# The Bee Cause Project Guide to STE(A)M Investigations for the Hive

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Watching your honeybees at work in the observation hive is fascinating for teachers and students alike. These tiny creatures collaborate to build and maintain a complex community within the hive. With the natural wonder of the hive made visible in the observation hive, there are endless opportunities to promote critical thinking and STE(A)M skills. Students can practice these 21st century skills while observing real world examples, and gaining a deeper understanding of and respect for the natural world.

> "We must make core subjects like math and science relevant for students, and at the same time, foster creativity, curiosity and a passion for problem solving. That's what STEM education does. STEM is about using math and science to solve real-world challenges and problems. This applied, project-based way of teaching and learning allows students to understand and appreciate the relevancy of their work to their own lives and the world around them. Once they grasp core concepts, students are able to choose a problem and use their own creativity and curiosity to research, design, test and improve a viable solution."
>
> - Vince Bertram as quoted in web article "Why STEM? Success Starts With Critical Thinking, Problem-Solving Skills", posted on wired.com

Basic knowledge about how plants and bees are dependent on each other is just the beginning. When students begin to see our role in the ecosystem – both the negative and positive impacts – they can ask relevant and important questions. With an engineering design or growth mindset they can work to find real solutions. And these critical thinking skills can be applied across the curriculum.

This guide will give you some ideas to help you get started with these investigations. And there are numerous websites with background information and lessons using the honeybee and hive as the backdrop for STE(A)M investigations.

If you do not already have our **Bee Wise Guide**, please use the link to download your copy. It is an excellent introduction to honeybees and the hive. And it provides much of the base knowledge students need to begin the conversation about the importance of honeybees and our role in their survival. The National Honey Board also has a great downloadable booklet called **The Honey Files**. Whether your primary goal is to have students learn about honeybees or to hone math and science skills, there are a myriad of opportunities to engage students with the world of bees and your observation hive!

## Resources

**Bee Wise Guide**
http://www.thebeecause.org/index.php/resources

**The Honey Files**
http://utah.agclassroom.org/files/uploads/estore/honey_files.pdf

video version
https://www.youtube.com/watch?v=VZV8Jq3ka4s&feature=youtu.be

Documentaries:

"Tales from the Hive" – PBS Nova
"Vanishing Bees" – vanighingbees.com
"More Than Honey" – morethanhoneyfilm.com
"Queen of the Sun, What the Bees Are Telling Us" – queenofthesun.com

# Pollination Investigations

Honeybees depend on plants just as much as the plants depend on bees. Many plants produce nectar, a sweet liquid, to attract bees and other pollinators. Bees gather this liquid as food. The nectar's scent attracts bees to the plant. Many flowers are also colored to signal that they contain nectar. The flowers are shaped to ensure that visiting honeybees will spread pollen in return for the food.

> As you can see, the partnership between bees and plants is important to life for both. Without plants producing nectar and pollen, bees wouldn't have food. And without bees visiting the flowers to collect nectar, many plants wouldn't be able to reproduce. This partnership benefits another group too – people!
>
> excerpt from
> *The Case of the Vanishing Honeybees* Sandra Markle

Approximately 30% of our crops, and as many as 90% of wild plants, depend on pollinators. Plants like blueberries and almonds depend entirely on insects for pollination. What would happen if there weren't enough bees? How could humans help? On the following pages are some investigations to help get students thinking about – and perhaps solving some of these problems.

# Investigations for Elementary

## Create a Better Pollen Basket

It is hard to improve on nature. Have students observe the way pollen baskets on the bee's legs can be filled with the yellow pollen. Pollen also sticks to the bee's body as it collects nectar and pollen. How does the pollen stick to the bee? Can the students think of a more effective adaptation than the pollen baskets?

After learning these basics, challenge students to:

- Create a bee that is better suited for collecting pollen for the hive or for pollination of plants.
- Have students become bees themselves, outfitted with their own version of pollen collecting adaptations.

## Fast Facts:

A honeybee will visit 50 to 100 flowers on a single trip out of the hive.

Honeybees pollinate more than 90 different kinds of food crops.

Bees see the color red as black. Anyone wearing red or black may be seen by the bees as a threatening predator.

## Bee Attractors

Honeybees do seem to see different colors, but not all colors. And they do not see colors the same way that we humans do. Bees don't see as many color variations. One color they do see that we do not is ultra violet. In another amazing adaptation of nature, flowers have ultra violet color markings in the areas where the nectar and pollen can be found! This, along with scent, guides the bees to just the right spot. The markings on the flowers can be seen in the classroom with UV lights.

Using this knowledge, have students consider how they might help honeybees find their way to flowering plants. What devices or strategies could attract bees to a garden or crop? Would this be beneficial? Could the bees be harmed by such a human intervention?

- Create and implement ideas on campus and monitor bee traffic.
- Design an urban environment that minimizes interference with the natural foraging process.

# Investigations for Intermediate and Upper Grades

## Static Electricity

As bees fly, they build up static electricity. This static electricity helps pollen stick to the bee's body as she flies from flower to flower because plants generally have a slightly negative charge. This combination of positive and negative charges allows for the cross pollination to take place. Is there a way to control static electricity around the bees or at the sight of the plants to maximize the amount of pollination taking place as the bees fly from one plant to another?

- Have students experiment with ways to use static electricity as a means to attract and hold on to other matter.

### Fast Facts:

Bees develop a positive charge when they bump into tiny dust particles as they fly through the air.

## Human Pollinators

Honeybees are responsible for pollinating at least 90 different kinds of food crops. And they do so with amazing efficiency. Colony Collapse Disorder (CCD), pesticides, mono-cropping and numerous other environmental factors are now placing the honeybee population at risk. A day may come when we do not have enough bees to pollinate our crops. Could humans do the job?

- Have students design clothing, devices or equipment to facilitate pollination.
- Have students explore techniques or tools for transferring pollen from one plant to another.
- Using their pollination suits or tools, have students attempt to pollinate a set number of plants as quickly as possible. Based on results, students revise their designs and/or technique. Is it reasonable to think that humans can replace bees in the pollination process?

Along with their ultraviolet vision, bees use each flower's own electrical field to help direct them right to the nectar.

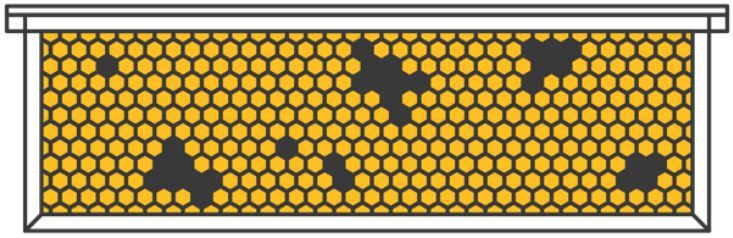
**See the National Park Services Bee Week curriculum for this and other interactive lessons.
https://www.nps.gov/subjects/pollinators/upload/FINALBee-Week.pdf

# Hexagon Investigations

What it is about the hexagon that makes it the best shape for the honeycomb. The consistent size and shape seem to be ideal for not only making honey, but also for growing new bees.

> "In 36 B.C., Roman scholar **Marcus Terentius Varro** came up with the answer of why honeycomb cells are hexagons, in what since has been called the **Honeycomb Conjecture**. Varro guessed that hexagon is the best way to divide a surface into regions of equal area with the least total perimeter - basically, it's the most compact (and therefore efficient) structure - but he couldn't prove it mathematically."
>
> from **The Honeycomb Conjecture**
> by Alex Sansantoso at neatorama.com

It wasn't until 1999, some two thousand years after Varro came up with his original conjecture, that a professor at the University of Pittsburgh, **Thomas C. Hales**, came up with the mathematical proof for Varro's original theory. The history of mathematics, the simplicity of geometric shapes, and the artistry of a shape repeated over and over again into a beautiful pattern are all connected here in the hive. The honeycomb is a fantastic starting point for explorations in all of these areas.



# Investigations for Elementary

## Spatial Relationships

Piaget (1954a) considered the concrete stage a major turning point in the child's cognitive development, because it marks the beginning of logical or operational thought. The child is now mature enough to use logical thought or operations (i.e. rules) but can only apply logic to physical objects.

Children in the concrete operational stage are typically ages 7 to 11. They gain the abilities of conservation (number, area, volume, orientation) and reversibility. Their thinking is more organized and rational. They can solve problems in a logical fashion, but are typically not able to think abstractly or hypothetically.

- Have children design their own honeycomb using pattern blocks or templates with the goal of no empty spaces between the shapes. Then have students classify the shapes that can be used and those that do not 'fit' together.
- Collect a wide variety of materials and have students construct 3-d honeycombs.

### Fast Fact:

Scientists found certain bees would start out making circles in the wax using their body as a tool. Scientists don't really know why it happens, but the bees seem to be using their body heat to melt the wax from a circle shape into a hexagon shape.

## Hexagonal Thinking

Hexagons make the perfect shape for the beehive. They can also be a great tool for organizing and processing information. Cut or punch multiple hexagons of at least 3 to 4 inches in diameter. Use the hexagons to create a graphic organizer web.

- Stage 1 – the teacher writes the information on the shapes, and then the students sort and organize them into a web with related shapes touching side to side.
- Stage 2 – students write their own information on the shapes, and then arrange them to show the relationships between the pieces of information.

# Investigations for Intermediate and Upper Grades

## Fast Fact:

Regular hexagons with equal sides and equal angles are a commonly found shape in nature. The honeycomb of bees, for example, is a naturally occurring instance of the hexagon. Minerals and crystals often form hexagonal shapes naturally, while the chemical compounds of graphene and benzene naturally form hexagons at the atomic level. -from reference.com

## The Ultimate Shape

So why the hexagon. Could another shape or design be more efficient? How can we demonstrate (or disprove) the efficacy of Varro's argument?

- Have students construct and compare various basic shapes. Consider structural integrity, capacity of the cells, amount of material needed to cover a finite area with each of the different shapes.
- Compare two shapes and write a proof for why one has greater strength or capacity.

## Tessellations

Tessellations are a fun way to explore shape and pattern. The honeycomb is a tessellation of hexagons with hundreds of bees working together to repeat the pattern simultaneously. Euclid is commonly credited as the Father of Geometry. On these websites; euclidthefatherofgeometry.weebly.com/tessellations.html, and mathforum.org/sum95/suzanne/whattess.html, you can find further discussion and explanations about the tessellation and its various forms.

- Only 3 basic shapes tessellate in a Euclidian plane. Experiment to determine why and write a rule for this. Why do you think the bees use the hexagon and not the other two shapes?
  - Is one shape superior to the others? How?
  - Formulate an equation for the volume of liquid a specific area of cells can hold. Does the equation hold true regardless of the size of the individual cells within the space?

# Hive Climate Investigations

Honeybees maintain a steady temperature inside the hive through the season. You can feel the warmth when you place your hand against the observation hive. While we go from winter to summer and back again the bees in the hive keep the temperature around the brood at 93-94*F (33.9-34.4*C). In the colder winter months, without brood to care for, the bees will cluster together for warmth. They can keep their temperature at 85*F (29.4*C) despite winter temperatures outside. The bees also manage to evaporate moisture from the nectar in the cells of the comb regardless of outdoor humidity levels. They work until the honey is approximately 18% water before they cap the cells.

> "The phenomenon known as *bee bearding* refers to the clustering or hanging of older bees outside the front face of the hive during very hot weather, giving the impression of a beard. This behavior is common on hot, humid days when temperatures reach high 80s and 90s (27-33*C)."
>
> excerpt from The Beekeepers Handbook
> Sammataro and Avitabile

Most of the time the bees are fine on their own. But in extreme temperatures, beekeepers may decrease stress on the colony by helping the bees to maintain a healthy climate in manmade hives. Are there things that humans could do to help the bees to maintain the ideal climate in the hive regardless of outdoor conditions?

# Investigations for Elementary

## Fast Facts:

1300 bees inspect and visit each larvae, visiting each larvae up to 7200 times!

Bees make 1 to 50 trips per day collecting pollen. These trips can last anywhere from 6 to 200 minutes.

## Warm in the Winter, Cool in the Summer

We know that honeybees are able to heat and cool their hive to maintain appropriate temperatures. Karl von Frisch was the first scientist to study bees in a systematic way. His investigations are credited with uncovering how bees smell, see, tell time and communicate. He is also said to be the first to decode the waggle dance and round dance. Though his explanations were not immediately accepted, he and two other scientists won the Nobel Peace Prize is Physiology in 1973 for their pioneering work with bees. (source: The Bee Book, 2016, published by DK)

- Test materials to find which are the most effective and efficient for heating and cooling.
- Design tools or interventions to help cool the hive in hot weather or to insulate the hive in cold weather.

## Design Your Own Hive

The bees seem to do well in manmade hives. But apiarists and scientists continue to look for better ways to care for and house bees.

- Have students design their own hives, telling why they made the design choices they did. What needs of a bee colony does their hive address?
- As a class, build you own hive. Rather than pre-cut wood and the standard design, collaborate on a structure that meets the needs of a bee colony and build it yourselves.

# Investigations for Intermediate and Upper Grades

## Climate Control

The bees needs to maintain a certain temperature around the brood and within the hive itself. They also need to be able to evaporate enough moisture from the honey before it is ready to be capped. Currently most hives are made from wood.

- Investigate the impact of painting the outside of the hive. Use models to determine if paint or its color has any impact on interior temperature.
- Construct hive models out of various materials. Monitor the temperatures (and humidity) in each to see if there is a superior material for hive construction.

### Fast Facts:

It takes the heat equivalent to that of a 20-watt light bulb to maintain the brood nest temperature.

## A Better Hive Design

Honeybees naturally seek dark, protected spaces to call home. They will build a hive in a tree, a cave, and even inside the walls of a house. There are several types of manmade hives most often used in beekeeping, but still apiarists seek to improve on the designs. Two recent developments are the Flow Hive and the  The Flow Hive was designed to harvest honey with less intrusion and stress on the bees. The Hive was designed as a means to control mite infestations without using pesticides or medicines on the hive. Still other designs could address other problems facing the honeybee population.

- Create a potential hive design that addresses an area of need for the bees or beekeepers.
- Design a hive to be placed in the wild, and not intended for harvesting. Think about what would be an optimal design for the bees to maintain on their own.

The most common types of hives currently are; top bar hive, Langstroth hive and Warre hive. What others have been introduced recently?

# In Conclusion…

The honeybees have *so* much to teach us! And with the observation hive you can see much of it firsthand. The social structure within a colony of bees is complex. Many of the trees and plants we depend on for food, can grow only with the help of pollinators. And there are useful products we take from the hive. Honey is the most familiar. The wax is used for many purposes, and propolis has medicinal value. There is so much to learn about and investigate.

While sharing the wonder of bees with your students, you are raising awareness about the challenges facing the bee population. With knowledge about the bees and the 21st century skills developed in STE(A)M lessons, the students and bees alike can look forward to a bright future. We hope this guide has given you some inspiration and ideas about how honeybees can bring your STE(A)M lessons to life!