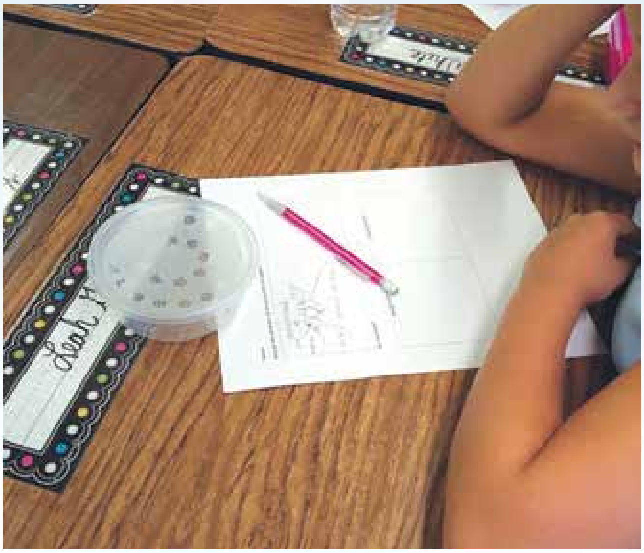
Who Is Your Champion?

A close look at how plant and animal structures can help solve a problem.

By Caryn Walker, Roberta L. Ethington, and Alyssa Y. Stark



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> **"I need to get to school faster!" "I need to be able to reach higher." "I hate it when I get hot when I'm running."**
>
> — *Fourth graders at St. Matthews Elementary School.*

Everyone has problems, from the smallest ant competing for a food source to the largest elephant needing to cool down. Fortunately, organisms have structures that function to help them solve these problems. So when a group of fourth-grade students look for solutions to their problems, who do they turn to? A biological champion, of course! Plants and animals have a long history of solving problems, and by imitating their strengths, students can generate ideas for a better future.

Currently, teachers are looking beyond the basic elements of core ideas to incorporate engineering practices; however, making this connection can be a challenge. We felt that by incorporating *biomimicry*, the practice of using nature as a guide to solve human problems (Baumeister 2014), into the existing *Next Generation Science Standards* (NGSS) fourth-grade science unit on structure and function, we could meet this challenge. Students ultimately explore the question: *What can we learn from plants and animals to help solve the problems we face in our lives?* Then, by working through the engineering design process, they created a model that demonstrates a solution to their problem!

Schoolyard Ants

Students had prior experience investigating plants and animals through observation and data collection. We separated our five 45-minute lessons into two sections: structure and function of ants and biomimicry. In the first lesson, we began by leading an outdoor investigation of local ant populations. We hoped that by examining ants found in the school yard, students would be able to draw conclusions about how ant structures function to solve their problems.

To gauge student knowledge, we asked: *What do you know about ants? What do you think we can learn by observing them?* Students shared their knowledge of ants and discussed how observing animals in their natural setting would be different from observing animals in the classroom. They decided it would be important to count the number of ants observed and to note their behaviors at different locations in the schoolyard. We reviewed outdoor learning and safety expectations before assigning students to a specific location. One hour prior to the lesson, we baited specific locations (ground, tree trunk, grass) with tuna fish and honey, so that students could observe ant foraging. Although students were instructed not to touch the baits, if you have a student with a fish allergy, canned chicken can be used as a substitute. While most ant species are not dangerous, some areas of the country do have species that sting. Instruct students not to handle ants and make sure they wash their hands if they touch the bait. Additionally, some of the baits could attract wasps. We suggest you assess your local environment and ant populations before implementing this lesson. This will also help you identify observation areas that have good levels of ant activity (i.e., near a colony).

⚠ CAUTION

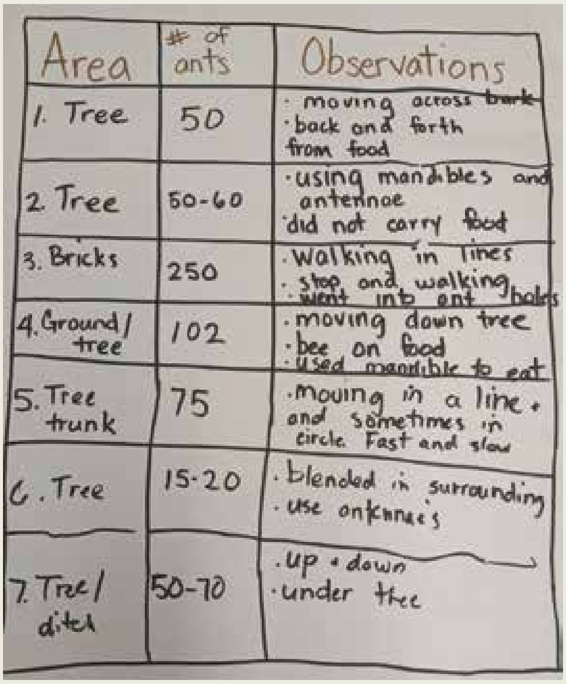
After completing observations and collecting data, each group processed the findings from their assigned location and shared their results (Figure 1). It was helpful when making comparisons among sites in class that the students had been allowed to look at other sites in the schoolyard after they had completed their own observations. Students concluded that ant behavior was very active in some areas and less active in others. Groups realized that most of the schoolyard ants were traveling, climbing, and eating. Their findings led directly into the next lesson, a closer investigation of ant structures and their functions.

In the second lesson, ants were placed in clear plastic containers with secure lids so that students could gather detailed information on their external structures. Instruct students to not open or shake the container to avoid harming the ants. Students were supplied with a small hand lens to aid their observations. Working together in groups of four, they answered the focus question, *How do the structures of an ant function to support its*

⚠ CAUTION

FIGURE 1.

Students' observations.



Area	# of ants	Observations
1. Tree	50	· moving across ~~bark~~ · back and forth from food
2. Tree	50-60	· using mandibles and antennoe · did not carry food
3. Bricks	250	· walking in lines · stop and walking · went into ant holes
4. Ground/tree	102	· moving down tree · bee on food · used mandible to eat
5. Tree trunk	75	· mouing in a line + and sometimes in circle. Fast and slow
6. Tree	15-20	· blended in surrounding · use ontennae's
7. Tree/ditch	50-70	· up + down · under tree

Students look for signs of ants (above); a close-up of an ant at the bait (left).

survival? Sharing their observations, they found that ants have a variety of structures with specific functions (Fisher et al. 2007; Figure 2). For instance, most groups noticed legs for walking, antennae for sensing their surroundings, and many observed the jaws of the ant used for eating. A few groups even noted that the ants had grips on their feet to hold on to the plastic dish, which was the next part of our lesson. We responded by saying, "The ants you observed have structures that help them cling to things in their environment. We can look more closely at their structures by testing how well they hold onto different surfaces."

Ant Adhesion

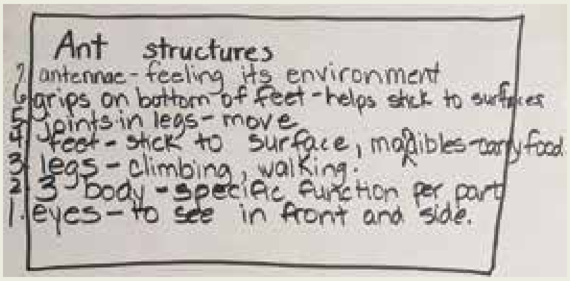
Next, students measured ant adhesion, first on plastic (smooth) and then on sandpaper (rough). Investigations were conducted in the small plastic dishes with lids used previously. For the rough surface, we cut out sandpaper (medium grit) and taped it to the bottom of the dish. We found that ants often climbed under the sandpaper. We suggest hot gluing the edges of the sandpaper to the dish to avoid this; it was a major struggle in class. Luckily we had three teachers and two volunteers to carefully move the ants from under the sandpaper for the students. Once the ants were in the center of their dish, students excitedly tested the ability of ants to hold onto each surface by lifting the basins up, one at a time, to 45°, 90°, and 180° angles in succession, and then recorded their observations (Figure 3). Prior to experiments we discussed angles and drew a picture on the board depicting the position of the dish for each angle. For more accurate measurements students can use a protractor. We then recorded each group's data on a overhead class chart (Figure 4, p. 42). Students found that all ants stuck to the rough surface but most ants fell from the smooth surface at 45° or 90°. As a class we found that one ant, out of all groups, was able to stick to the smooth surface upside down (180°). This is because individual ants are different, and some may be better than others at adhering to smooth surfaces. This is a basic concept in biology and can be discussed with the class as something similar to the variation in height within our own classroom (i.e., some people are taller and some ants are stickier).

Students record their observations about ants.

When students came together to discuss their findings, one student said, "It (the ant) must have grips on its feet because it can climb and not fall." Another student said, "I think it has grips to walk upside down!" We then asked, *What do our results show?* The students were able to claim that ants are better able to hold onto the rough surface than the smooth surface. We probed, *What is the evidence?* They pointed out that on the smooth surface, the ants fell off when tilted at an angle, whereas, on the rough surface, the ants were able to hold on at all angles, even 180°. Next, we prompted students to think back to their ant observations outside and asked, *Did your group see ants on rough or smooth surfaces? What surface outside is like the sandpaper?*

FIGURE 2.

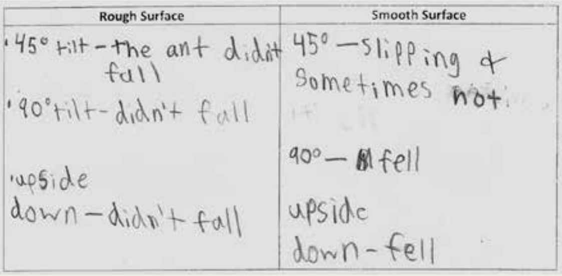
Students assigned functions to ant structures.



Ant structures
7. antennae - feeling its environment
6. grips on bottom of feet - helps stick to surfaces
5. joints in legs - move
4. feet - stick to surface, mandibles - carry food
3. legs - climbing, walking.
2. 3 body - specific function per part
1. eyes - to see in front and side.

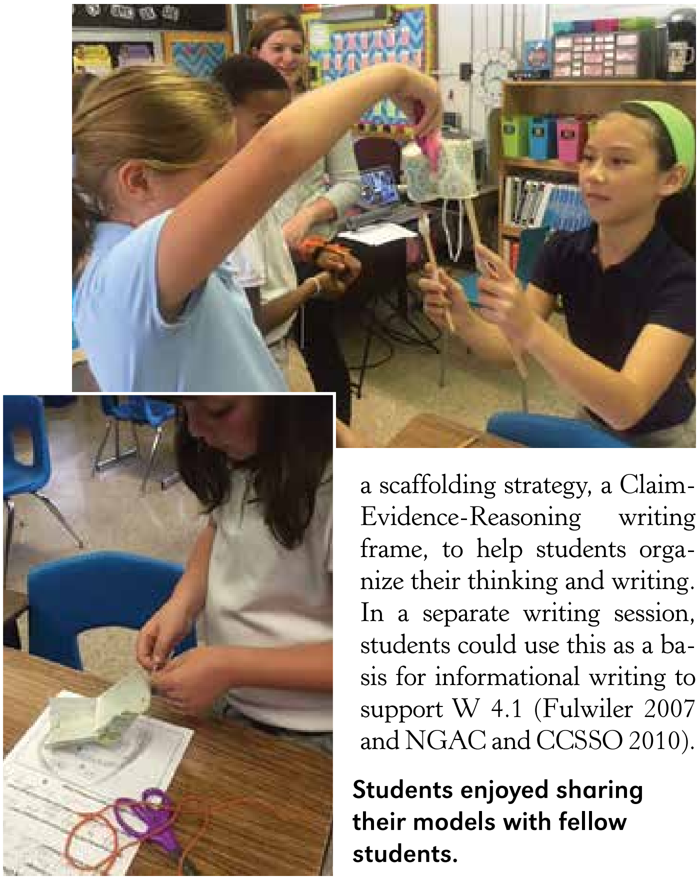
FIGURE 3.

Data collection on ant climbing.



Rough Surface	Smooth Surface
45° tilt - the ant didn't fall	45° — slipping & sometimes not.
90° tilt - didn't fall	90° — fell
upside down - didn't fall	upside down - fell

What surface outside is like the plastic? Students concluded that tree bark was rough and leaves were smooth. We asked, *What information does this tell us about the ant's ability to hold onto different surfaces in their environment?* Based on the students' claim and evidence, they now had support for the argument that ant structures encourage movement on rough surfaces more than smooth surfaces. We introduced a scaffolding strategy, a Claim-Evidence-Reasoning writing frame, to help students organize their thinking and writing. In a separate writing session, students could use this as a basis for informational writing to support W 4.1 (Fulwiler 2007 and NGAC and CCSSO 2010).



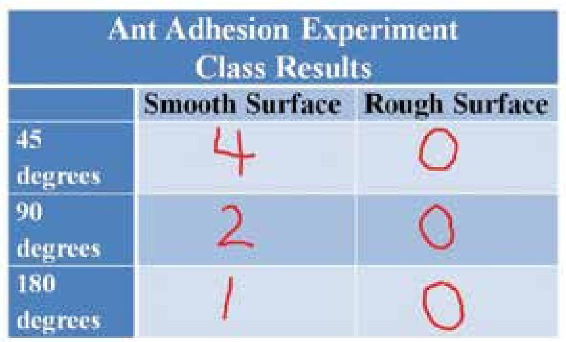
Students enjoyed sharing their models with fellow students.

Solving Problems

We began the third lesson with the question: *Have you ever had difficulty solving a problem, like trying to grab something that is slippery or too high to reach?* We guided students to think back to the ants they observed: *How did the ants solve the problem of finding food in the school yard?* They responded that ants can hold onto rough surfaces because they have structures that grasp things. We reaffirmed what they had learned. Animals need to survive in their environment, and they have certain structures that function to help them do this. We showed them a high magnification picture of an ant foot and asked: *How do you think this structure helps the ant survive in its environment?* This image made students gasp. They noticed ants not only had claws to grip but foot pads as well (Figure 5). If time permits, students can first observe ant feet on their own by placing an ant on glass and looking through it

FIGURE 4.

Class data chart.



Ant Adhesion Experiment
Class Results

	Smooth Surface	Rough Surface
45 degrees	4	0
90 degrees	2	0
180 degrees	1	0

TABLE 1.

Examples of student problems, biological champions, structures and functions, and biomimetic design.

Student	Problem	Biological Champion	Structures and Functions	Design
Leah	Gets hot when running	Elephant	Trunk to spray water	Tubelike structure made of straws that can fling water upward by strings to the runner
Elliot	Can't jump far	Lynx	Strong, springy leg muscles to jump	Springlike attachment for shoes
Elise	Can't reach tall things	Giraffe	A long neck to reach food that others can't	Long, flexible gripping device that can retrieve items

with a hand lens, then comparing what they see to the high magnification image of the ant foot. The visualization of the ant foot supported their claim that the ant's foot must have gripping devices to stick to surfaces.

Stating *scientists and engineers often look at models to help solve problems*, we asked: *How could the model of the ant foot help a scientist or engineer solve a problem?* We guided students to think about the usefulness of ant's structures and why humans would imitate them. We then introduced students to the idea that animal structures can be imitated to solve problems in the real world by using biomimicry. We shared that scientists and engineers look to a biological champion—a plant or animal that has a special strength due to the functioning of a particular structure. We provided a number of interesting examples; Velcro was inspired by plant seeds, termites build self-heating and cooling buildings, and the lotus leaf never gets dirty.

We then turned the focus back to the students and asked them to think about the environment they live in and what kind of problems they face. Students talked at their tables and came up with several frustrations. Next, we posed the question: *Based on your problem, what plant or animal is able to accomplish this task due to a particular structure and its function?* This animal, we explained, would be their biological champion. We gave the example: *I have a problem with slipping when I try to cross icy surfaces in the winter. Who could be my biological champion?* One student shouted, "I know, the penguin!" In reply, we asked, "So what structure does the penguin have that supports its ability to walk across ice without slipping?" The students then understood that if walking across icy surfaces was their problem, their biological champion would be the penguin because of its ice-puncturing claws. Students then began to brainstorm problems and biological champions. We found that students could use prior knowledge to develop their ideas; however, learning to research biological champions could be a valuable supplementary lesson to this unit.

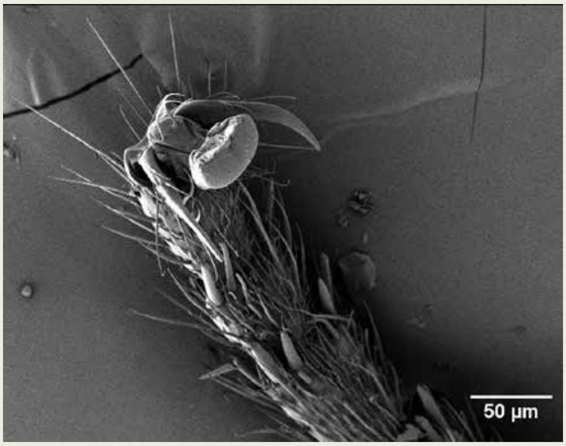
Once biological champions were identified and clear connections between structure and function were established, the discussion turned toward the design process. We asked the class, *Looking at the structures of your biological champion, what could you design that would help solve your problem?* Students used the ideas from their champions' structures to solve their challenge. As some students struggled with their designs, we called for attention and shared the work of other students who were on track. One student's problem was getting cold in the middle of the night because she kicked off her covers. She thought of an animal that was able to keep warm in a cold climate and designed a suit that acted like the blubber of a polar bear. The class saw her design, and for the struggling students, the lightbulbs clicked on. Modeling student work provided the scaffolding needed to support student understanding and kick-start their thinking. Students drew their biomimetic solutions on a record sheet, which outlined the structures and functions they were using for inspiration from their biological champion, and how those relate to their problem (Figure 6, p. 44).

Ant Collection

Ants used for the observation with a hand lens lesson and the ant adhesion investigation were collected from a local park a few days prior to instruction. Ants that work best in the investigation are terrestrial ants that can be found in and under logs. When collecting ants, carefully roll logs over to find a colony. Make sure you are looking in the middle of the day when it is warm. Ants are hard to find when it is cold, so save this lesson for late spring, summer, or early fall. Once a colony is located, use a hand shovel to collect as many ants as needed; extra is always better. Dirt and wood for them to live in for a few days is preferred. Use a tall bucket for storage and make sure the soil and wood stay moist. A paper towel with water and a bit of tuna (or chicken) and honey will keep the ants alive for a few weeks if needed. Be sure to collect ants from the ground and not from a tree—ants from trees are really good stickers and won't show the difference in adhesion this lesson is aimed at! This variation could be used as an additional lesson about species differences and habitat use. Again, be aware of the presence of stinging ants in your area.

FIGURE 5.

Ant leg at high magnification.



In the final lesson, students created models of their design using assorted materials. Student work spanned from skunk-inspired spray bottles to cat-inspired eyeglasses. A few examples are listed in Table 1, p. 42. We used the performance task of creating a solution to a problem by using a biological champion to assess student understanding of how structures can function to help survival. Students enjoyed sharing their models, explaining their process, identifying their biological champion, and showing their creations. Due to time constraints, students were not able to make functional prototypes; instead their models served as a representation of their thinking. We focused on how developing models is an important step in the early stages of the design process. This series of lessons helped the class prepare for their summative assessment of their larger unit of study. They showed a much deeper understanding of not only the content but also the application of their knowledge. Additionally, we found that students with learning differences or underrepresented groups, such as girls in engineering, were actively engaged throughout the lesson, eagerly thinking of and designing their models, often asking for another worksheet to design a second model. In conclusion, we know that the next time our students are outside and they see an interesting plant or animal, or watch a squirrel climb a tree, they will wonder, *How is that organism a biological champion?* ■

A student tries on her design.

Caryn Walker is an elementary science resource teacher at Jefferson County Public Schools in Louisville, Kentucky. Roberta L. Ethington is a third-grade teacher at St. Matthews Elementary School in Louisville. Alyssa Y. Stark* (alyssa.stark@louisville.edu) *is a postdoctoral associate in the Department of Biology at the University of Louisville.

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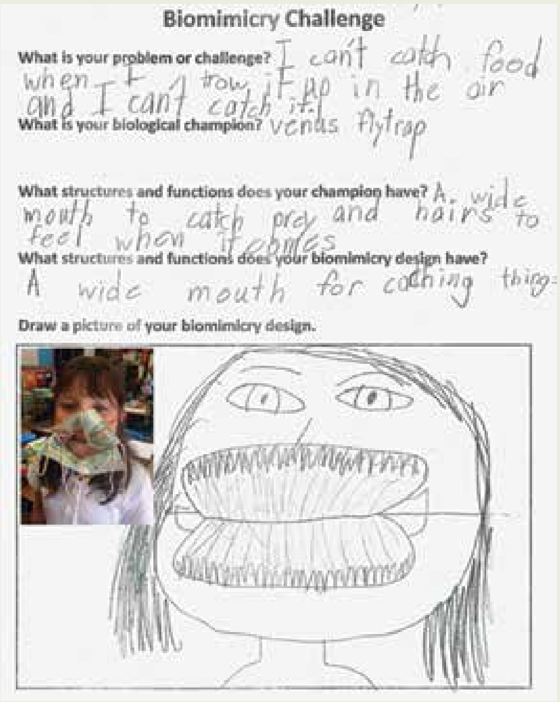
FIGURE 6.

Biomimicry challenge.



Biomimicry Challenge

What is your problem or challenge? I can't catch food when I trow it up in the air and I cant catch it.

What is your biological champion? venus flytrap

What structures and functions does your champion have? A wide mouth to catch prey and hairs to feel when it comes

What structures and functions does your biomimicry design have? A wide mouth for cathing thing

Draw a picture of your biomimicry design.

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NSTA Connection

Download a rubric, lesson sequence, additional resources on biomimicry, and a PowerPoint lesson at *www.nsta.org/SC1607*.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013):

4. Structure, Function, and Information Processing

www.nextgenscience.org/pe/4-ls1-1-molecules-organisms-structures-and-processes

The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities. The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectations listed below.

Performance Expectation	**Connections to Classroom Activity** *Students:*
4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.	• collect observational data on ants in the schoolyard environment and evidence that they have structures that function to support their survival. • design a structure based on plant/animal structures and their function.
Science and Engineering Practice	
Engaging in Argument From Evidence	• collect data and observational evidence of ant adhesion to determine how structures support their survival. • analyze data to form a claim and provide evidence to support the claim. • construct an explanation.
Disciplinary Core Idea	
LS1.A: Structure and Function • Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior and reproduction.	• investigate the structure of ants in their schoolyard and classroom to evaluate how structure and function affects survival in their environment. • design a structure that would function to support human survival.
Crosscutting Concepts	
System and System Models	• examine the system of structure/function relationship in plants and animals. • use models to demonstrate their understanding of how structures function to support survival.

Connecting to the *Common Core State Standards* (NGAC and CCSSO 2010):

ELA/Literacy

W.4.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information (4-LS1-1)