)
- Blindfolds optional – one for each pair of students in class
- Collection of natural objects (i.e., seed pods, seeds, branches, leaves, rocks, etc.)
- Pictures of biomimicry examples (Garden provided)
- Recycled material for post-activity (purchase kit from Garden or collect your own as a classroom)

Learning Objectives
Upon completion of this curriculum, students will be able to...
- Practice and demonstrate a variety of observation techniques
- Identify opportunities for biomimicry in a real-life setting by understanding that nature can inspire solutions to challenges
- Construct a model of a nature-inspired solution to a human problem
- Justify claims using supporting arguments
Pre-Field Trip

Explain to the students that they will be visiting the Desert Botanical Garden where they will have the opportunity to view desert adapted plants. By using their senses to observe their surroundings at the Garden, by asking questions, and by learning about adaptations, the students will brainstorm how these adaptive characteristics can inspire solutions to real-life, human challenges. For example, the saguaro cactus has internal and external structures that help it stand tall and thrive in extreme conditions. The structures of the saguaro could inspire humans to build stronger, taller, and/or more energy efficient buildings.

Art Installation Video

Show your students one or all of the installation videos. Ask students to carefully observe because they will need to refer back to this information later for a writing assignment. Feel free to show the video(s) multiple times.

  This video is about Fred Lonberg-Holm’s Florasonic sound installation project at the Lincoln Park Nature Conservancy. He encountered many challenges and speaks about one very relatable challenge in the beginning. Please be advised that only the first 1:40 should be shown to students as additional audio content may not be appropriate.

- https://www.youtube.com/watch?v=h8cRtz-pnPw 3:52
  This time lapse video is about Daniel Goldstein and his studio’s installation of the large piece “Gathering Waves: A Hanging Sculpture”. It illustrates the complexities of transporting and hanging with such a large installation. No audio is required.

- https://www.youtube.com/watch?v=HdseJKACRM 3:43
  This time lapse video is the creation of a sculpture from the 2013 International Ice Sculpting Competition in Maui, HI. There are many opportunities to discuss challenges with this piece, including melting, the public interference, weight, carving multiple pieces, etc. No audio is required.

Older Students: Ask your students to watch one time and then to take notes a second time.

Written Reflection

Spend a few minutes discussing with your students what they saw during the video(s). Ask them to write one or more sentences expressing a challenge or problem they saw in the video. For example, they may write about the size, weight, or shape of the sculptures.

Younger Students: Ask them to write descriptive words instead of complete sentences.
Older Students: Write additional sentences about how the challenges were solved in the video. This can be written as a narrative or informational text. Or have students write comparison statements about what they saw in the video versus challenges they have experienced when putting something together.

**Biomimicry Introduction**

Biomimicry is defined as a “science that studies nature’s models and then imitates them or takes inspiration from these designs and processes to solve human problems.” The word originated from the Greek *bios* meaning ‘life’ and *mimesis* meaning ‘imitation’ (Benyus, 1997).

Biomimicry is a change in thinking; humans learn from nature instead of learning about nature. Students should be encouraged to observe details and structures of plants and/or animals, ask questions about why those structures exist, and understand how they help the organism survive/function.

Biomimicry is not about designing a pair of slippers that look like butterflies. Instead, it is about studying what makes the color in butterfly wings and asking the question; how could humans make color in a similar, more sustainable way for computer or television screens.

You will find that it is ok not to know all the answers, as you and your students can hypothesize and learn together!

For more information on Biomimicry, check out these links:

- [https://www.ted.com/talks/janine_benyus_biomimicry_in_action 17:42](https://www.ted.com/talks/janine_benyus_biomimicry_in_action)
  In this Ted Talk, Janine Benyus not only explains what biomimicry is, but also discusses real world products that are inspired by nature.

  This article from the Smithsonian presents some of the work they are doing with biomimicry of moths and butterflies as well as helping to explain biomimicry as a process.

  This article from BBC News provides an overview of biomimicry as well as providing some common examples from a more business and technology oriented perspective.

**Exploring Nature**

- *Adapted from the Biomimicry Institute’s ‘Seeing Function’ curriculum*
- *Students use their senses (other than sight) to observe and describe a natural object.*
If possible, take the class outside for this experience. If this is not possible, build your own collection of natural objects for an indoor exploration. These can be objects found outside in your neighborhood, local park, or even at the grocery store. A reference chart (p.4) lists possible natural materials and a blank chart (p.5) can be copied for the older students.

**Younger Students:** Share an object with the entire class. Ask them to say or write words that describe the object. Dig deeper with each description to get them thinking about why those objects have particular structures. Ask “what makes you say that?” or “how would that structure help the object?” You may also divide your class into pairs or small groups and give each group an object to discuss with their peers. Make sure they use all of their senses (sense of taste will be at the teacher’s discretion) to describe the object. It might help to have several of the same objects so it can be passed around the room.

**Older Students:** Have students work in pairs. One partner will be blindfolded (students can close eyes or objects can be inside of a bag) while the other has a paper and pencil. *Remind the non-blindfolded students to keep the blindfolded students safe at all times.*

The blindfolded partner uses all of their senses other than sight to explore the object (sense of taste will be at the teacher’s discretion). Meanwhile, the other partner records on paper all of the words the blindfolded partner used to describe the object. For example, they might say that it is lightweight, smooth, hard, has an earthy smell, etc. After several minutes, switch the blindfold and repeat roles with a new object.

Next, have the partners discuss what it felt like to use their senses other than sight. Did they enjoy it? Did they feel anxious? Have each partner guess what object they were observing. Then encourage discussion about the adjectives used to describe the object. What purpose do these characteristics serve? How do they help the object or the larger natural object it belongs to?

For example, if a pair was examining a seed. What do you think makes it so hard? Maybe because it has a seed coat? Why might a seed coat be hard? To protect it from harsh weather conditions? To prevent water loss? So animals don’t eat them? *Remember, at this point it is less about knowing the correct answer and more about thinking it through.*

Do this several times by having pairs exchange objects. Conclude this activity with a large group discussion to share observed structures and the importance of those structures.
<table>
<thead>
<tr>
<th><strong>Objects</strong></th>
<th><strong>Structures and Functions</strong></th>
</tr>
</thead>
</table>
| **Seeds**  | Hard coat – Protect from weather and prevent water loss  
Prickly – Attach to animals to disperse the seeds  
Feathery – Can be dispersed by the air  
Light weight – Can be dispersed by floating in the water  
Smooth – They have more starch and can store more water |
| **Examples include:** Mesquite, palo verde, cocklebur, clematis, dandelion, nuts, beans, corn kernels |
| **Seed pods** | Bumpy – Forms around the seed to protect it  
Cracked – To let the seed escape |
| **Examples include:** Texas ebony, palo verde, agave, green beans, sugar snap peas  
*People allergic to peanuts are often allergic to mesquite |
| **Leaves**  | Small – To prevent water loss by minimizing pores  
Fuzzy – To protect the leaf from the sun  
Waxy – To prevent water loss by having a water resistant coating |
| **Examples include:** Any living plant, aloe, creosote, and palo verde in particular, lettuces, spinach, kale |
| **Branches/Stems** | Bumpy/Ridges – To grow leaves/branches from  
Hard – Provide structure and support  
Wet – water and nutrients transported through stem |
| **Examples include:** Any outdoor plant, palo verde in particular, cinnamon (not ground), broccoli stalks, celery |
| **Roots**  | Long – Absorb more rain water with more surface area  
Thin – Can grow easily in the soil  
Pointed – Can grow deep to reach more water  
Round – Can store water when it’s collected  
Hairy – Has tiny roots to collect more water |
<p>| <strong>Examples include:</strong> Any living plant, carrots, jicama, celery root |
| <strong>Other Suggestions</strong> | |
| <strong>Bird’s nests, saguaro Boots, Honeycomb, turtle/tortoise shell, skulls, pelts</strong> |</p>
<table>
<thead>
<tr>
<th><strong>Observations</strong></th>
<th><strong>Structures and Functions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(while blind-folded)</td>
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</tbody>
</table>

- **Hard, smooth**  
  *Seed Coat = protection, holds water in*
Comparison & Reflection

- Students observe a natural organism and the man-made design it inspired. Completing a Venn diagram with the class will help them compare and contrast characteristics.

Draw a large Venn diagram on the board. Explain to your students that you are going to discuss real-life examples of biomimicry -- man-made technology that was inspired by a structure and its function in nature. Begin by showing them the provided pictures of biomimicry examples (fully complete the activity with one pair before moving onto the next).

- Burr and Velcro
- Kingfisher and the Japanese Bullet Train
- Boxfish and Concept Car

In addition to the pictures, read the provided informational text aloud or silently. Using their visual observations of the pictures and the knowledge they gained from the text to complete the Venn diagrams as illustrated with descriptions of the examples in the appropriate areas. Discuss their similarities and differences. Why is it a good idea to model man-made solutions after functions and structures in nature?

Younger Students: Instead of a Venn diagram, have the class list observations that are the same and different.
Burr and Velcro
Burr and Velcro

Reading Sample:
One summer day in 1948, a mountain climber and inventor, named George de Mestral, decided to take his dog for a hike. When they got home, the man and his dog both returned home covered with burrs, the spiked seed pods that stick to fur so that they can grow other places. The man wondered, “how does this stick to my pants and my dog’s fur?” He looked at them in a microscope so that he could see it up close. He saw all the small hooks that help the burr to stick to the tiny loops in the fabric of his pants. The man had an idea! "I will design a unique, two-sided fastener, one side with stiff hooks like the burrs and the other side with soft loops like the fabric of my pants. I will call my invention 'velcro'. It will be better than a zipper at holding things together."

People were mean and laughed at his idea, but he still thought it was a good idea. Together with a weaver in France, he made his velcro. He tried all sorts of different things until he figured out how to make the hook part like a burr. He sold over sixty million yards of Velcro a year, and no one laughed at him anymore.

**Kingfisher and Japanese Bullet Train**
Reading Sample:

Japan has some very fast trains called bullet trains. They were so fast that they caused a loud boom when they came out of tunnels!

The booming was because of the shape of the front of the train.

With the old bullet train front, the train was pushing air in front of it through the tunnel really fast. So when the air came out it made a lot of noise, like the sound a balloon makes when it flies around the room. But this was like a really big balloon that woke up many unhappy people and animals. But Mr. Nakatsu liked to watch birds, and he knew that the kingfisher didn’t make a splash or noise when it dove into the water to catch fish. He thought this could help fix the problem with the trains.

Kingfishers move very fast and have a long thin beak this helps them move fast when they dive in the water and hunt for fish. When they dive the water flows past their beak, it’s not being pushed down by their beak.

Because the train has the same problem of pushing the air, he thought, “I wonder if I could use this idea to change the shape of the front of the bullet train.” He redesigned the front of the train to look like a kingfisher’s face. It has a pointy part to it just like the beak of the kingfisher. And sure enough when they tried out that new train, it moved through the tunnels without creating booms. And it saved them more energy because it didn’t have to push the air.
Boxfish and Concept Car
Boxfish and Concept Car

Reading Sample:

The yellow boxfish, with fins that look too small to move its large body, is an unlikely source of inspiration for a car. The car company, Mercedes-Benz, thought differently. Their engineers saw the box-shaped fish as the perfect example of a sleek design and used the fish’s shape as inspiration for a new concept car in 2005. What resulted was a light-weight, energy efficient and safe vehicle for consumers.

With its sleek design, the concept car consumes 20 percent less fuel than other cars you see on the road. The boxy shape of the fish not only provides easy movement through the water, but it also allows for the fish to escape unharmed when bumping into other underwater organisms. The car engineers copied the same design resulting in a vehicle that is 40 percent stiffer than the average car, helping to prevent dents. It also weighs 30 percent less which improves the overall efficiency.
Post-Field Trip

Biology to Design Challenge

Biomimicry can start with an inspiration found in nature that can help solve a human challenge; or scientists may be working to solve a human challenge first and look to nature for inspiration. This culminating challenge will focus on the nature inspiration coming first.

Discuss with your students that they will listen to a story and then pretend to be the main character, Clark, who is presented with a challenge. They can work individually, in pairs, or in small groups.

Read the following story and discuss what things the boy needed to survive. Then discuss what things plants need to survive and how they have adapted to thrive in the desert environment. Have the students think back to what they experienced on their field trip to the Desert Botanical Garden and use their booklets for reference. Then let them know that they will be challenged the same way as Clark; to build something that can collect and contain water using a variety of found objects and inspiration from nature.

- Give each group/student a Challenge Kit from the Garden filled with recycled materials or collect your own recycled materials and divide evenly amongst the groups
- Have each group use the knowledge they gained from the field trip to the Garden, the background from the story, and the found objects to design a container to collect and contain water.
- For example, is there something a desert plant does to collect/store water that humans could do too? Your students might be inspired by the barrel cactus and construct a design for a tube that could expand to collect and store water after a big rain. Remember, these models do not actually have to DO what they are modeling, just represent it.
- Once completed, each group or individual can present their model to the entire class.

STORY: Clark wakes-up bright and early one summer morning. His family is camping in the Sonoran Desert and the morning air feels cool on his skin. Clark is visiting the Sonoran Desert for the first time. He lives in Oregon where there are forests with lots of trees and rain. He doesn’t know what really happens in the Sonoran Desert, but he will find out soon! He spots a coyote nearby finishing his breakfast. “What is that coyote eating?” Clark asks himself.

As Clark’s family sleeps in the RV, Clark quietly sneaks-up behind the coyote. Tip toe, tip toe, tip toe. Suddenly the coyote sees Clark and takes off running with its breakfast still in its mouth. Clark wants to figure out what the coyote is eating, so decides to run after it! The coyote runs across the creek; Clark follows. It runs past a group of agaves with their curved leaves growing
out of the center; Clark follows. It runs past a saguaro that is taller than Clark’s house; Clark follows. It runs around a big boulder; Clark follows.

Suddenly Clark can’t see the coyote. He looks around and sees nothing but desert. Clark really wants to know what that coyote was eating so he starts looking for clues on the ground, but the ground is so hard, there aren’t even any tracks! “I know! I will go back to camp and see if there are clues there that will tell me what that coyote ate.”

All of the sudden Clark realizes that he doesn’t know where camp is. “I remember crossing a creek, but I don’t see one, this desert is so dry. I remember passing some agave, but there are tons of those. I remember passing a huge saguaro, but I don’t see any THAT big around here.” Clark is scared. He now realizes that he is all alone in a very big desert.

Clark guesses what direction he ran from and decides to walk that way, hoping to find his camp. He walks and he walks. He starts to get thirsty, but he still does not see the stream he crossed with the coyote. The more he walks the thirstier he gets.

As he walks, Clark starts to notice trash on the ground. “I must be getting near a town or road; people must be near here if they left trash. That sure was nice of them to let me know I was on the right track, but that’s not very good for that poor coyote.” As he walks, Clark picks up all of the trash, but still cannot find a road or town.

Clark spots a great big mesquite tree. “That looks like a good place to rest, I’ve been walking a long time,” he said to himself. Just as Clark started to feel sorry for himself again, BOOM-CRACK! Clark jumps high in the air. It was a loud clap of thunder. “I had better get going” thinks Clark, “or I’m going to get very wet.” Clark doesn’t know a lot about the desert, but he experienced a monsoon storm the day before and knows how much rain there would be. When it starts to rain, Clark opens his mouth toward the sky and lets the water fill his dry mouth and parched throat, but he is still thirsty.

Clark realizes that he is sharing the same water as the coyote that drinks from the stream and the plants that drink from the ground. At this moment, he feels connected to the desert. As part of the desert he knows that water is scarce and he will need all help he could get. “If only I had a bigger mouth and could catch the water and save it for later!” With the rain pounding on the back of his head he realizes that since he couldn’t find coyote’s stream, he will have to drink like the plants.

He tries to remember how the plants drink. There are a bunch of agaves nearby so he takes a closer look. They all have water in the center just sitting on their leaves. He observes the plant a little closer. The leaves are curved! All the rain collects on their curved leaves and then pours
down to the center where Clark guesses their roots are. He tries to suck-up the water from on top of the leaf, but it pokes him instead.

Next, he examines a nearby saguaro cactus. He wants to see what their leaves look like, but he doesn’t see anything that looks like leaves. He only sees sharp spines covering the cactus, which don’t seem helpful for collecting water. Then he notices an arm of the saguaro has recently fallen to the ground. The inside of the cactus is wet and the outside is dry. This reminds him of his juice box, and how it holds juice inside, but it is dry on the outside.

The trash that Clarks is holding is starting to get slippery and difficult to hold. A couple of cups and tin cans are filling with water, making them heavy. “I’ve got it!” Clark yelled. “I will take all of my trash and make it into something that will be bigger than my mouth, move the water like the agave leaves, and save it for later like the saguaro!” Clark spreads out all of the trash he found and gets to work.

The rain water collector works really well; Clark drinks and drinks. He now feels strong enough to figure out where his camp might be. He picks up his new rain collector and container, full of fresh water, and starts walking. He walks until he finds the stream which now looks more like a river. He follows it downstream until it leads him to the lake. “I’m saved!” he thinks. “The water has saved me and brought me back to my family.” “Where have you been? We have been worried,” his mom squeals. “Oh, I just went for a walk with my new coyote friend,” he replies. “What is this?” his mom asks, finally noticing his trash creation. “It’s my new water bottle that the plants taught me how to make,” he said with a smile.
What to do Next

Share Your Work
Please share your students’ nature inspired design models with the Desert Botanical Garden.

- Please feel free to share your photos or anything else by emailing formaled@dbg.org
- Don’t forget to include your school and grade!

What to do with containers and leftover stuff?
We hope you and your students enjoyed learning about desert ecology, design, and biomimicry. We understand that there may have been more items in your containers than you needed. As a lesson in sustainability and protecting our environment, the Desert Botanical Garden Education Department prefers that the items are not immediately discarded into the trash. Please reuse and repurpose materials to keep them out of the landfill. Here are some ideas...

- Share the extra items with other teachers, the art teacher, or teacher organizations (such as Treasures for Teachers)
- Donate them to afterschool programs or other youth organizations at your school
- Ask the students what they would like to do with the extra items
- Use the materials for a future modeling project
- Let students keep some of the more interesting items
- Plant seeds, a seasonal vegetable, or native plant in your plastic pot containers
- Recycle anything you can (i.e., remove the twine and recycle the cardboard container pieces)
- Make a mural and use the items to spell out a word like “recycle.”
References


Burr Example Images–
http://justseven.blogspot.com/2010/04/wild-velcro-plant.html


Kingfisher Example Images -


Boxfish Example Images –
http://biomimicrykth.blogspot.com/2012/05/boxfish-car.html

http://www.designboom.com/contemporary/biomimicry.html
Art Installation Video and Written Reflection

Blindfold Exploration

Comparison Reflection
Third – 3.RI.2, 3.RI.3, 3.RI.7, 3.RI.9, 3.RI.10, AZ.3.RI.10, 3.SL.2, 3.L.4
Fourth – 4.RI.1, 4.RI.2, 4.RI.3, 4.RI.7, 4.RI.9, 4.RI.10, AZ.4.RI.10, 4.SL.2, 4.L.4

Biology to Design Challenge
Third – 3.RL.3, 3.RL.3, 3.L.4
Fourth – 4.RL.1, 4.RL.2, 4.RL.3, 4.L.4

Arizona’s College and Career Ready Standards - Math

Art Installation Video and Written Reflection
Third – N/A
Fourth – N/A

Blindfold Exploration
Third – 3.MP.3
Fourth – 4.MP.3
**Comparison Reflection**
Third – 3.MP.3
Fourth – 4.MP.3

**Biology to Design Challenge**
Third – 3.MP.4
Fourth – 4.MP.4