

# Bee-ing an Engineer with Wisconsin Fast Plants®

*An Engineering Challenge Supporting K-2 Next Generation Science Standards*



Lessons excerpted from the 2014 K-2 Unit: *Investigating Plants with Wisconsin Fast Plants* developed by the *Wisconsin Fast Plants Program*, UW-Madison available online at [www.fastplants.org](http://www.fastplants.org)

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## Bee-ing an Engineer with Wisconsin Fast Plants

### An Engineering Challenge Supporting K-2 Next Generation Science Standards

Developed by the Wisconsin Fast Plants Program, University of Wisconsin-Madison

#### Grade Level: K-2

**Time needed:** Approximately 45 min/day for 4-5 days

**Learning Goals (Performance Expectations)** Students who demonstrate understanding of the practices, Disciplinary Core Ideas, and Crosscutting Concepts that are the focus of this lesson will:

Develop a simple sketch or drawing to illustrate how the shapes and structures included in their solution will function as needed to solve the bee replacement challenge, and communicate with others an evidence-based explanation, supporting claims about how their proposed solution would function. (Aligned with NGSS\* K-2-ETS1-2)

Use materials to design and construct a simple model that mimics how some insects collect and transfer pollen as they visit flowers, carrying out their part of an ecological relationship that helps both the insect and flowering plant meet their needs (food and reproduction). (Aligned with NGSS\* 1-LS1-1, 2-LS2-2)

### Supported Next Generation Science Standards\*

Students who demonstrate understanding can:

**K-2-ETS1-2.** Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

**1-LS1-1.** Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.\* [Clarification Statement: Examples of human problems that can be solved by mimicking plant or animal solutions could include designing clothing or equipment to protect bicyclists by mimicking turtle shells, acorn shells, and animal scales; stabilizing structures by mimicking animal tails and roots on plants; keeping out intruders by mimicking thorns on branches and animal quills; and, detecting intruders by mimicking eyes and ears.]

**2-LS2-2.** Develop a simple model that mimics the function of an animal in [dispersing seeds] or pollinating plants.\*

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Asking Questions and Defining Problems</b> Asking questions and defining problems in K-2 builds on prior experiences and progresses to simple descriptive questions.</p> <ul style="list-style-type: none"> <li>Ask questions based on observations to find more information about the natural and/or designed world(s). (K-2-ETS1-1)</li> <li>Define a simple problem that can be solved through the development of a new or improved object or tool. (K-2-ETS1-1)</li> </ul> <p><b>Developing and Using Models</b> Modeling in K-2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.</p> <ul style="list-style-type: none"> <li>Develop a simple model based on evidence to represent a proposed object or tool. (K-2-ETS1-2)</li> </ul> <p><b>Analyzing and Interpreting Data</b> Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations.</p> <ul style="list-style-type: none"> <li>Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (K-LS1-1)</li> </ul> <p><b>Engaging in Argument from Evidence</b> Engaging in argument from evidence in K-2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s).</p> <ul style="list-style-type: none"> <li>Construct an argument with evidence to support a claim. (K-ESS2-2)</li> </ul> <p><b>Obtaining, Evaluating, and Communicating Information</b> Obtaining, evaluating, and communicating information in K-2 builds on prior experiences and uses observations and texts to communicate new information.</p> <ul style="list-style-type: none"> <li>Communicate solutions with others in oral and/or written forms using models and/or drawings that provide detail about scientific ideas. (K-ESS3-3)</li> </ul>	<p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people. (K-2-ETS1-2)</li> </ul> <p><b>LS2.A: Interdependent Relationships in Ecosystems</b></p> <ul style="list-style-type: none"> <li>Plants depend on animals for pollination [or to move their seeds around]. (2-LS2-2)</li> </ul> <p><b>LS1.A: Structure and Function</b></p> <ul style="list-style-type: none"> <li>All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow. (1-LS1-1)</li> </ul>	<p><b>Structure and Function</b></p> <ul style="list-style-type: none"> <li>The shape and stability of structures of natural and designed objects are related to their function(s). (K-2-ETS1-2)</li> </ul>

\* The above table and references to Next Generation Science Standards (NGSS) throughout these lessons originates from and refers to the following work available online and in print: NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

## Engineering Challenge

How can you design a model that mimics the way a bee pollinates Fast Plant flowers? Design a simple model that would work like a bee to pollinate the Fast Plants in our classroom.

1. First, develop a simple sketch or drawing to illustrate your solution, and give an evidence-based explanation, supporting your claims about how its shapes and structures will function effectively (like a bee).
2. Next, use materials to develop the solution that was designed, including any improvements to the design that may have come about during peer review.

NOTE: This problem was a real issue for scientists who first sent Fast Plants into space to learn if flowering plants could reproduce in space. (See more about Fast Plants in space at [www.fastplants.org](http://www.fastplants.org)).

## Lesson Context

This engineering challenge is situated in a K-2 unit that engages students in a series of inquiries to learn that plants need light and water, while also learning about the nature of science and engineering practices. The class observes the phenomenon that kicks off the entire unit when a vase holding a bouquet of flowers loses water. Wondering *Do plants need water to grow?* emerges from this observation, and students then engage in a series of inquiries that involve growing Wisconsin Fast Plants.

Throughout the inquiries to learn if plants need water (and later, if plants need light) students engage with the crosscutting concept of structure and function. For example, in this engineering-focused lesson students explore their Fast Plants' flowers and learn how flowers and their internal structures are related to their functions (in pollination and reproduction). Also, students explore how bees have structures that are associated with pollination functions, using "bee sticks" to pollinate their flowers and observing bee and flower structures with guidance. A reading about pollination in Fast Plants further supports students to understand the role that pollination plays in flowering plant reproduction.

## Observed Phenomenon Underpinning the Engineering Problem:

The phenomenon that students observe, giving context to the engineering challenge is that bees' bodies collect and transfer pollen from one Fast Plant flower to another.

## Culturally Responsive Considerations

Integrating students' cultural identities into the storyline of this unit can be done in a number of ways, including the following: Wisconsin Fast Plants are in the group of plants that are called *Brassicas*, and *Brassicas* are used around the world for food. From turnips to broccoli, and cabbage to cauliflower, the diversity of forms that *Brassicas* take are the result of plant breeding done—primarily by women (who are typically the farmers)—in cultures around the world. These plant breeders were engineers, trying to solve the challenge of feeding their families. Nomadic people who needed food that could travel well, for example, bred *Brassicas* that became what we know as turnips. Chinese cabbage, on the other hand, keeps well in cool storage, but would not endure travel well. Students can investigate the role of *Brassicas* in their own families, past and present. Your class can explore by tasting and observing different *Brassicas* served in a variety of traditional dishes.

In addition to the *Brassica* connection, this unit's lessons incorporate five stories that were written for the Wisconsin Fast Plants Program to support students learning about what plants need to grow and reproduce in the context of stories from around the world. These readings are in a reader called *Reading Green* that is written at a grade four reading level and is well suited for reading aloud to younger students. *Reading Green* stories were written intentionally for integration with English Language Arts and Social Studies lessons. (Copies of *Reading Green* are available from Carolina Biological Supply, online at [www.carolina.com](http://www.carolina.com))

## Supported Common Core English Language Arts Standards\*

English Language Arts Standards » Speaking & Listening » Grade 2	English Language Arts Standards » Writing » Grade 2
<p><b>Comprehension and Collaboration</b></p> <p><b>CCSS.ELA-Literacy.SL.2.1</b> Participate in collaborative conversations with diverse partners about <i>grade 2 topics and texts</i> with peers and adults in small and larger groups.</p> <ul style="list-style-type: none"> <li>■ <b>CCSS.ELA-Literacy.SL.2.1a</b> Follow agreed-upon rules for discussions (e.g., gaining the floor in respectful ways, listening to others with care, speaking one at a time about the topics and texts under discussion).</li> <li>■ <b>CCSS.ELA-Literacy.SL.2.1b</b> Build on others' talk in conversations by linking their comments to the remarks of others.</li> <li>■ <b>CCSS.ELA-Literacy.SL.2.1c</b> Ask for clarification and further explanation as needed about the topics and texts under discussion.</li> </ul> <p><b>CCSS.ELA-Literacy.SL.2.2</b> Recount or describe key ideas or details from a text read aloud or information presented orally or through other media.</p> <p><b>CCSS.ELA-Literacy.SL.2.3</b> Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.</p> <p><b>Presentation of Knowledge and Ideas</b></p> <p><b>CCSS.ELA-Literacy.SL.2.4</b> Tell a story or recount an experience with appropriate facts and relevant, descriptive details, speaking audibly in coherent sentences.</p> <p><b>CCSS.ELA-Literacy.SL.2.6</b> Produce complete sentences when appropriate to task and situation in order to provide requested detail or clarification. (See grade 2 Language standards 1 and 3 <a href="#">here</a> for specific expectations.)</p>	<p><b>Text Types and Purposes</b></p> <p><b>CCSS.ELA-Literacy.W.2.2</b> Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.</p> <p><b>CCSS.ELA-Literacy.W.2.3</b> Write narratives in which they recount a well-elaborated event or short sequence of events, include details to describe actions, thoughts, and feelings, use temporal words to signal event order, and provide a sense of closure.</p> <p><b>Production and Distribution of Writing</b></p> <p><b>CCSS.ELA-Literacy.W.2.5</b> With guidance and support from adults and peers, focus on a topic and strengthen writing as needed by revising and editing.</p> <p><b>Research to Build and Present Knowledge</b></p> <p><b>CCSS.ELA-Literacy.W.2.7</b> Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations).</p> <p><b>CCSS.ELA-Literacy.W.2.8</b> Recall information from experiences or gather information from provided sources to answer a question.</p>

\* Contents of the above table excerpted from the Common Core State Standards Initiative online at [www.corestandards.org](http://www.corestandards.org): © Copyright 2010. National Governors Association Center for Best Practices and Council of Chief State School Officers. All rights reserved.

## Overview Calendar

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
	<p>This calendar shows the recommended start dates for lessons and can be modified to meet your own classroom requirements. For additional details about Wisconsin Fast Plants (planting, tending, troubleshooting, producing seed, and more) visit our website at <a href="http://www.fastplants.org">www.fastplants.org</a>.</p> <p>Set up lighting system and prepare planting materials prior to Lesson 2.</p>					Lesson 1: A bouquet of flowers
Week 1	3	4 Lesson 2: Do plants need water? Exp 1	5 Lesson 3: Planting Fast Plants	6	7	8
			Lesson 4: Gathering and recording information			9
Week 2	10	11	12	13	14	15
	Lesson 4: Gathering and recording information			Lesson 5: Explanations, Exp 1	Lesson 6: Do plants need water? Exp 2	16
	<b>Thin Fast Plants</b>				Fill water reservoirs	
Week 3	17	18 Lesson 7: Do plants need light? Exp 3	19	20	21	22
			Lesson 8: Bees and pollination			Lesson 9: Designing a bee solution
		Reading Green Story 1				
			Reading Green Story 3			
Week 4	24	25 Lesson 10: Explanations, Exp 2	26	27	28	29
			Reading Green Story 5			Lesson 11: Explanations, Exp 3
	Pollinate	Pollinate	Pollinate	Pollinate	Fill water reservoirs	
					Reading Green Story 2	
Week 5	Lesson 12: Completing the life cycle By Week 5 pods develop, seeds form, and students can experience the full flowering plant life cycle. Reading Green Story 4 describes the structure and function of seeds.					30

## Materials

### Lesson A

*For each student:*

- bee stick materials (see Teacher Page A Making Bee Sticks)
- 1 copy of Student Page A *Honeybees*

*For each group of 2-3 students:*

- One deli container growing system with flowering Fast Plants
- Lily flower (optional)

*For the class:*

- *Structure and Function* Chart (see Teacher Page B *Sample Structures and Functions Chart*)
- Reading Green Story 3 *Fast Plants*\*

### Lesson B

*For each student:*

- drawing materials

*For the class:*

- a wide variety of materials for model construction (see Advance Preparations)
- *Structures and Functions Chart* from Lesson A
- Reading Green Story 5 *The Bee-less Beehives*\*
- *We are learning like scientists and engineers when we . . . Chart*



\*Reading Green stories are available from [www.carolina.com](http://www.carolina.com)

## Prior Knowledge Considerations

Students need to understand basics about the life cycle of flowering plants: that plants produce offspring by developing seeds, and seeds grow into a new plant that grows until it is able to develop flowers.

### Some Relevant Typical Prior Conceptions Students May Hold\*

#### **1. Plants do not reproduce in the same sense that animals do.**

Plants and animals both reproduce sexually with sperm and egg uniting to form the first cell of a new individual – the fertilized egg. There is an equal contribution of male and female hereditary material, just as in animals. Children may hold this idea because they associate reproduction with the act of mating in animals and they do not observe females or males in plants. **Implications:** Engage students in actively pollinating flowers, observing the transfer of pollen (containing sperm) to pistils (containing eggs) so that fertilization can occur, then make comparisons to the more familiar mating in animals.

#### **2. Plants are neither male nor female.**

Plants have male and female reproductive structures. The male structures produce sperm and the female structures produce eggs. In many cases, both male and female reproductive structures occur on the same individual (in flowering plants, they are found in the flower). In other cases there are individuals of “separate sexes.” Children may hold this idea because they don’t observe what is familiar to them as a female or male and they don’t understand that plants reproduce sexually. **Implications:** For Fast Plants to successfully reproduce, sperm contained in the pollen from the male structures of a flower must be transferred to the eggs contained in the female structures of a different flower. This is why pollinators are essential; pollen cannot simply fall from the anthers to the stigma of the same flower (if this happens, the sperm is aborted in most cases). Many types of flowers are able to self-pollinate, but Fast Plants are not.

The position of the stigma relative to the anthers is another good example of the relationship between structure and function. In flowers that *can* self-pollinate, the pistil is typically shorter than the anthers so that pollen can drop directly from an anther to the stigma. Look closely at the relative positions of the stigma and anthers in Fast Plants to see how the relationship of these structures serves the function of cross-pollination.

#### **3. Flowers are for insects to feed upon.**

Children often think that one life form exists to serve another. When they observe insects feeding on flowers, this may be a conclusion. Life forms, however, do not have a “purpose”; they have functions, which may include being beneficial to other life forms. Flowers do function to provide food for many insects, but the sole function of a flower for the plant is reproduction. **Implications:** Understanding the function of flowers is fundamental to this lesson, and learning about the interdependence and mutual benefits that bees and flowers share can clarify misconceptions about the “purpose” of flowers.

#### **4. Fruits are always sweet, fleshy products of plants.**

A fruit is the ripened ovary formed from a flower. A fruit contains the seeds. Many things that children consider vegetables are actually fruits, including pea pods, cucumbers, peppers, and tomatoes. Nuts and pods are also fruits. **Implications:** After successful pollination occurs in Fast Plants, the pistil of the flower elongates and becomes the fruit. This fruit can be compared to a green bean or snap pea to show how the seeds are contained within. After two weeks, it will be easy to see the Fast Plant seeds developing inside the pod that formed from the pistil by holding a pod up to a light.

\* Descriptions of *Children’s Ideas About Animal Life Cycles* provided by the Annenberg Learner website with teacher resources and professional development across the curriculum, Life Science: Session 4 online at: <http://www.learner.org/courses/essential/life/session4/ideas.html>



## Lesson A: Bees and pollination

### Lesson 8 in the original unit, Week 3: Tuesday - Thursday (Days 14 - 16)

During the days that are supported by this lesson, students observe flowers on their 14 to 16 day old Fast Plants and bee structures, learning to connect how the shape of a structure is related to its function. Then, students make and/or use bee sticks to conduct pollination. Finally, students look closely at how pollen is carried on bee bodies and where pollen moves within the flower as concrete examples of the relationship between structure and function.

#### Advance Preparations

- a) Plan what will be the most effective strategy for reading aloud the Reading Green Story 3, *Fast Plants* during these two days.
- b) Prepare bee sticks in advance or prepare materials for students to make bee sticks on Tuesday so that they can dry and be ready for use on Thursday or Friday if flowers are open. See Teacher Page A *Making Bee Sticks* for instructions. The bees are less likely to break while making the bee sticks if they are placed in a sealed plastic bag with a moist tissue so they are less dry and brittle.
- c) Obtain small magnifier boxes or other magnifiers that students can use to look closely at flowers and a dried bee. If possible, prepare a method to project a magnified view of a bee for the class to see and discuss.
- d) Prepare a wall space or chart paper to create a *Structures and Functions Chart* in which a simple sketch of the structures that students observe in Fast Plant flowers and then bees can be recorded along with their functions in pollination and reproduction.

Teacher background information about pollination is provided in the Teacher Pages to support teaching students about the roles of the different structures they observe.

- e) Make a copy for each student of Student Page 3 *Honeybee*. Students will need either crayons or colored pencils to color this page (with plenty of yellows to go around).

**NOTE:** Plan for students to have at least three opportunities to pollinate the class's Fast Plants with bee sticks while they are flowering so that enough seeds will be produced that students can learn what results from pollination (pollinating every other day or so for a week during flowering is fine).

#### Lesson Implementation Outline

1. Begin with closely observing flowers.
  - a) Create a *Structures and Functions Chart*, using observations that students make about the structures visible in Fast Plants' flowers. Use Teacher Page B *Sample Structures and Functions Chart* as a guide.
  - b) If you are able to take a picture of a Fast Plant with an iPad or use a microscope camera, you will be able to zoom in and show students the pollen grains and more closely observe the other flower structures.
2. Read with students Reading Green Story 3, *Fast Plants*. In this story, students learn about where Fast Plants originated, how Fast Plants reproduce, and hear about other students growing Fast Plants and making bee sticks.
  - a) Hold discussions to relate the examples of flowering Fast Plants in the story to the developmental stage that the class's Fast Plants are now reaching.

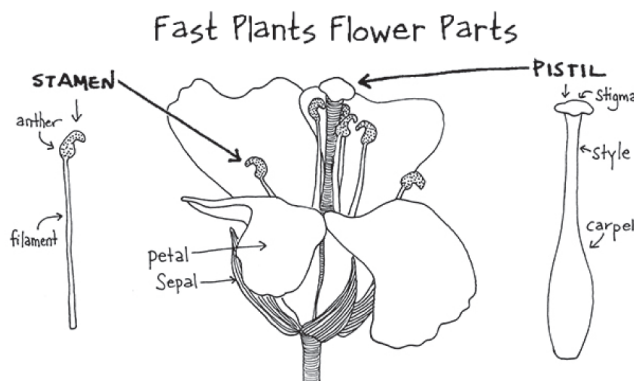
- b) Keep in mind that the learning goal for students is to understand that plants have structures that are shaped in ways that are related to their functions. Memorizing the names of plant parts is not a goal in these lessons.
  - c) Again, have students look closely at the parts inside their Fast Plants' flowers, and add to the class *Structures and Functions* chart as needed..
  - d) You may choose to bring in cut lilies from a florist for students to examine and compare to their Fast Plants' flower structures (these are frequently available at little or no cost if you ask for flowers that are too old to sell). Lilies have large flowers with easy to see structures.
3. Using Teacher Page A *Making Bee Sticks* as a guide, have students make or provide bee sticks for the class.
  - a) Guide students through a session of carefully observing bees.
  - b) Focus on identifying body structures and making inferences about their functions. Use Teacher Page B *Sample Structures and Functions Chart* as a guide; however, allow students to learn about those structures related to pollination after they can see pollen on their bees (see #4-#5).
  - c) Reinforce the ideas that are presented in the *Fast Plants* story that explain the relationship between bees and plants.
4. Begin the first pollination by explaining how students need to "fly" gently among the flowers on their plants, carefully landing their bee inside of one flower and rolling it around a bit, then moving on to another flower.
  - a) Project a picture of Fast Plants flower and remind students how pollen must move from the anther of one flower to the pistil of another to make a baby Fast Plant that will be protected inside a seed.
  - b) Playing the song *Flight of the Bumblebee* and having students buzz as they pollinate is one of the many clever ways teachers have made pollination special in their classrooms.
  - c) Have students pollinate all flowers at least two days. Pollinating every-other day for 7-10 days will result in better pod and seed production.
5. After pollination, look closely again at the bees and flowers for signs of pollen in new places (e.g. stuck to various parts of the bees and on the stigma of the flowers). Projecting a bee and flower for the class to look at together is helpful and offers another good opportunity for an interactive discussion about how structures are shaped for their functions (e.g. the hairs on bees pick up pollen well, the fat part of a bee's hind leg gives the bee more room to carry pollen, the bright yellow petals attract bees, etc.)
  - When students are finished looking at their bees, they can be safely stored by sticking the toothpick into the soil near their Fast Plants.
6. Distribute copies of Student Page 3 *Honeybees* for students to color. The purpose of adding color is for students to record where they understand pollen can be found on Fast Plant flowers and on bees visiting flowers.
  - Circulate as students color to check for understanding, asking students to say how they think the shapes of various structures relate to their functions.
7. At least every-other day from this point forward, give students time to observe seeds develop from flowers on their Fast Plants and record and/or talk as a class about their observations.
  - Encourage students to look closely at the soil and wick, also. There may be roots (another observable plant structure with an important function) visible through the side of the deli-container or growing down along the wick.

## Teacher Page A: Making Bee Sticks

### Fast Plants and Bees

In Fast Plants, bees and other insects distribute pollen. Fast Plant pollen is heavy and sticky—unable to be easily wind-borne. Bees are marvelously coevolved pollen vectors (transferring devices) for Fast Plants.

Bees depend on flowers for their survival. Sugars in the nectar provide carbohydrates to power flight and life activities. Pollen is the primary source of proteins, fats, vitamins, and minerals to build muscular, glandular, and skeletal tissues in bee larvae.



Bees are members of the insect family Apidae, which are unique in that their bodies are covered with **setae** (feather-like hairs). The bright yellow petals of Fast Plants flowers act as both beacons and landing pads for the bees, attracting them to the flower and guiding them to the nectaries. The bee drives its head deep into the flower to reach the sweet nectar secreted by the nectaries, brushing against the anthers and stigma in the process. Quantities of pollen are entrapped in its body hairs, and bees gather as much of this pollen as they can to carry back to their hive (Teacher Page B *Structures and Function Chart* has more details about how bees transport

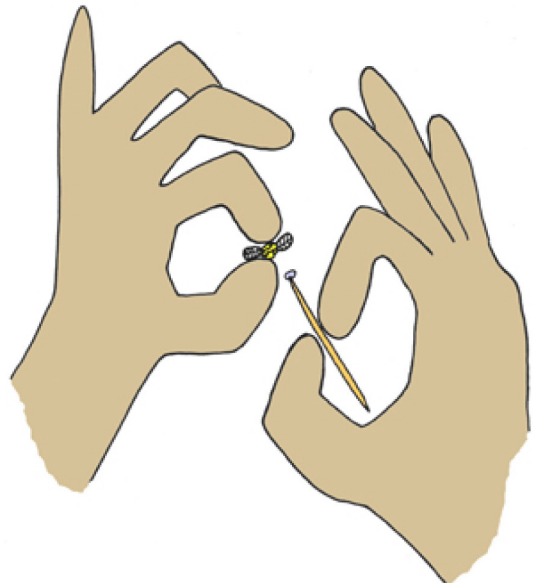
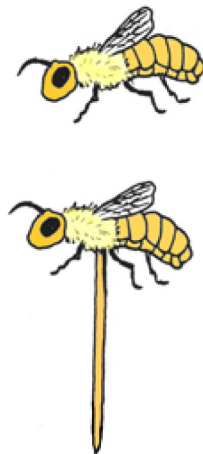
pollen in “pollen baskets” located on their hind legs. Still, much pollen remains stuck in their setae.)

As the bees work from plant to plant, pollen on the setae is carried from flower to flower. The transfer of pollen from an anther to a stigma is known as pollination. When pollen is transferred from one plant to another, the process is called **cross-pollination**.

### Making Bee Sticks

- Put a drop of glue on the end of a round toothpick.
- Push the “glue” end of the toothpick into the top of the bee’s thorax.
- Stick the toothpick into a piece of Styrofoam or similar material so the bee is undisturbed while the bee stick dries.
- Dry the bee sticks overnight (or at least for a couple of hours).


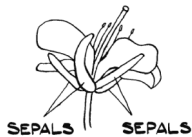
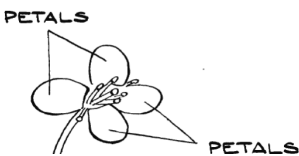
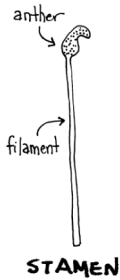
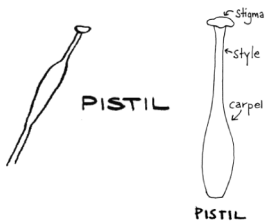
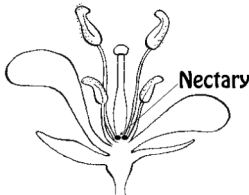
### Bee sticks






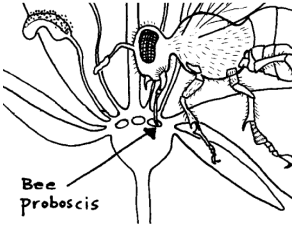
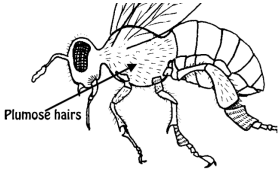
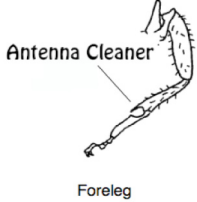
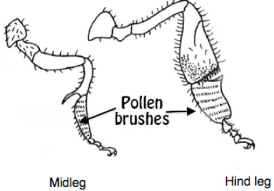
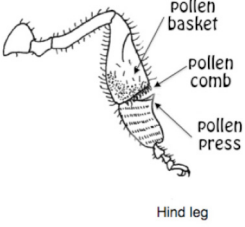
## Teacher Page B: Sample Structures and Functions Chart

NOTE: The detail given here for structures' functions is intended to support *teachers* who will then translate and communicate at the appropriate grade level for their students.

Evidence of Structures and Their Functions: Flowers	
Structure	Function
	Fast Plant flowers are the reproductive structure of these fruit-producing plants. Although there are many different types of flowers, most flowers have the same basic parts.
	Sepals are modified leaves and are usually green. Early in flower development, sepals wrap around the developing flower, forming a bud that is visible around 8-12 days after planting Fast Plants.
	Petals are modified leaves that are usually colorful. Fast Plants petals are yellow, and they have four. Petals usually serve to attract pollinators to a flower and provide a "landing pad."
	Stamens are the male parts of the flower that lie inside the ring of petals. Stamens consist of a long stalk or filament with a pollen-carrying anther at the tip. The anthers release pollen after the flower opens.
	<p>Pistils are the female parts of the flower that lie inside the ring of stamens, at the center of the flower. The pistil collects pollen on its sticky top structure, called the stigma. Inside the base of the pistil (called the carpel) are the eggs that will develop into Fast Plant embryos contained inside of seeds when fertilized by sperm. The sperm comes from pollen that successfully stuck to the stigma.</p> <p>When a pollen grain lands on and sticks to a stigma, it grows a pollen tube that extends into the style of the pistil so that the sperm can travel down the tube to meet the eggs contained in the carpel.</p>
	Nectaries are tiny structures around the base of the pistil (see below) that produce a sugary sap. This nectar is highly nutritious and attracts pollinators. The glistening nectar and plump nectary can be visible in a carefully dissected flower.

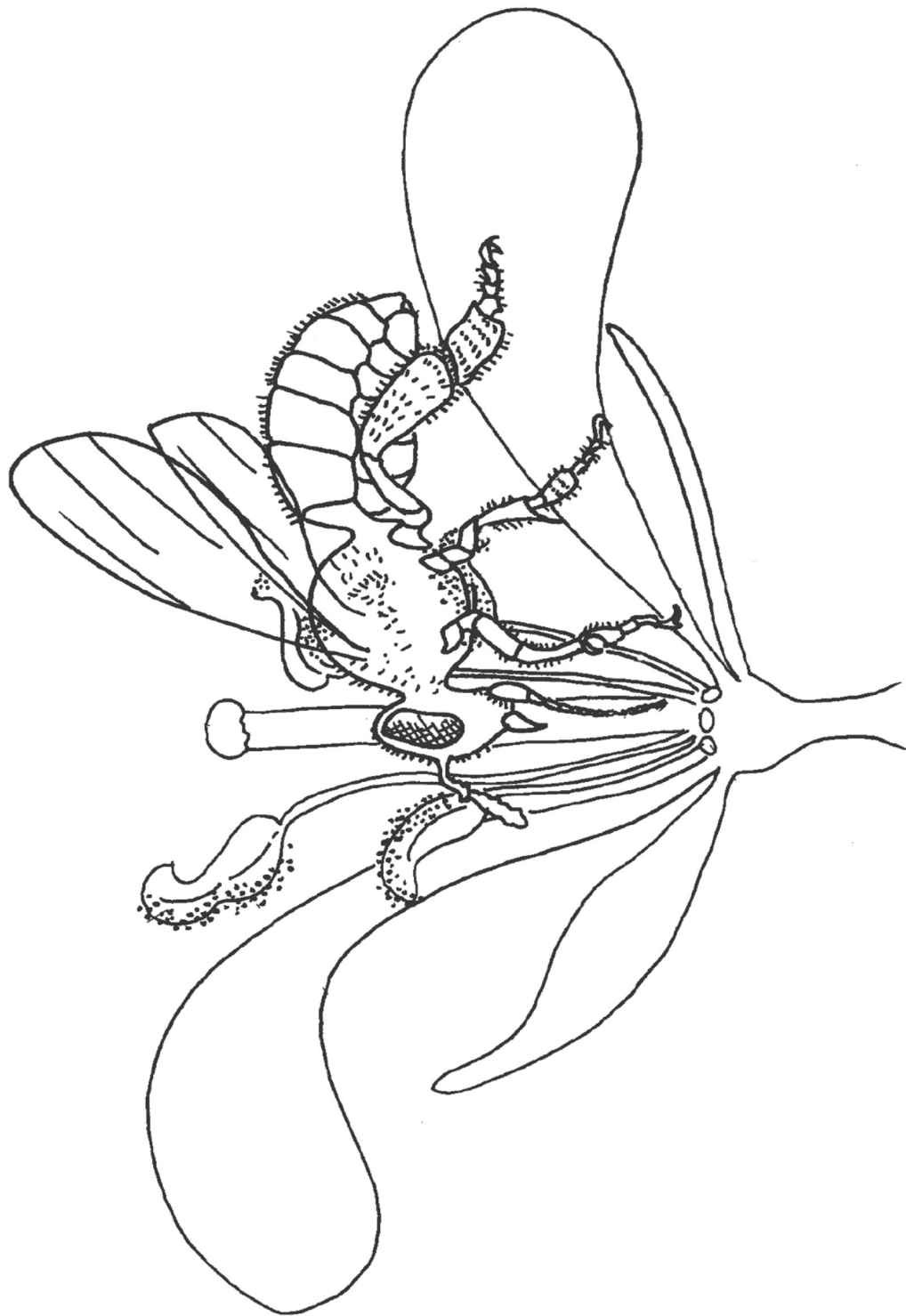


## Teacher Page B: Sample Structures and Functions Chart (continued)

Evidence of Structures and Their Functions in Pollination: Bees	
Structure	Function
	Bees and other pollinators visit flowers to obtain nutrition. Flowers—with their sugary nectar and protein rich pollen—are an important food source for bees. Wings allow bees to fly from flower to flower, and their legs allow them to land on flower petals and move about, seeking nectar.
	The bee's proboscis is a tube-like mouthpart that allows the bee to reach deep into a flower and suck out the nectar.  In this feeding process, a bee's body disturbs parts of the flower, picking up pollen from one flower and transferring it to the stigma and pistil of another flower.
	The plumose (feather-like) hairs on a bee's thorax are well suited for collecting sticky pollen. As bees search for nectar within a flower, pollen rubs off of a flower's anthers and gets stuck on these and other body hairs.
	The bee's foreleg has a notched region that contains spines. Bees can rub this part of their forelegs over their heads and antennae to brush off and collect pollen that became stuck there.
	A bee's mid and hind legs are lined with spines that serve as pollen brushes to collect pollen that sticks to its head, thorax, and forelegs.
	The bee's pollen basket is the final destination for pollen that it collects. Using the pollen comb, the bee transfers pollen from the pollen brushes onto the pollen press. By flexing its leg, the pollen is packed into pollen baskets, which are enclosed by long, rigid hairs. When a bee's pollen baskets are full, it returns to the hive, bringing pollen to feed its colony.



## Student Page A: Honeybees





## Lesson B: Designing a bee solution

### Lesson 9 in the original unit, Week 3: Friday (Day 17) and into Week 4

This lesson begins on Day 17 (meaning 17 days after planting) and could be done in a single long day or spread out over several days. Students have the opportunity to use a wide variety of materials to design a solution to a problem (no bees). The solution will be a simple model that mimics the function of a bee in pollinating plants. Students can test their models and compare them to bee sticks during Week 4.

#### Advance Preparations:

- a) Read through this lesson, and plan a timeline for designing, building, and testing a solution as outlined in Steps 1-11. These activities can be carried out during Week 4 as needed and enriched by Reading Green Story 5, *The Bee-less Beehives*.
- b) For this lesson a wide variety of materials need to be available from which students can choose to make a model that mimics the function of a bee in pollinating Fast Plants. The following is a list of potential materials:

cotton balls	stir sticks	tape
small pompoms	twigs	clay
small feathers	straws	string and/or macramé cord
Velcro (both hook and soft sides)	pencils	marbles, silky materials, and other materials that would not work well to pick up or deposit pollen
pipe cleaners	glue	

#### Lesson Implementation Outline

1. Begin this lesson by posing a challenge to the class with a prompt such as: *What if I could no longer get bees like we used to make our bee sticks? How could you make a model that would work like a bee does in pollination? That is the problem that I want you to solve by engineering a solution.*
  - a) Explain and add to a *We are learning like scientists and engineers when we . . .* chart that scientists and engineers: *Ask questions, make observations, and gather information to help think about solving problems*, and encourage students to do this, too.
  - b) Begin supporting students to understand this engineering challenge by holding a review session about the relationship between bees and Fast Plants. Begin by asking, *What do bees do for Fast Plants?*
    - Refer back to the *Structures and Functions Chart* developed in Lesson A.
  - c) Help students recall from Lesson A where pollen was gathered by the bee and their observations about where pollen is located in the flower.
2. After the class has reviewed and explained how bees move pollen from one Fast Plant flower to another, continue with an interactive discussion for students to **define what the solution to the following problem would need to include for it to replace the functions that bees provide for Fast Plants**. Write this “engineering problem” on the board or chart paper: *“How can you design a model that mimics the way a bee pollinates Fast Plants’ flowers?”*

***Engineering Problem: How can you design a model that mimics the way a bee pollinates Fast Plants' flowers?***

Hold an interactive discussion in which you build on students' ideas to develop a list of criteria for the solution to this engineering problem. The key idea that students need to grasp from this discussion is that a successful model needs to mimic the pollen transfer that bees accomplish for plants when they fly from flower to flower. However, for this particular solution, the model does not need to mimic the many other things that bees do.

Also, guide the discussion to address that bees typically do very little damage to flowers as they spread pollen, and a successful solution in this case needs to do the same.

From this discussion, use students' words, and chart what the key criteria will be for a solution to the problem. The class criteria should, at a minimum, include the following:

- is able to move from flower to flower
- does not break the flowers
- collects pollen and carries it flower to flower
- collects at least enough pollen that we can see the pollen with a hand lens (or iPad photo, or...)
- is small enough to fit inside of a Fast Plant flower and rub against the inside parts of the flower

3. Add to the *We are learning like scientists and engineers when we . . .* chart that scientists and engineers also *Define and develop solutions for problems*. Explain and provide a timeline for how students will work individually like scientists and engineers to develop possible solutions that could be built from the materials available (you may also allow other materials, provided students check with you, first).

- a) The first step is for students to think and study the materials available.

- b) Then, students work individually to draw a simple picture that shows their plan for a solution and prepare to explain why their plan will solve the problem well.

- Guide students to use color to show which structures in their plan are intended to accomplish the function that is important for the solution to be successful. Use a prompt such as: *Color your picture so that we know what part of your model you have designed to pick up pollen. Be ready to explain how your model solves the problem by replacing the bee's role.*

- c) Circulate among students as they are making their drawings, asking how the shape of specific parts of their model help it function as needed to solve the problem. **Refer explicitly to the class criteria for a good solution that was defined in #2.**

- d) Next, students present their drawings to communicate their ideas for a solution. Feedback will be given at this time, and designs can be modified. *Note: At this point students could be placed in groups to carry out their plans and build bee models; although, working individually can have advantages for some learners.*

- e) Add to the *We are learning like scientists and engineers when we . . .* chart that scientists and engineers also *Communicate solutions with others using drawings that include details about scientific ideas.*

5. Explain the class timeline for building and testing students' models.

6. When ready to build the models, provide materials and space. Have students construct their bee replacement solutions, and give them time to dry as needed.
7. Follow your plan for having students test their solutions by using their models to pollinate plants.
  - Have students look closely for signs that pollen was successfully transferred from flowers to the model. Use a document camera or dissecting microscope if available (or hand lenses) to look closely with students at their models for signs of pollen transfer on both the model and flower stigmas. Also, look for flower breakage and other evidence that the model did or did not meet the class criteria for a successful model. *Guide students to carefully record these observations as a class and/or individually; this is the evidence that students will use to explain how their solutions worked and engage in argumentation.*
8. Provide grade level appropriate opportunities for students to write about and present the different solutions that were generated and tested. Guide students to use argumentation practices to present a case that their models were successful (or not), and evaluate which models seemed to meet the goals for mimicking a bee pollinating Fast Plants.
  - a) Models that do not work as solutions for the problem are important, too. Students can learn from these “failures” that engineered solutions usually require multiple trials and refinement. Students can still present solutions that did not work out, using evidence-based claims to explain why they do not think the model was successful (same sentence stems as in “b”).
  - b) Sentence stems like the following can be used to support students in formulating an argument in support of a model that they believe was successful in solving the problem:  
*I think this model is a good solution because \_\_\_\_ (evidence) \_\_\_\_*  
*To make this model a better solution for the problem, I would \_\_\_\_ because \_\_\_\_ (evidence) \_\_\_\_*
  - c) As students present their solutions and arguments, coach their classmates to critique each other’s claims about the success of their models, using statements such as:  
*I agree with your claim about your model because \_\_\_\_ (evidence) \_\_\_\_*  
*I disagree with your claim about your model because \_\_\_\_ (evidence) \_\_\_\_*
9. Add to the *We are learning like scientists and engineers when we . . .* chart that scientists and engineers *Make and use models, and argue with words about explanations or solutions*. Use the chart, and review as a class all the different ways students engaged in science and engineering practices to make their models.
10. Use Reading Green Story 5, *The Bee-less Beehives* to reinforce students’ understandings of the relationship between flowering plants and pollinators.
11. Conclude this engineering experience with a class reflection on how the shape of the materials they chose to use in their bee models (structures) influenced how well the solution worked (function).

