The Cornell Lab of Ornithology

Investigating Evidence

Inspire investigations through outdoor observations and citizen science!

TEACHER'S GUIDE

Curriculum overview

Getting kids outside through citizen science is a great way to inspire curiosity and questions! This curriculum will help you turn these observations into investigations and encourage kids to draw their own evidence-based conclusions.

The Cornell Lab of Ornithology
BirdSleuth **K–12**

Investigating Evidence is part of the BirdSleuth curriculum developed by the Cornell Lab of Ornithology

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TheCornellLab of Ornithology

BirdSleuth K–12

Investigating Evidence

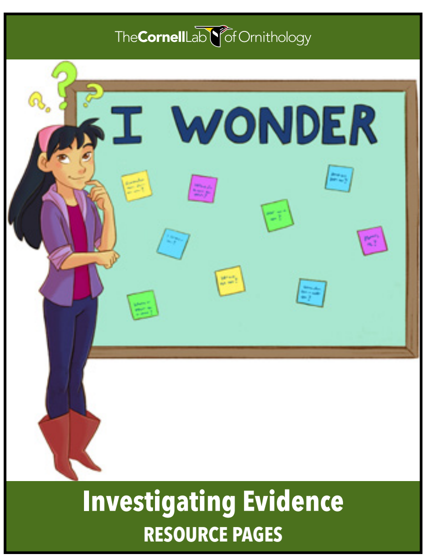
Table of Contents

Teacher's Guide

Page

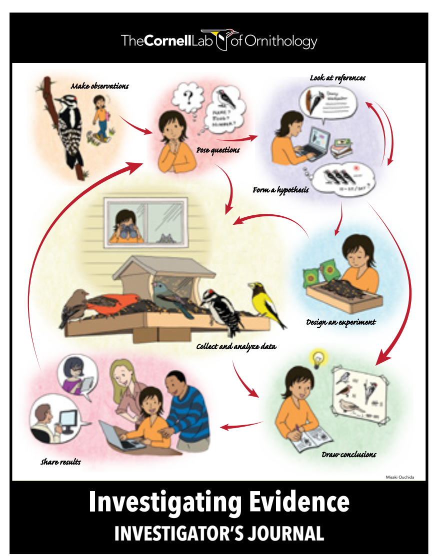
Resource Pages

(32 pages)



Investigator's Journal

(18 pages)



Introduction

BirdSleuth: Investigating Evidence

What is BirdSleuth's *Investigating Evidence*?

Science is *sleuthy*! Scientists observe carefully, ask questions, collect evidence and data, conduct investigations, and draw evidence-based conclusions. The Cornell Lab of Ornithology's BirdSleuth team helps you bring the excitement of scientific investigation to students.

Birds are an accessible way to motivate young people to go outside, observe their environment, and understand the importance of where they live. Wherever you are, and whatever the season, you can find bird species in your area. BirdSleuth curriculum kits and free resources focus on getting kids outdoors, learning to identify birds, participating in citizen-science projects, and conducting real science investigations.

By engaging in this BirdSleuth unit, students learn to observe birds carefully, ask questions based on their observations, and then figure out how to answer those questions and share their results. *Investigating Evidence* will help you guide students through the scientific process. It is also a perfect complement to any of our curriculum kits.

Student Inquiry Through Citizen Science

Citizen science invites "regular people," including K–12 students, to contribute their observations of something—birds, frogs, plants, weather, the night sky—to a central database, which professional scientists can analyze. It vastly extends scientists' observational powers and allows them to ask and answer questions that otherwise would be impossible to tackle. For young people, it's a chance to connect with the outside world in a real, meaningful, and fun way!

Misaki Ouchida

Participating in citizen-science projects can give context to student observations and be the perfect segue into doing science investigations. Students engaged in the Cornell Lab of Ornithology's citizen-science projects have been asking and answering their own questions about birds for nearly 20 years, conducting original experiments and observational studies. Questions range from "how do the kinds of birds we see change during the year?" to "will big birds like jays scare away smaller birds?" to "why aren't we seeing more birds at our school, and what can we do to get more to visit?"

Citizen science provides a great opportunity for educators. Instead of memorizing the "scientific method," students engage in investigations and discover for themselves the multifaceted nature of scientific research. This directly supports the *Next Generation Science Standards* mandate for students not only to know scientific concepts, but also to "use their understanding to investigate the natural world through the practices of science inquiry." Monitoring birds, butterflies, or other taxonomic groups helps students draw connections between a healthy environment and productive habitats that support diverse forms of life. Students are motivated knowing that their data will be used to address real-world issues of local and global concern.

One seventh grader described citizen science: "Scientists can't be everywhere, so kids from all over can record data and send it in." We encourage you to use citizen-science observations as a "question generator." The curiosity that arises during observations will spur great investigations! As you read through these lessons, keep your eye out for "Citizen-Science Spotlights," which highlight some wonderful citizen-science projects to use with students. Also visit **www.birdsleuth.org/inquiry** for links to additional projects.

What are the lessons and main ideas of *Investigating Evidence*?

In this curriculum, we've provided resources and ideas to help guide students to ask and answer their own questions. Scientific investigation is a powerful way of understanding science content and processes. Students learn how to ask questions and use evidence to find answers. While doing their investigations, students collect evidence from a variety of sources, develop explanations from the data, and communicate and defend their conclusions.

Lesson 1: Observe and Wonder

Scientific investigations begin with observations and questions. Students explore the environment and ask their own questions. They read about practicing scientists and discover the ways to answer scientific questions.

Lesson 2: What is Science?

Science is a particular way of understanding the natural world. Through readings and videos about real-life scientists, students address the notion of "scientist" and learn how scientists conduct research.

Lesson 3: My Investigation

Doing a scientific investigation requires a testable question and a process appropriate for answering that question. Students begin outlining and planning their scientific study.

Lesson 4: Testing Hypotheses

A hypothesis is a testable statement about the natural world which can be supported or rejected by experiments or observations. Students explore hypotheses and controlling variables in an experiment.

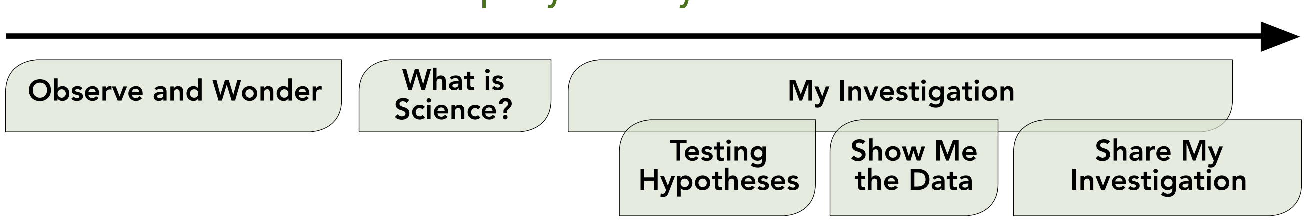
Lesson 5: Show Me the Data

Graphs summarize and illustrate data. Students learn about bar, pie, line, and scatterplot graphs.

Lesson 6: Share My Investigation

Science advances when scientists clearly communicate their findings. Students become familiar with the parts of a scientific presentation and how to convey the results of their investigation.

Unit Timeline: one week, a semester, or a year-long project... it's up to you and your students!



Visit www.birdsleuth.org/inquiry for useful links and resources, including PowerPoint presentations, rubrics, and support documents.

Setting Up for Success

Questions to Consider:

How will you focus student investigations and inspire questions?

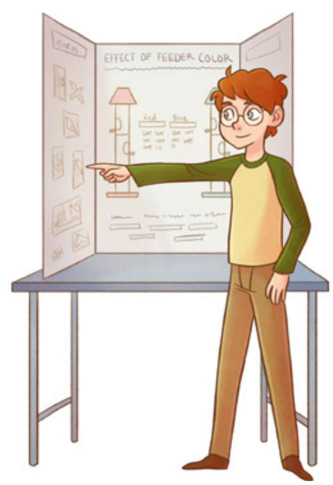
You may want to constrain the focus of student investigations to a particular topic, taxon, or theme to help you manage the questions and investigations that arise. For example:

- While on a nature walk, instruct students to focus their observations and questions on a particular taxon (birds, insects, frogs, squirrels, moss, etc.).
- Select a particular topic, like bird feeding or nesting. A bird feeder, nest box, or bird cam can be a wonderful focus.
- Have students address a problem or issue they see in your schoolyard.
- Instruct students to focus on an animal species that can be observed in your schoolyard or local area.
- Investigate a body of water such as a nearby stream, pond, or vernal pool.

How will students conduct investigations?

- How long do you have for the unit? (Some questions will be difficult to answer in the span of a 2-week unit. Consider reviewing questions to make sure they can be addressed in the time you have.)
- Will they need to do an experiment? Conduct an observational study? Consult online or print resources? Examine citizen-science data? Some combination? Or is the format flexible?
- Will they work in teams, as a class, or individually? Can they choose whether they work with a partner or group? Will you assign group members? What do you need to do to prepare them for collaborative work?

How will students present their work?



- Will they complete a written report? What length and/or format will be required?
- Will graphs be required?
- Will they submit their report to the Cornell Lab of Ornithology for publication? Will the reports be compiled into a class science journal? Might they publish a school newsletter?
- Will they prepare a display? Will they take part in a science fair? Will they share what they have learned with the school or with parents at a festival or open house?
- How will you assess their work?

Depending on the format of the investigations and presentations, you may want to emphasize or remove certain lessons. See the "Classroom Case Study" box on page 7, for an implementation strategy example, and see **www.birdsleuth.org/inquiry** for additional resources that will help you teach this unit, including sample rubrics and professional development opportunities.

Meeting the Standards

The *Investigating Evidence* curriculum will help you to lead students through the process of answering questions they pose about the natural word. The strength of this curriculum is not in the science content it contains, because that is dependent on the questions your students ask. The strength is in its ability to be applied to any science content, engaging students in science practices while building English and math skills. *Investigating Evidence* is a framework to follow as students investigate the questions they have posed. You can employ it in any area of science you teach.

Next Generation Science Standards

A Framework for K–12 Science Education (NRC, 2012) lays out the vision that students will learn about science by integrating content knowledge with experience in the practices of scientific investigation. Students should be engaged with fundamental questions about the natural world and how scientists investigate and seek answers to these questions. The *Framework* identifies eight scientific practices for the K–12 science classroom. Each is supported by *Investigating Evidence*.

NGSS Scientific Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The Nature of Science and NGSS

The nature of science is included in the *Next Generation Science Standards* and is covered by this unit. The basic understandings about the nature of science are the following:

- Scientific investigations use a variety of methods
- Scientific knowledge is based on empirical evidence
- Scientific knowledge is open to revision in light of new evidence
- Scientific models, laws, mechanisms, and theories explain natural phenomena
- Science is a way of knowing
- Scientific knowledge assumes an order and consistency in natural systems
- Science is a human endeavor
- Science addresses questions about the natural and material world

Common Core State Standards

This unit encourages students to read, reflect, pose questions, collect and analyze data, and share results verbally and in writing. It meets many of the math & ELA Common Core state standards.

For additional information on how this curriculum specifically meets standards, please see the PDF available on our website. This document includes examples of NGSS, and Common Core math and ELA standards that are addressed throughout this curriculum.

BirdSleuth Investigator Magazine

Each fall, the Cornell Lab of Ornithology publishes *BirdSleuth Investigator*, written by and for students, which features exceptional student reports, investigations, and illustrations. This full color, glossy magazine celebrates and encourages the scientific endeavors of curious children as they explore the natural world around them.

Possibilities for student submissions are broad, and we encourage students to be creative. Scientific reports, including descriptive studies and experiments, make up the majority of each issue. Some articles describe the investigations of individual students while others summarize a classroom's bird counts for the year. These reports are supplemented with student artwork. For example, we might include illustrations of blue jays along with the report "Do Blue Jays Scare Away Smaller Birds?" We are also interested in receiving creative nonfiction, poetry, artwork, and photos of students engaged in bird study and habitat improvement. While our magazine traditionally focuses on birds, we're open to considering submissions about other types of investigations.

As you work through *Investigating Evidence*, engaging your students in scientific processes culminating in sharing results, we hope you will submit some of your students' work for consideration to this publication. See the BirdSleuth web site at **www.birdsleuth.org/inquiry** and the lessons in this unit for more details and guidelines for submissions.

Order copies or download a PDF of <u>*BirdSleuth Investigator*</u> *to kick off your unit and inspire students. We also encourage you to submit your students' work.*

CLASSROOM CASE STUDY

Ms. Ellwood's 8th grade class

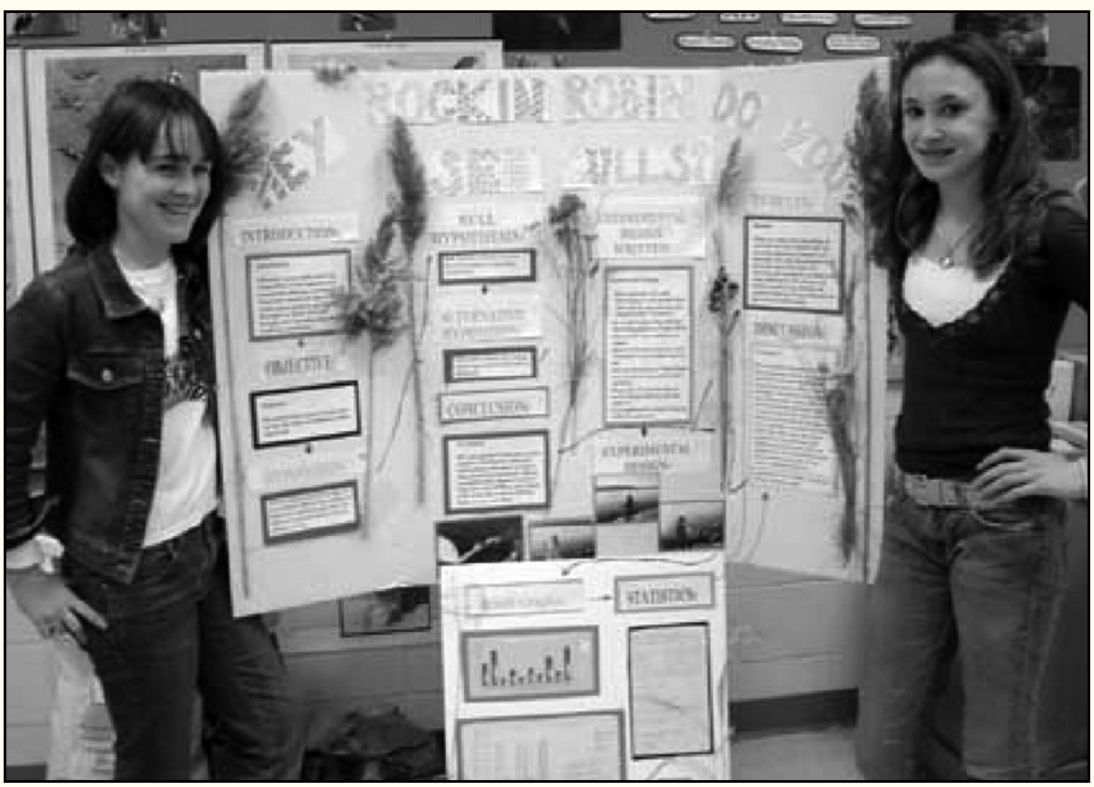
Each year, Ms. Ellwood has her students conduct investigations in her classroom. She has groups of two to four students work together to design and implement experimental studies on birds. She requires each group to complete a minimum of eight observation periods at home or at school. Most of her students finish their experimental observations within two to three weeks.

Each group of students writes a scientific paper to submit to *BirdSleuth Investigator*. Each group also prepares scientific posters to display in the school's entryway so that the entire community can admire the research. They also give oral presentations in class as part of their assessment.

Peer review has been a critical component of the investigation and paper-writing process in Ms. Ellwood's class. Using a peer review sheet, students critique each other's scientific papers and posters. Students turn in their peer reviews with their final poster, so Ms. Ellwood can evaluate whether they acted on the suggestions given. She allows each group to indicate if they didn't agree with any aspects of the peer evaluation.

Over the years, Ms. Ellwood found that it is best to require that students submit sections of their projects as they complete them so she can give feedback and recommendations as they progress. As she says, "Mini due dates help keep them on track!" Ms. Ellwood also recommends providing a grading rubric to the students so they can self-evaluate their performance as they go along.

Due to students' concerns about individual grades on group projects, she built in a "safety net." Students each sign a "poster contract." If one student doesn't do his or her part when completing the poster, the other group members' grades are not affected.



Two of Ms. Ellwood's students with the poster they presented

Lesson 1: Observe and Wonder

Big Idea: Scientific investigations begin with observations and questions.

Overview: Students explore the environment and ask their own questions. They read about practicing scientists, and discover the components of investigations and ways to answer scientific questions.

Learning Objectives

Students will be able to…

- make observations and ask questions about what they see;
- purposefully make use of the "I Wonder" Board;
- differentiate between questions that can be answered through (1) reading reference materials, (2) exploring existing data, (3) observational study, and (4) experimentation.

Time and Location: 90 minutes; outdoors if possible

Resources Needed

- Resource pages 1–3: Kinds of Questions, Vultures: See or Smell?
- Poster board, sticky notes

Getting Ready

- Set up the "I Wonder" Board.
- Set parameters for student investigations. For example, which citizen-science projects or what taxa or system might you focus on (birds, butterflies, your schoolyard, etc.)?

Teacher Background Information

Inspiring Inquiry

Students need meaningful opportunities to explore the environment to inspire questions based on observation. A short walk around your schoolyard or local park, during which students are encouraged to explore their surroundings using all of their senses, can awaken curiosity and spark exciting questions. Whether it is watching pumpkins rot, waiting for a chick to hatch, observing a butterfly emerging from its chrysalis, or witnessing birds visiting a feeder, the mysteries of nature can inspire a multitude of questions. Here are some tips from teachers who have used nature to spark student inquiry:

- **Share your observations**. Provide the time and tools students need to record their observations. This can be as simple as 15 minutes in your schoolyard with a notebook and pencil. Perhaps find a "secret spot" your class can visit on a regular basis. Look and listen. Make observations over time. Have quiet time, but also encourage discussion.
- **Model asking questions.** Ask questions as you observe. Turn your own observation statements into questions. For example, you might observe that a bird is holding a worm. Change your statement into questions like, "How many worms does a bird eat?" or, "How did that bird find the worm?" or, "Will it eat the worm or take it back to the nest?"

- **Resist the urge to answer every question**. Simply begin to collect them. This releases you from the pressure of needing to know the answer to every question. It also encourages creative and free-spirited student inquiry, and will lead to even more questions.

The "I Wonder" Board

During this unit, you'll lead students through a scientific investigation. To accomplish this, students need to begin thinking like scientists. Scientists are constantly asking questions about the world around them.

The "I Wonder" Board provides a place to store and display student questions. These questions have many uses. They can be categorized, revisited, or answered.

During class or while you're outdoors, questions might arise that you can't explore due to time constraints, because you are not sure how to address them, or you want students to consider them more deeply. All of these questions should be placed on the "I Wonder" Board.

Barbara Jacobs-Smith

"I Wonder" Board

Designate a space for the "I Wonder" Board and have sticky notes available. Encourage students to write their questions on the notes and put them on the "I Wonder" Board. Over time, the "I Wonder" Board will provide a wealth of ideas that can form the basis of independent research. Students will want to return to questions that they are genuinely interested in (e.g., "Why do birds, insects, and frogs make noise?" "How does a bird know what kind of nest to build?" "Why is some grass in the yard dead, while some is extra green?").

Conducting the Activity

1. "I Wonder" Board

Introduce the topic you've chosen as a focus of the student investigations (such as questions generated during a particular citizen-science project, observations of birds, insects, or a local stream, or a schoolyard issue or problem you'd like to address).

Introduce the "I Wonder" Board. Explain what it is and how it works. Invite students to post questions that are focused on the chosen topic.

Inspire initial observations and questions by taking kids through an activity related to the topic of focus (such as a nature walk, participating in a citizen-science project, watching a bird cam, or other opportunities to observe in or out of the classroom).

Give students time to reflect on what they have observed during this initial experience and to add their related questions to the "I Wonder" Board.

2. Kinds of questions

Ask students to share ways they think scientific questions can be answered.

Hand out copies of Resource page 1, "Kinds of Questions" and/or project a copy in front of the class. Use the "I Wonder" graphic to introduce the four ways in which questions can be answered:

- <u>Reference Materials:</u> These are questions for which you "look up" answers. Often, you'll have to read and synthesize information from several reliable sources before reaching a conclusion. The references you use are based on the findings of scientists who asked this question and did research before you. (For example: Which animals are the fastest? How do birds know when and where to migrate? How do lightning bugs light up?)

- Explore and Analyze Data: You'll look at other people's data (for example, the eBird data submitted by people all around the country) to answer these questions.
- Observational Study: To answer this kind of questions, you'll need to collect data as you observe the natural world. (For example, if you were curious about what kinds of birds lived in your yard, or wanted to know if different species of birds behave differently, you could observe these things and take notes.)
- Experimental Study: To answer this kind of questions, you'll generate the data yourself by conducting an experiment. (For example, if you were curious about whether birds preferred one kind of seed over another, you could put out the seeds and collect data to find out!)

Note: Students will sometimes mention "surveying people" as a way to find answers. Survey questions typically ask about opinions. Therefore, they are social science questions. Depending on your teaching goals, you may or may not want to pursue this kind of questions. Examples of survey questions include, "What animal is the favorite of the fourth grade students?" and "How many sixth graders have a bird feeder at home?" To answer these questions, students would need to conduct surveys and compile data. Such surveys typically result in data that can be displayed graphically in pie charts or bar graphs.

If students mention, "asking someone who knows the answer," you may wish to liken that to reference material questions. In either case, the resource (whether written or a person) must be a reliable source of information.

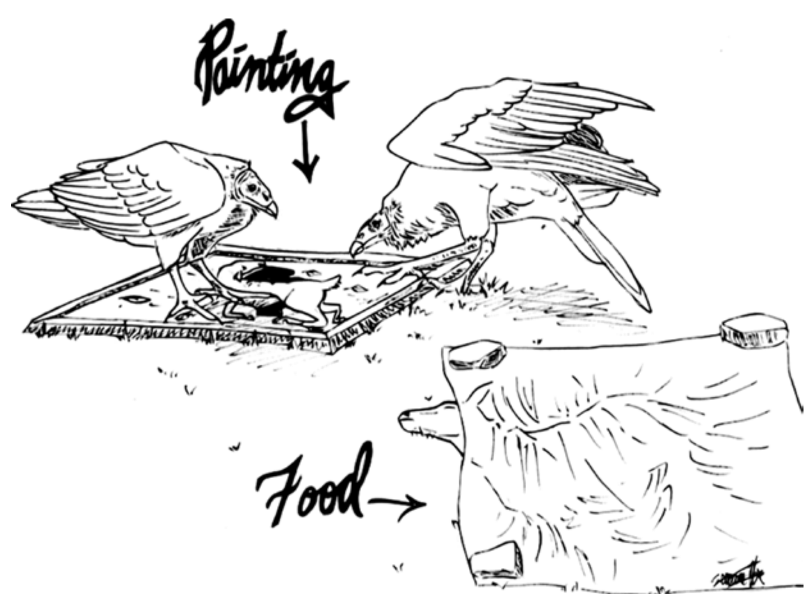
3. How do scientists ask and answer questions?

Present the problem: Vultures eat smelly dead things and scientists wondered how do they find their food—smell or sight?

Ask: How could scientists find the answer to this question?

As a class, in small groups, or individually, have students read Resource page 2–3, "Vultures: See or Smell?" Ask:

- What caused John James Audubon to wonder about how vultures find their food? *(He noticed that he could get close to vultures as long as they did not see him. This made him think that maybe their sense of smell wasn't as good as previously believed.)*
- How did he answer his question? Was Audubon's method experimental or descriptive? *(He designed several experiments—fake dead animals and camouflaged stinky meat.)*
- How did others test Audubon's conclusion? *(Some used paintings of dead animals to test if vultures find food by seeing it. Later on, other scientists used stinky chemicals to see if vultures would be attracted.)*
- Could Audubon have used reference materials to answer his question? Why or why not? *(Reference materials at that time probably all stated that vultures found their food by smelling it. If Audubon*



Severine Hex

used only those references, he would not have learned something new.)

- Could he have used existing data to answer his question? Why or why not? *(There were no pre-existing data because Audubon was likely the first to pose his hypothesis and test it. This was before the Internet, so even if someone had conducted this study, it would have been very difficult for Audubon to know about it and be able to access the results.)*
- Why is it important that Audubon shared the results of his inquiry? *(By publishing his findings, Audubon made it possible for others to learn about, question, and build upon his research.)*

Reflect and Evaluate

- Discuss: Has anyone found answers to any of the "I Wonder" Board questions since they were posted? If so, how?
- Discuss: Which of the "I Wonder" questions is the class still interested in answering? How do you think we might go about finding the answers? *(Make sure students realize they can look up the answers to some questions or for others, devise ways of finding answers themselves.)*
- As a class, find examples of the four kinds of questions on your "I Wonder" Board. Some questions can be answered in multiple ways, so allow for discussion.

Extensions

1. **Brainstorming questions:** Encourage students to develop a sense of wonder and curiosity through developing their own questions. Use a jumping-off point such as an article, blog, photograph, fossil, bug in a jar, terrarium, or potted plant. Students should ask as many questions as they can based on what they read or see. They are ONLY asking, not looking for answers yet. Set a time frame (5 to 10 minutes). Ask students to write the questions exactly as stated, with no discussion or attempting answers. If someone makes a statement, the group should change it to a question.
2. **Ranking "top" questions:** Have each group choose their top three questions from the brainstorm. (You will need to define "top"—most interesting, best for a long-term assignment, most effective for conducting an experiment.) Each group will present to the class their top three questions and the reasons they were chosen.
3. **Sort questions:** Sort the brainstormed questions into the four types mentioned in the "Kinds of Questions" article.

CITIZEN-SCIENCE SPOTLIGHT: MAMMALS

Because humans are mammals, we feel a special kinship with our hairy brethren. We relate to the mother bear protecting her cubs, the squirrels chasing each other around a tree trunk, the whale gracefully coming up for air and singing to its pod. While many scientists are studying mammal biology and behavior, they can't be everywhere and observe everything.

Enter the citizen scientist, or a classroom of young citizen scientists, eager to learn new things and to be the extra eyes and ears that researchers need to thoroughly study particular species. Because mammals are often active and relatively easy to identify, they are great subjects for citizen science.

A sampling of projects focused on mammals: eMammal, Pathways: Wildlife Corridors of NM, Seward Park Coyote Tracking, Bat Detective, Whale FM, Project Squirrel, Wildlife Watch (includes mammals)

Lesson 2: What is Science?

Big Idea: Science is a particular way of understanding the natural world.

Overview: Students address the notion of "scientist" and learn about the features of the science process through readings and videos about real-life scientists.

Learning Objectives

Students will be able to…

- analyze a "Meet a Scientist" report to determine the question investigated, how and what data/information was collected, and what conclusions were made;
- describe, in their own words, the key features of science.

Time and Location: 70 minutes; indoors

Resources Needed

- Resource pages 4–9: "Meet a Scientist" reports (1 per group, six reports total)
- Journal pages 1–2: My Scientist, Meet a Scientist
- "I Wonder" list (from Lesson 1)
- "Meet a Scientist" resources (links to videos and articles at **www.birdsleuth.org/inquiry**)
- Research materials (such as books, internet access, field guides)

Getting Ready

- Decide how you will facilitate sharing the "Meet a Scientist" reports and online resources, and prepare accordingly.
- Copy Resource pages and Journal pages as desired.

Teacher Background Information

The Nature Of Science

One of the most exciting aspects of teaching science is conveying how science is done and then engaging students in this process of discovery. Here are some key features of science to consider as you teach this unit:

- Science is a particular way of understanding the natural world, and is built upon our innate curiosity. It is based on asking questions and making observations.
- Science is limited to methods and explanations derived from nature. We use our senses and instruments to give us information about the world around us. Science does not allow for supernatural elements.
- Scientists always base their explanations or conclusions on evidence. Explanations have to be supported by empirical evidence and are testable in the natural world.
- Scientific knowledge is simultaneously reliable and tentative. Having confidence in scientific knowledge is reasonable, but realize that our understanding may be modified in light of new evidence or better understanding of prior evidence.
- Contributions to science are made by people all over the world.

Conducting the Activity

1. Draw a scientist

Ask students to think about a scientist at work. Invite them to imagine the details in the scene. Ask:

- Where is the scientist?
- What does the scientist look like? What is the scientist wearing?
- What is the scientist doing and what tools are being used? Is the scientist working alone or with others?

Then, give students about five minutes to draw or describe in their journals a scientist at work. (Journal page 1, "My Scientist").

When students are done, ask them to share some of the details of their pictures or descriptions. Ask:

ALEX

A student's scientist drawing

- How many drew male scientists? Females? How old are they?
- How many of the scientists are working inside? Outside?
- What tools are they using?
- Who drew a "mad scientist?" Why? What are some stereotypes about scientists and are they true?
- Who drew a scientist doing something that you'd like to do?

Challenge the group to develop a list to be posted of different kinds of scientists or "science jobs," and continue to add to the list as opportunities and ideas present themselves.

2. Read and discuss the "Meet a Scientist" reports and online resources

Divide the class into groups of three to five students. Tell students that they will be introduced to a conservation scientist. Assign each group one of the scientists. Give students the written report to read and/or give them access to the related *Crossing Boundaries* Conservation Scientists videos. Give them time to learn about and discuss their scientist and answer the questions about the scientist's work (Journal page 2, "Meet a Scientist").

When students are finished, have each group briefly describe their scientist to the rest of the class. You might ask each group to introduce the researcher's question, describe the data or information that the researcher collected and how they gathered it, and explain what, if any, conclusion(s) the researcher made.

After each group has reported, discuss the following questions:

- What do each of these scientists have in common? *(Possible answers include asking questions, collecting data, studying nature, understanding the Earth/conservation.)*
- How does the work of these scientists differ? *(Possible answers include studying different animals, working outside versus inside, traveling to different locations around the country and in other parts of the world.)*

3. Discuss the nature of science

Lead students in a discussion about science and scientists. You may wish to brainstorm ideas on the board for later reference. Ask questions such as "What is science?" and "What do scientists do?" and generate a list of traits such as:

- Scientists are creative in the questions they ask and the methods they use to answer them.
- Scientists collect data and information. They look for evidence that will help them draw conclusions.
- Scientists work together, getting ideas from each other and from their own experience and research.
- Scientific ideas change and grow. One observation or experiment often leads to new questions.

Ask:

- Have you ever experienced any of these traits while working in or learning about science? *(Students may share examples from scientific investigations they have read about, seen on TV, done themselves, or that they are familiar with because they know a scientist personally.)*
- How are these traits illustrated by the scientists in the "Meet a Scientist" reports?

4. Draw a concept map of the scientific process

Illustrate "doing science" by creating a concept map of the scientific process, pulling from the resources provided. See Teacher Insight box, page 16, and share the "I Wonder" graphic (Resource page 1), and "The Scientific Process" image on the cover of the student journal, which is also available as a poster to purchase at the BirdSleuth website (**www.birdsleuth.org/inquiry**). Ask:

- What types of activities are common to all scientists? *(Make observations, ask questions, draw conclusions, share results)*
- *What steps are sometimes, but not always, necessary in conducting scientific research? (look at reference materials and resources, develop a hypothesis, design an investigation, collect and analyze data)*

Explain that the questions you ask determine your path through the scientific process: Some questions require experimentation and collecting data, some require exploring existing data, and some require research to find the answer.

Let students know that throughout the unit, they will continue to investigate how science and scientists work. This will prepare them to develop their own questions and collect data and information to help them answer questions. Save the concept map you create for later reference.

Reflect and Evaluate

These reflection questions can be discussed in class or assigned as in-class or homework writing assessments.

1. Have students compare and contrast the scientists they read about in the reports with the scientist they drew earlier. Ask them,
    - In what ways are they similar?
    - How are they different?

   Make a list with similarities and differences, or create a Venn diagram.
2. Ask students how their understanding of the word "scientist" has changed since learning about the conservation scientists.

3. Compare and contrast the scientists in these reports with the young scientists found in *BirdSleuth Investigator*. (Print or purchase back issues at **www.birdsleuth.org/student-publication**.) How are they alike? How are they different?
4. Working individually or in pairs, create artistic or creative versions, (which might include drawings, animations, or a presentation) of the scientific process concept map.

Extensions

1. **Meet a real scientist:** Invite a professional scientist to visit your class. You can find a scientist at your local college or university, by asking a company or business, enlisting a former student or a parent of a student, asking a scientist to Skype with your class, or by contacting your local nature center, state park, or wildlife refuge. Ask the scientist to talk about their work and invite students to ask questions.
2. **Scientists in the news:** Have students find articles about scientific research in the news, online, or in magazines. Using additional copies of Journal page 2, answer questions about the scientists and their research.
3. **Write about a scientist:** Encourage students to write a "Meet a Scientist" report or create a podcast about a scientist they find interesting. Compare and contrast the scientists that the students chose. (How many students chose female scientists, and how many chose males? Did most choose indoor or outdoor scientists? How many study animals, versus plants, versus other things?)
4. **Nature of Science:** Have students find specific examples of the nature of science in the "Meet a Scientist" reports and share them with the class. Have students work together to find similarities among the scientists in terms of the nature of science. Finally, ask students to summarize their findings, emphasizing the features of the nature of science. These can be shared in a whole group discussion or as a writing assignment.

CITIZEN-SCIENCE SPOTLIGHT: BIRDS

The Cornell Lab of Ornithology loves birds! We want to share that passion with you. You can find birds any time of year, in almost any location. Watching birds invites curiosity about biology, ecology, behavior, physics, engineering, history, and even art.

eBird is a global citizen-science project that has revolutionized the way the birding community reports and accesses information about birds. The observations of each participant join those of others in an international network. eBird then shares these observations with a global community of educators, land managers, ornithologists, and conservation biologists. eBird has become the foundation for a better understanding of bird distribution across the western hemisphere and beyond.

After becoming familiar with eBird, students may begin to wonder and address questions such as:

- Why are there so many more woodcock sightings in central Maine than central New York?
- When can we expect the first hummingbirds to visit our feeders?
- Are migratory birds arriving earlier, at the same time, or later than they did 50 years ago?
- How many different birds have I seen this year compared to last year?

Other bird citizen-science projects: Project FeederWatch, NestWatch, Celebrate Urban Birds, Christmas Bird Count, Hummingbirds at Home, Great Backyard Bird Count.

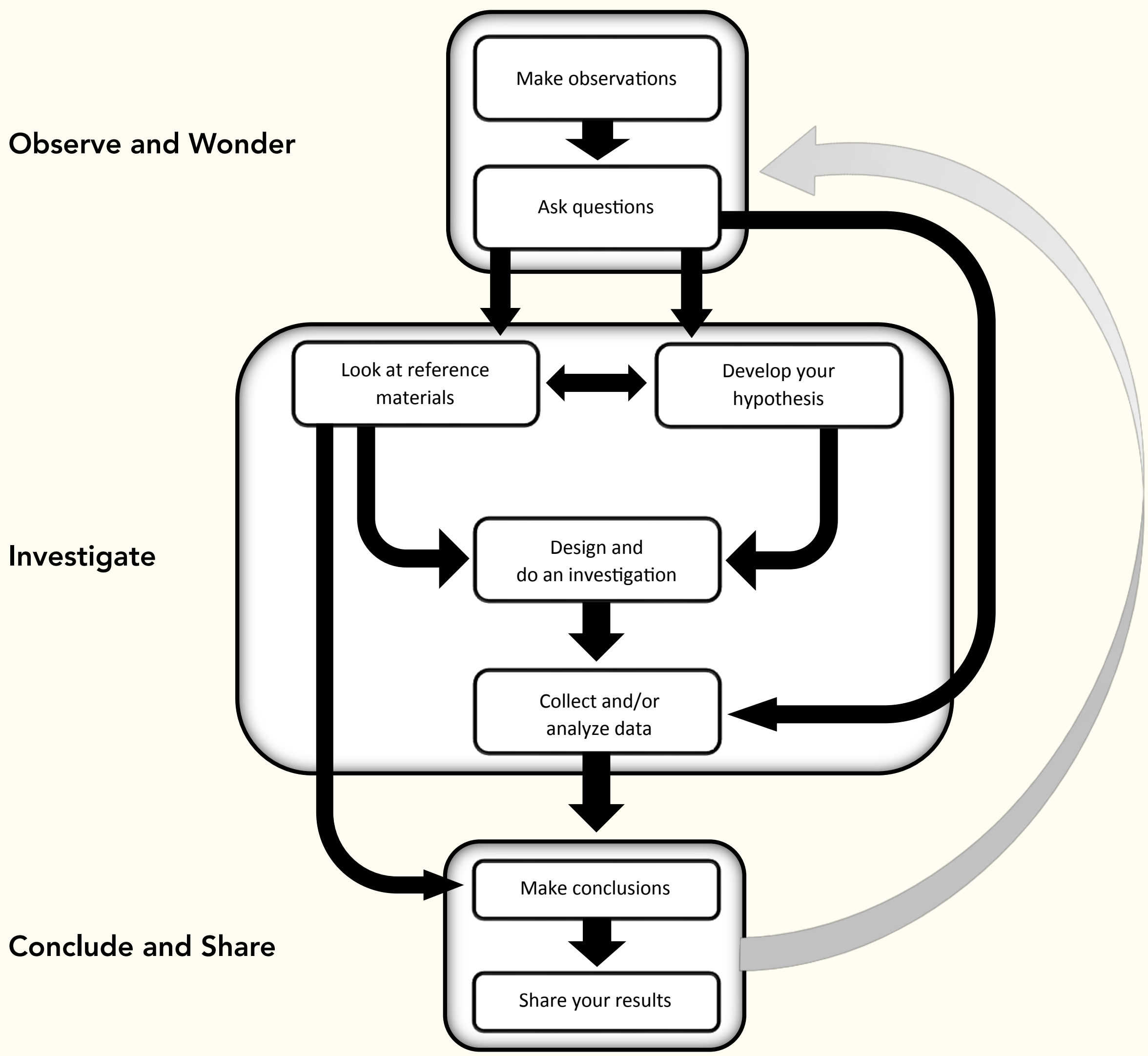
TEACHER INSIGHT

The Scientific Process

Younger or less experienced students might visualize the basic process that scientists use as a series of ordered steps (often called the "Scientific Method"):

1. **Observe** the natural world and look for patterns or things that surprise or puzzle.
2. **Define** questions to investigate based on these observations.
3. Develop a **hypothesis** to test.
4. **Collect and analyze information (data)** to test the hypothesis.
5. Look at the results, then come to **conclusions**.
6. **Share** the results.
7. **Ask more questions** based on these observations.

Doing science is not as simple as a linear progression, however. It doesn't always mean "doing experiments." The following concept map of the scientific process shows this complexity:



Lesson 3: My Investigation

Big Idea: Doing a scientific investigation requires a testable question and a process appropriate for answering that question.

Overview: Using planning documents and through group discussion, students begin developing their scientific study.

Learning Objectives

Students will be able to…

- design an investigation to answer a scientific question;
- describe the content included in a scientific report;
- describe the factors that make a resource reliable.

Time and Location: 70 minutes; indoors, plus ongoing time for research and investigation

Resources Needed

- Resource pages 10–11: Annalisa's Report
- Resource page 30: Sharing My Report
- Journal pages 3–8: Project Plan, Project Checklist, Project Notebook
- Research materials (such as books, the Internet, field guides)
- Computer with Internet access

Getting Ready

- Make copies of "Annalisa's Report" for each student group.
- Decide on the format of your students' investigations.
- Assign due dates for the various parts (Project Checklist, Journal page 4).
- Develop a rubric to use when evaluating students' completed investigations (sample rubrics are available at **www.birdsleuth.org/inquiry**).

Teacher Background Information

This lesson and associated Journal pages scaffold student projects. Begin with this lesson but move into lessons 4 and 5 as students begin to create hypotheses and collect and analyze data.

As stated in the introduction to this unit, make sure you've considered how students will conduct their investigations. For example, you might wish to specify:

- The kinds of scientific questions students can investigate and how long the investigations will take;
- The format for the investigation, whether an experiment, observational study, writing a research report, or analyzing citizen-science data;
- Teams or partners if students are not working individually or as a class.

Conducting the Activity

1. Read "Annalisa's Report"

Pass out a copy of "Annalisa's Report" on chickadees to each student or group (Resource pages 10–11). Give students 10 minutes to read the report. Direct them to pay close attention to the section headings (in bold) and the information found in each section.

After students have finished reading, lead a discussion about each section of her report, recording the students' responses on the board in a table similar to "Scientific Report Components" found on Resource page 30.

Tell students that by including this information in each section, Annalisa was able to organize her work and make sure that her report was complete. Whether students do a written report, oral presentation, or poster, including these sections will help them to stay organized and make sure their project is complete.

2. Brainstorm ways to present findings

Annalisa wrote a report to share her findings. Tell students that an important part of the scientific process is sharing results, so others can learn about the natural world from their work. Ask students to brainstorm ways that scientists might share their findings. If they struggle, you could remind them of the "Meet a Scientist" reports they read and any experience they have in sharing scientific findings (perhaps at a science fair). Make sure students mention:

- written reports (magazines, Internet, science journals);
- meetings with other scientists, journalists, or politicians;
- the media (TV, Facebook, blogs, Twitter, radio, newspapers, etc.).

3. Explain the final product and plan

Invite students to take part in a complete scientific investigation that begins with one of their questions. Share your expectations for their final product (i.e. Will they write a report? Create a podcast or PowerPoint presentation?) and how they will accomplish this (i.e. Will they work individually, in teams, or as a class?). Work with them to complete Journal page 3 ("Project Plan") before they begin their investigation.

If you wish to have students submit their final reports to the Cornell Lab of Ornithology, share *BirdSleuth Investigator* with them so they can see examples (free download, see **www.birdsleuth.org/inquiry**).

4. Fill out Project Checklists

Ask students to look at the Project Checklist (beginning on Journal page 4) and review the process they will use throughout the unit. Review the nine stages of the project:

1. Choose a scientific question that can be explored given the time and resources you have. *(Make sure students' questions are answerable.)*
2. Read about your topic and summarize what you learn. Write down citation information for all the resources you use. *(You may need to review with students the information they will need to collect in order to make a citation.)*
3. Develop your hypothesis.
4. Outline your materials and methods. *(Make sure students have selected materials that are available. Check their data sheets for clarity and completeness. Carefully consider the side effects and safety of students, animals, and the environment. See Teacher Tip box: "Safety Considerations" on page 19.)*
5. Do your study, collecting data and/or making observations.

6. Organize your data into tables and graphs. Analyze and/or interpret your data.
7. Create a first draft of your project.
8. Peer review.
9. Revise your work and turn in your final project.

Share with students your expectations for their final product and the rubric you will use to evaluate their work. Assign due dates for each of the above steps. Students should record due dates on their Project Checklist (Journal page 4). Explain the process for getting their plans approved and how that is documented.

TEACHER TIP

Safety Considerations

Experiments can have unintended negative effects and teachers need to watch out for these. For example, food and water additives (food coloring, cayenne) can be harmful to birds and other animals. Ask yourself, is the food being offered harmful to the target animal and/or other animals? Will it attract unintended animals like predators or pests?

This illustrates the importance of planning before starting an experiment. Before approving a project plan, make sure your students have considered everything they may need to do. Are there any safety concerns with methods (height issues, mechanical, time of day, etc.) or with materials the students may have to use (power tools, chemicals, etc.)?

Be wary of anything you might add to the environment and be sure to do some background research before beginning. Making harmful changes to the environment may be done unknowingly. For example, in one experiment, mesh shower poufs were placed in trees to examine bird response to novel objects. But researchers realized that birds could get caught in the material, and the project was changed to avoid potential harm. A seemingly simple thing, like putting out dryer lint as a nesting material, could harm birds if it contains chemical residues or is sticky enough to damage feathers.

5. Practice doing background research

Ask students where they might look if they wanted to know something about a particular species of animal, for example, to find out where it lives, what habitat it prefers, what it eats, etc. *(Possible answers include watching the animal, looking online, reading a book, finding a field guide, or asking an expert.)*

Individually or in small groups, challenge students to search for such information in at least two resource types (for example, using online and printed resources). Recommend that students check several online sites to make sure the information is confirmed and correct. Read more about Wikipedia as a resource in the "Teacher Tip" box on the next page.

After allowing time for preliminary research, ask:

- What resources did you use?
- What did you learn?
- Do you think all sources are equally good or reliable? Can you trust everything you read?
- What makes some resources better than others? *(For example: current or up-to-date, unbiased, reliable, or based on a trusted source.)*

Tell students that when scientists have questions or have made an interesting observation, they often do background reading to see what is already known. This helps them develop a good

TEACHER TIP

Wikipedia as a Resource

Wikipedia's extensive content often makes it a great place to begin the research process. However, since anyone can edit a Wikipedia article at any time, it's difficult to cite, and should not be used as an actual reference. A better idea is to use Wikipedia as a jumping-off point, as a place to learn background content and discover related topics. Then, use the list of references at the bottom of the article to search for scholarly articles.

research question and form a hypothesis. Scientists share background research in their scientific reports. The introduction is where scientists explain their ideas and hypotheses, using evidence from prior research.

6. Let's get started: developing a question

Invite students to develop a research question, either individually or as a group, and record it on Journal page 5. Sources of good questions include your "I Wonder" Board, questions generated in Lesson 1, and the "Background Research" they just completed. Look over student questions and make sure they are answerable given the time and resources available.

7. Creating a research plan

After questions are approved, ask students to complete a preliminary plan in the Project Notebook (Journal pages 5–7, questions 1–5). Review their plans and make suggestions for improvement. If they are using a data sheet, ask them to submit a draft of the data sheet prior to collecting data. When their plans have been approved, invite them to begin their study.

Continue with Lessons 4 and 5, providing the time and resources students need to conduct their investigations. As they progress, they should record their work on their data sheets and in their Project Notebook (Journal page 7–8, questions 6a–6c.) This journal can be used later to outline their poster/presentation/paper.

Reflect and Evaluate

1. What makes some resources better than others? How can you tell if a website is a reliable source?
2. Have you found unreliable sources in your research? What makes you think they are unreliable?

Extensions

1. **Evaluate a Student Scientist's Work:** Have students choose and read an experiment in *BirdSleuth Investigator*. (Print or view back issues at **www.birdsleuth.org/student-publication**). Just as they did with "Annalisa's Report," students record information about the parts of the report in a table similar to "Scientific Report Components" found on Resource page 30. Are any components missing? Has this young scientist done something particularly well?
2. **Science in the News:** Have students find articles about scientific research in the news, online, or in magazines. What scientific report components are included in the news report? What components are missing? Why would the reporter decide to include or not include different parts of the scientist's report? How is news reporting different from a scientist's report?
3. **Help a scientist:** Research opportunities for students to get involved with scientists and real science locally —such as taking part in citizen-science projects, volunteering at local science organizations, participating in a science fair, finding programs for high school research—and have the students share what they've found with the rest of the class.

Lesson 4: Testing Hypotheses

Big Idea: A hypothesis is a testable statement about the natural world which can be supported or rejected by experiments or observations.

Overview: Through readings and a presentation, students learn about the importance of creating a testable hypothesis and controlling variables in an experiment.

Learning Objectives

Students will be able to…

- define the term "hypothesis";
- write a testable hypothesis;
- identify independent and dependent variables within an experimental study;
- describe why it is important to control variables in an experimental study.

Time and Location: 90 minutes; indoors

Resources Needed

- Projection of Resource pages 12–13: Hypothesis Help
- Resource pages 14–23: Variables in Your Experiment, Will a Fake Cat Scare Birds?, Answering Your Scientific Questions
- Journal pages 10–11: Identifying Variables & Sample Experimental Plan
- PowerPoints: (available at **www.birdsleuth.org/inquiry**) "Variables in Science Experiments" and "Hypothesis Help"
- Graph Paper
- Questions from the "I Wonder" Board

Getting Ready: Download the "Variables in Science Experiments" and "Hypothesis Help" PowerPoint presentations. Review the notes included for the slides.

Teacher Background Information

The concept of "hypothesis" can be difficult to understand, probably because we sometimes use the term to mean "guess." A hypothesis isn't a guess. It is a testable statement about the natural world which can be supported or rejected by experiments or observations.

A hypothesis

- *is tentative in nature (it can either be supported or rejected by experimentation);*
- *is both possible and plausible;*
- *investigates cause, not just confirms observations;*
- *proposes a specific relationship between two variables (an independent variable and a dependent variable);*
- *points toward the design of the experiment to test it;*
- *is written after background research and observation, but before conducting the experiment;*

- *states what kind of data will be collected;*
- *must be testable (both the independent and dependent variables can be measured).*

A hypothesis is NOT

- *a question,*
- *a guess,*
- *only a prediction,*
- *able to be "proven."*

In the past, a hypothesis has been called an "educated guess," but too often students focus on the word "guess" instead of the word "educated." Scientists develop hypotheses after research and observation, sometimes after many years of learning about a phenomenon. Hypotheses are based on prior knowledge, not hunches. Students should be able to state why they believe their hypothesis may be true.

Confusion between the terms hypothesis and prediction is also common. Predictions are stronger than guesses, because predictions rely on data and research to help us think about what will happen in the future. A well-written hypothesis goes further by proposing why something will happen, creating an experimental design that can be tested. A hypothesis develops a prediction into an investigation.

One standard to writing hypotheses is the "If… then…" format. The "If" is the independent variable. The "then" is the dependent variable. The If/then format helps to set up a relationship between the variables. (Adding "because…" to the end of the "If/then" hypothesis can sometimes help to clarify the relationship between the variables and to make the student's reasoning more clear.)

An example of students practicing prediction and hypothesis writing is included in the Classroom Case Study box on page 28.

CITIZEN-SCIENCE SPOTLIGHT: PHENOLOGY/ECOLOGY

When do plants flower, insects emerge, and birds migrate? How does pollution affect rivers, oceans, and the ecosystem? These are some of the questions scientists are addressing through the studies of phenology and ecology. Young people can help these studies by employing their natural curiosity, energy, and keen eye for detail.

For example, Project BudBurst and *Nature's Notebook* offer hands-on opportunities for learning about the natural world through the lens of phenology (the study of how the cycle of changes in nature relate to the seasons, weather, and climate). Phenology data is already producing useful results, for example, predicting the expansion of highly allergenic ragweed and showing changes in bloom dates of plants due to climate change. While participating in these projects, students may wonder…

- Why does a tree shed its leaves in the fall?
- What do changing seasons mean for birds?
- How do seasons affect habitats and their inhabitants?
- Are the plants in my yard blooming earlier or later than they used to?

Other phenology and ecology citizen-science projects: Journey North, YardMap, Vital Signs, Snapshots in Time, Bioblitzes, Global Garlic Mustard Field Survey

Conducting the Activity

1. Introduce the term "hypothesis"

Refer students to the science process concept map they made in Lesson 2. Introduce students to the concept of a hypothesis as an important part of scientific investigation. Ask:

- How would you define hypothesis? *(Students' responses should include the understanding that a hypothesis is a testable statement about the natural world which can be supported or rejected by experimentation or observations and is based on prior reading, observation, or investigation.)*

Project "Hypothesis Help" (Resource page 12) and, as a class, read the first two sections aloud as you uncover them one by one:

- "What do I wonder?"
- "What do I already know?" (Ask students to craft a hypothesis and propose possible methods for testing it.)

Then, uncover the third and fourth sections. Continue reading aloud.

- "How do I turn my idea into a hypothesis?"
- "How do I test my hypothesis?"

Alternatively, or in addition, present part 1 of the "Hypothesis Help" PowerPoint.

Discuss the stated hypothesis for this study about feeder birds. Ask students:

- What might a graph look like if the stated hypothesis is <u>supported</u> by data? (You may wish to draw the graph on the board. Refer to the graphs on Resource page 13 or project that page for the class.)

Continue reading to the class the last three sections of "Hypothesis Help:"

- "How do I know if my hypothesis was supported?"
- "What if I didn't find any differences?"
- "What if I found something other than what I expected?"

Draw an example of what a graph of the data might look like if the hypothesis is <u>rejected</u>. For additional practice, show part 2 of the "Hypothesis Help" slideshow. Have students answer the questions within the PowerPoint either as a class or in small groups. (Discuss their answers with the whole class.)

Sometimes students think they have "failed" if they do not support their stated hypothesis. Ask:

- How might you feel if the evidence led you to reject your hypothesis?
- If our hypothesis isn't supported, should we conclude we must have done something wrong? Why or why not?

Tell the students that any outcome of a scientific study contributes to our understanding of the world if the study has been well designed. Any outcome (whichever hypothesis is supported) is valuable. Hypotheses and experiments are not about being right or wrong; they are useful tools for exploring and understanding the natural world.

2. Give students practice

Read the following scenario: *Isabella and her class were studying birds and wanted to investigate their feeding habits. They added sunflower seed and mixed seed in separate identical feeders and watched how many birds came to each. Isabella thought the birds might like the sunflower seed better and eat more of it during the hour the class watched the feeders, so she wanted to make* *a prediction. She remembered that predictions state what you think will happen and why.*

Ask:

- What would be an example of a clear prediction Isabella could make? *(Example: I predict that more birds will visit the sunflower seed feeder over the course of an hour because I noticed that the class needs to buy sunflower seed more often than mixed seed. Sunflower seed is higher in fat and protein than the other seed we use.)*
- What would be an example of a hypothesis? *(Example: If birds prefer sunflower seed over mixed seed, then more birds will visit the sunflower seed feeders during the course of an hour because they will choose the food that is more nutritious.)*

Remind students of the four kinds of questions they learned in Lesson 1 (experimental studies, observational studies, exploring data, and looking at reference materials). Tell them that they'll now spend some time concentrating on experimental studies.

3. Present the variables slideshow

Often, scientists test hypotheses by doing experiments. Present the "Variables in Science Experiments" PowerPoint slide show to emphasize the different kinds of variables in an experiment. Note: A script you can use when presenting the PowerPoint can be found in the "Notes" section of each slide. To follow up, you may wish to have your students read the article "Variables in Your Experiment" (Resource pages 14–15).

TEACHER INSIGHT

"Control" And "Constants"

A **control** is the "unchanged" part of an experiment. It's the baseline that isolates the independent variable's effects on the experiment and can help rule out other explanations of the experiment's results. *Before Amy's experiment, there was no cat present, so she had to measure the amount of seeds that birds ate before she put the cat out. The "no cat" group was the control.*

Constants are all the variables that you try to keep the same, those that do not vary or change during the experiment. *Amy tried to make only one change: adding a fake cat. Examples of constants include type and amount of seed, feeder location, and time elapsed.*

4. Read and discuss Amy's experiment

Hand out copies of "Will a Fake Cat Scare Birds?" (Resource pages 16–17) to each student. Have students read it and discuss the questions at the end of the report with their group.

1. What was Amy's hypothesis? *(If a fake cat is placed next to a bird feeder, then less bird seed will be eaten.)*
2. What was the independent variable in this study? *("Fake cat" or "no fake cat.")*

3. What was the dependent variable in this study? *(How much bird seed is eaten during a week.)*
4. What variables did Amy hold constant? *(Time frame, kind and amount of seed, location, bird feeders.)*
5. What questions or concerns do you have about her methods? *(Possible concerns include length of study, details of the "fake cat," for example its smell or size, which may have affected the birds' reactions, other environmental variables such as temperature, wind, sunshine—was the weather the same both weeks? If it was a stuffed bird or a "friendly" stuffed bunny, would it have scared the birds? Was it the cat or just the fact that something new was there?)*

After groups have had time to discuss their ideas, review their answers as a class. Then, discuss these questions:

- Were there any other things Amy should have (or could have) kept constant? *(Amy did a good job keeping as many variables constant as she could. That said, we don't know if any real cats may have impacted the experiment.)*
- Could Amy's experiment have "proven" that the cat affected the number of birds at the feeder? *(A hypothesis cannot be proven, only rejected or supported. Amy's experiment supports her hypothesis, but additional time would have provided more data to determine the strength of the support.)*
- Was the study well-designed? *(Opinion based; see points above.)*

See the Teacher Insight box "Was Amy's Experiment Fair?" below for more information on the answers to these questions.

Conclude by emphasizing the features of Amy's study that make it experimental:

- The independent variable was manipulated: "cat" and "no cat." These are called the "treatment" and "control" groups.
- Other variables were held constant (the location and kind of feeder, the kind of bird seed). This helps to make the experiment a "fair test."

TEACHER INSIGHT

Was Amy's Experiment Fair?

Note that many factors could affect the number of birds coming to the feeders besides the cat. Some possibilities include differences in the temperature or the amount of rain during the weeks that the experiment took place. Although Amy did a good job keeping as many variables constant as she could, it would have been helpful for Amy to tell us whether any of these might have affected her results.

Be aware that students may consider evidence such as the data that Amy cites as "proof" of a hypothesis. A hypothesis cannot be proven, only rejected or supported. Scientists continue to collect evidence and alter and refine their explanations based on the evidence.

5. Additional Practice—Hypotheses and Variables

- *Identify variables.*
  Working in pairs, ask students to practice identifying variables for the three experimental questions on Journal page 10, "Identifying Variables." You may wish to do one of the questions together as a class as an example. Discuss student ideas and allow them to correct any misconceptions they've recorded in their journals.

- *Discuss an experimental plan in detail.*
  As a class, choose one of these research questions (or another question of your choosing) to discuss in more detail. For example, if students want to determine whether noise affects the number of birds in the school courtyard, students might suggest, "If we play loud hip hop music, then we will see fewer birds in the courtyard," as a hypothesis.

  Ask students to work in small groups to create an experimental plan that would address the class hypothesis. Each group should develop a list of methods and materials for conducting the study, identify the independent and dependent variables, and describe the control variables. Students should record their thoughts by answering the questions on Journal page 11, "Sample Experimental Plan."

- *Generate consensus about the plan.*
  Ask one group to share their plan and ask for class peer review of that plan. You should make sure that students have fully addressed the idea of controls in an experiment. You may need to have several groups share their plans and make comments to arrive closer to this ideal.

To conclude, generate a class list of all of the variables that they'd need to hold constant in the class experiment.

See, Classroom Case Study, "Discussing the Experimental Plan" (page 28) for an example of a discussion that took place in a "BirdSleuth classroom" where there was an investigation of the seed preferences of birds.

Identifying Variables – Sample responses for Journal page 10.

Read these three experimental questions. For each question, underline the independent variable and circle the dependent variable. Then write a hypothesis you might test to answer the question.

Question 1: Will more birds visit our schoolyard if we put up a birdbath?

Write a hypothesis:

- If we install a birdbath near our bird feeders, then more birds will visit our feeders per day.

Question 2: Do toads call more when it is warmer?

Write a hypothesis:

- If the air temperature rises, then toads will call more frequently.

Question 3: Does the type of plant wooly bear caterpillars eat impact how fast they grow?

Write a hypothesis:

- If we feed wooly bears a strict diet of kale, then they will spin cocoons sooner than if we feed them dandelion.

Reflect and Evaluate

1. Have students read the "Answering Your Scientific Questions" article (Resource pages 18–23) and answer the five "What do you think?" questions included there.
2. For homework or in class, instruct students to write the first draft of their introduction, using information they recorded in questions 1–4 on Journal pages 5–6. Specify whether the draft should be hand-written or typed. *Remind students that the purpose of the introduction is to provide background information from past research that validates their current hypothesis. Detail is important because this section will serve as the basis for the rest of their investigation and report.*
3. Ask students to reflect on the progress of their projects. These questions can be assigned in class or for homework. They can also serve as classroom discussion questions.
   - Are you surprised by any information or data you have discovered so far? Explain.
   - Evaluate the first draft of your introduction:
     - Revise your draft for clarity and meaning:
       - Does it sound right when you read it aloud?
       - Does it contain all the information needed to make sense?
     - Edit your draft for mechanics:
       - Have you checked your punctuation, capitalization, and spelling?
   - Do you have good background information and is it cited correctly?
   - How well do you explain why the question was chosen or why it is important to study?

Extensions

6. Using "Meet a Scientist" reports, *BirdSleuth Investigator* experiment articles, or other scientific reports or articles, answer the same questions that were asked about Amy's report:
   - What was the hypothesis?
   - What was the independent variable in this study?
   - What was the dependent variable in this study?
   - What factors were held constant?
   - Were there any other things that should have been (or could have been) kept constant?
   - What questions or concerns do you have about the scientist's methods?
   - Was the study well-designed? How could it have been improved?
7. Look at introductions from other scientific reports (from *BirdSleuth Investigator* or other sources). Ask:
   - What is done well?
   - What needs improvement or is missing?
   - Does the introduction make you want to find out more about the scientist's investigation? Why or why not?

CLASSROOM CASE STUDY

Discussing The Experimental Plan

Ms. James teaches a mixed 3rd–4th grade class in rural New York. They conducted a bird feeder study as a class. Before the study began, she had small groups brainstorm how they thought the study should be designed. The groups had a great discussion about these experimental plans.

When the first student group shared their plan, they stated, "We would make two identical feeders from soda bottles and fill one with one kind of mixed birdseed and the other with a more expensive brand of mixed birdseed. We would hang the feeders in the same tree and count and record the number and kind of birds that visited each feeder for a one hour period." Ms. James asked the students what their hypothesis was, and the students replied that they thought the birds would visit the feeder with the expensive seed more often because it probably contains more of their preferred seed types.

Was it a great plan to have the feeders in the same tree? One student commented, "If they hung the feeders in different trees, they may not know whether the birds liked one of the trees better or if they actually preferred one kind of food or the other." Another student commented, "If you did hang them in different trees and one tree was close to a noisy playground and the other tree was in a quiet area, birds may not visit the noisy tree regardless of what kind of food was in it." Ms. James and several other students agreed.

The other student groups were asked whether they had considered this in their plans. One student said that her group planned to hang the feeders in different trees, but all in the same area. Discussion was lively about whether that was OK. In the end, the group decided not to change their plan, but to make sure other things (like height and general location of trees) were held constant.

Finally, Ms. James asked the students whether they thought an hour of feeder watching was enough. Students shared their plans to count birds and compared ideas between groups. Most groups had more extensive plans to count birds and felt that the more time spent counting, the more accurate the results would be. One group suggested that it was better to weigh or measure the amount of seed remaining, rather than just the number of bird visits, since a bird could visit the feeder to check the food, but not actually eat it. The class agreed that would improve the study, so their new-and-improved hypothesis became, "If we offer birds a choice of mixed birdseeds, then they will eat more of the expensive seed." They were excited to begin their experiment.

Lesson 5: Show Me the Data

Big Idea: Graphs help summarize and illustrate data.

Overview: Students learn about types of graphs and visually represent data with bar, pie, line, and scatterplot graphs.

Learning Objectives

Students will be able to…

- correctly identify and describe four kinds of graphs commonly used in science: pie charts, line graphs, scatterplots, and bar graphs;
- create an appropriate example of a pie chart, line graph, scatterplot, and bar graph to represent data;
- explain how the four types of graphs are used to represent different kinds of information.

Time and Location: 90 minutes, more if you explore eBird data; indoors, ideally in a computer lab

Resources Needed

- Resource pages 1, 24–29: Kinds of Questions, Graphs of Bird Data, Graphing My Data
- Journal pages 7–9, 12–15: Project Notebook, Types of Graphs, Graphing Practice
- Graph paper
- Computers with Internet access
- PowerPoint: (available at **www.birdsleuth.org/inquiry**) "Grackles Graphing" tutorial

Getting Ready:

- Copy the Resource pages for each student or group.
- Project or provide class handouts of "Graphs of Bird Data."
- Review "Grackles Graphing" and make a plan to use it.

Conducting the Activity

1. Look at real world graph samples

Project for the class and/or give each student the "Graphs of Bird Data" handout (Resource page 24), which illustrates four kinds of graphs you will discuss: pie, line, scatter, and bar. Take a few minutes for students to interpret what each graph "says."

Then, ask students to compare and contrast the graphs, focusing on how the data are presented and any differences they might notice between the kinds of data presented in each. Create a list of the graphs' similarities *(e.g. all have a title, they are pictures of data)* and differences *(e.g. some have lines, others have bars; all have numbers except the pie chart*) on the board.

2. Discuss graphs

Remind students that in Lesson 3, they also saw examples of bar graphs in "Will a Fake Cat Scare Birds?" (Resource pages 16–17) and different kinds of graphs in the "Answering Your Scientific Questions" article (Resource pages 18–23). Begin a class discussion about how and why people use graphs. In your discussion, ask:

- What is a graph? *(Graphs visually represent raw data or statistics. They turn numbers into pictures.)*
- What kind(s) of graphs have you made? Describe what you have already learned about making and interpreting graphs.
- What challenges have you experienced? *(Examples include deciding how to fit the data on the page, deciding what type of graph to use, making them look good.)*
- Why do people make graphs? *(To analyze data, to help determine the significance of data, to provide a new perspective of the data.)*
- Why do you think information is often presented in graphs instead of just in lists or tables? *(Graphs highlight relationships, patterns, and trends. They make the information in lists and tables easier to interpret and share. Each graph communicates one idea from the data in a clear and orderly way.)*

3. Discuss choosing the right kind of graph

Have students read "Graphing my Data" (Resource pages 25–29) and/or go through the "Grackles Graphing" tutorial. Review the terms "independent variable" and "dependent variable." Discuss how different types of graphs are better at illustrating different kinds of data. Make the following points by appropriately referencing the four "Graphs of Bird Data" (Resource page 24).

- Line graphs are preferred for showing changes over time because they better represent a continuum of data.
- Scatterplots are similar to line graphs, and good for showing trends in data. They show how much one variable is affected by another.
- Bar graphs are used to compare two or more categories of things.
- Line, bar, and scatterplot graphs all have a dependent variable that is measured and plotted on the y-axis.
- Pie charts show proportions and always add up to 100%.

Students should record these ideas in the table on Journal page 12, "Types of Graphs."

4. Generate class graphs

Practice making a sample graph of each type with simple class-generated data (see samples below). Students should record a sample graph of each of the four kinds in Journal pages 13–15, "Graphing Practice." Alternatively, enter the data into Excel to create graphs.

<u>Pie Chart</u>

Examples to graph: what proportion of students choose a given favorite sport, bird, or food? See the sample pie chart, Figure 1.

Steps for making a pie chart:

1. Collect and organize the data in a table with column and row headings (see Table 1). Remember, pie charts are used to display percentages and the total of all categories adds up to 100%.
2. Calculate the proportions and circle degrees for each item in the table. (For younger students, calculating circle degrees is not necessary; estimating and drawing the proportions will suffice).
3. Draw a circle to represent a pie chart.
4. Transfer the data to the graph by drawing segments in the circle. Distinguishing sections by color is the standard way to tell them apart.

5. Decide on a title for the pie chart. The title should go at the top and summarize the variables studied.
6. Create a key to identify the sections of the pie chart.

Favorite cafeteria food	Number of students	Percentage of students	Circle degrees (% x 360)
Pizza	8	40%	144
Hamburgers	5	25%	90
Chicken Nuggets	3	15%	54
Other Foods	4	20%	72
Total	20	100%	360

Table 1: Favorite cafeteria foods

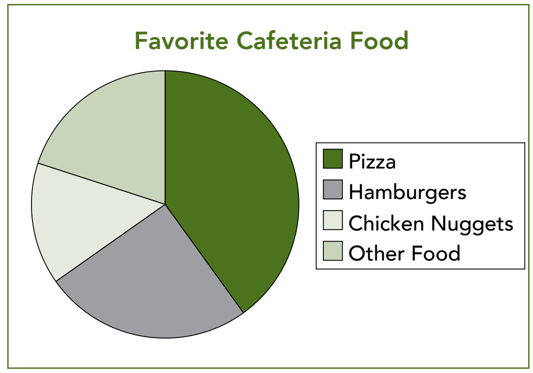


Figure 1: Sample pie chart

Line Graph

Examples to graph: a student's growth in height or weight since birth, the daily high temperature over the course of last week. See Figure 2 for an example.

Steps for making a line graph:

1. Collect and organize the data in a table with column and row headings (see Table 2).
2. Draw a right angle to represent the graph axes.
3. Label the x and y axes of the graph. Lay out the scales for each axis. (For the example below: height in inches, 0–60; age in years, 1–10).
4. Transfer the data to the graph by adding data points and drawing a line connecting the dots.
5. Decide on a title for the graph. The title should go at the top and describe the relationship between the variables represented.

Kerry's height since age one	
Age (in years)	Height (in inches)
1	27
2	32
3	37
4	40
5	42
6	45
7	48
8	50
8	52
10	54

Table 2: Student's growth

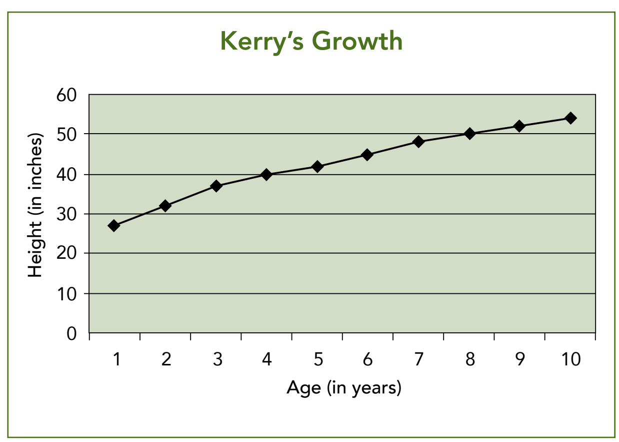


Figure 2: Sample line graph

Scatter Plot

Examples to graph: the number of minutes that students spent studying for an exam versus the grade they received, height versus arm span, time spent playing video games versus grade point average. See Figure 3 for an example.

Steps for making a scatter plot:

1. Collect and organize data in a table with column and row headings (see Table 3).
2. Draw a right angle to represent the graph axes.
3. Label the x and y axes of the graph. Lay out the scales for each axis. The scales should be long enough to encompass the data. Almost always, the scales should start at zero.
4. Transfer the data to the graph by adding data points.
5. You may choose to draw a best-fit line through the points if they seem to be correlated. (This has not been done in the sample, but it appears there is a positive correlation between time spent studying and test score.)
6. Decide on a title for the graph. The title should go at the top and describe the relationship between the variables represented.

Student	Hours spent studying	Test score
1	3	80
2	5	90
3	2	75
4	6	80
5	7	84
6	1	55
7	2	64
8	0.5	48
9	1	42
10	7	100
11	1.5	81
12	2.5	82
13	3.5	82
14	4	91
15	1.5	61

Table 3: Study time and associated test score

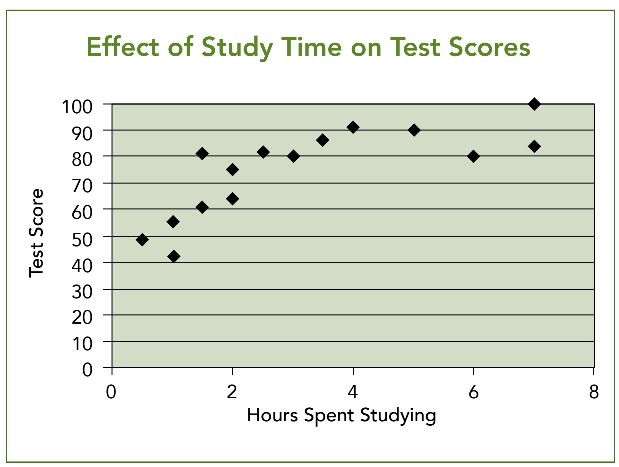


Figure 3: Sample scatter plot

Bar Graph

Examples to graph: movies students have recently watched, pets they own, or favorite ice cream flavors.

Steps for making a bar graph:

1. Collect and organize the data in a table with column and row headings (see Table 4).
2. Draw a right angle to represent the axes of the graph.
3. Label the x and y axes for the graph. Lay out the scale for the y-axis and the categories for the x-axis.
4. Transfer data to the graph by drawing bars on the graph.
5. Decide on a title for the graph. The title should go at the top and describe what the graph is about.

Kind of Pet	Number of students who have at least one of this kind of pet
Dog	6
Cat	7
Fish	8
Rodents	5
Others	3

Table 4: Pets owned by students

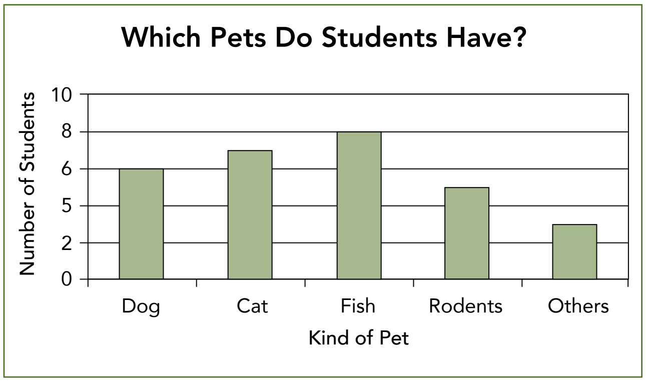


Figure 4: Sample bar graph

Ask students to complete the graphs for their investigation and the discussion section of their research report at this time (Journal page 8). The Teacher Insight box below offers more information to help students interpret their data. Students should exchange their graphs and discussion sections with another group, pair, or student who will review their work and give feedback and suggestions. Review their revised graphs.

In class, discuss and correct any common mistakes found in the graphs, and post good examples of each type of graph.

TEACHER INSIGHT

Helping Students Interpret Data

Consider the following questions to help students make sense of data:

- What patterns do you notice?
- What do the data "show?"
- How well will each type of graph represent the data? Is one more effective than the others for this particular type of data?
- What do you think the data mean? What can you conclude?
- What generalizations do you think you can make based on your data/observations?

Reflect and Evaluate

Have students write answers to the "What Do You Think" questions in the "Graphing My Data" article (pages 25–29).

Extensions

1. Explore eBird Data: Project Resource page 1, "Kinds of Questions." Emphasize the "Explore and Analyze Data" jumping-in point on the diagram. To answer these kinds of questions, students will need to look at data that have already been collected. The Cornell Lab of Ornithology's citizen-science databases are a great resource. For example, eBird is full of data about the kinds and numbers of birds seen around the world. Its online graphing and mapping tools make it simple for students to address many kinds of questions about bird distribution and abundance. Visit eBird at **www.ebird.org** to explore this resource. For more support, consider purchasing BirdSleuth's *Most Wanted Birds* kit to help students contribute to and use the eBird citizen-science database. The kit includes useful bird ID resources and PowerPoint presentations to help students contribute to and analyze eBird data. Order this kit at **www.birdsleuth.org**.
2. Look at newspapers or search online for graphs associated with current events. Ask students to interpret the graphs.
3. For students who finish early or need extra graphing practice, use the interactive PowerPoint tutorial: Grackles Graphing.

CITIZEN-SCIENCE SPOTLIGHT: INVERTEBRATES

Step outside, look in the vegetation, dig in the dirt, peer in a pond, or walk on the beach. Everywhere you go, you'll find invertebrates. Projects involving diverse species such as insects, spiders, horseshoe crabs, worms, and starfish give everyone (including students!) the opportunity to connect to animals all around the globe. Given the problems facing insects (such as decreasing numbers of native bees, Monarchs, and native ladybugs) and the problems caused by invasive species (from Emerald Ash Borers to Zebra Mussels), student participation in many of these projects can truly make a difference.

Invertebrates are everywhere and their behaviors encourage lots of questions. Students may begin to wonder…

- How many different types of ants can we attract to a cookie on the sidewalk?
- Where do insects, worms, or spiders go in the winter?
- What kind of bees are coming to the flowers in my yard?
- Which insects in my yard are native, and which are not? Which are beneficial and how can we attract more of them?

Consider participating in one or more of these projects: School of Ants, Monarch Larvae Monitoring Project, Great Sunflower Project (bees), Lost Ladybug Project, Bugs in our Backyard, Spot a Ladybug, Viburnum Leaf Beetle Project, Great Lakes Worm Watch, Dragonfly Swarm Project

Lesson 6: Share my Investigation

Big Idea: Science advances when scientists clearly communicate their findings.

Overview: Students become familiar with the parts of a scientific presentation and how to convey the results of their investigation.

Learning Objectives

Students will be able to…

- prepare a poster, oral presentation, newsletter article, or scientific report that summarizes their work;
- give constructive feedback on another student's scientific report or presentation;
- consider feedback when revising their own report or presentation.

Time and Location: Two 40-minute sessions, plus additional time for students to prepare their projects or reports; indoors

Resources Needed

- Resource pages 30–32: Sharing My Report
- Journal pages 16–18: Peer Review Checklist
- Copies of *BirdSleuth Investigator* magazine (order online or print yourself, see **www.birdsleuth.org/inquiry**)
- Computers
- Poster supplies (if students create posters)

Getting Ready:

- Review your expectations and how students will present their findings.

Conducting the Activity

1. Prepare a draft project.

At the conclusion of their research, give students time in and/or out of class to write the first draft of their report/poster/article/presentation using their journal notes. Give feedback and suggestions during the process, encouraging students to give a detailed account. *(Have they included suggestions for improving their study in the discussion section? Are all the materials listed? Are the methods written like a recipe that someone else could follow? Do their graphs illustrate important findings? Have they considered other explanations for their results?)*

Scientific papers and posters should use a standard format for their content. If your students are presenting their reports as either a scientific paper or poster, have them read the article "Sharing My Report" (Resource pages 30–32).

2. Introduce peer review.

Remind students that after they write a report, it is not yet ready to be published. Scientists send their work to other scientists who review it and make suggestions for improvement. This is called the peer review process. Invite students to peer review each other's work.

Although peer reviewers need to give suggestions for improvement, their criticism should be constructive. Lead a discussion about how the peer review process should be a positive one. Make a list on the board called "What makes a good peer review?" Add adjectives and ideas the class suggests for conducting a positive review process *(respectful, helpful, kind, thoughtful, specific, encouraging, creative, honest, clear, readable, reasonable, useful)*. Start by making a positive, true comment and then give suggestions for improvement. End with a different positive, true comment.

3. Conduct a peer review of papers.

Pass out the Peer Review Checklist (Journal pages 16–18) and discuss it with the students. Have students exchange work with their peer reviewers. You may wish to review all reports at this stage as well.

When the reviews are complete, students should receive copies of each of the Peer Review Checklists completed about their project. Encourage students to thoughtfully consider the feedback they have received and incorporate all reasonable suggestions.

4. Complete the final project.

Students will revise their projects, taking into account any useful suggestions from their peer reviewers. You may find it useful to ask them to explain any review comments that they reject, emphasizing that it's fine to do so as long as they can justify this decision.

5. Share your findings and feedback.

Review all completed projects. Invite students to submit their revised reports online to *BirdSleuth Investigator* magazine. Please also send us any photos, illustrations, or sample student work (journals, posters, graphs). See the Teacher Insight box on the next page for additional ideas about how your students can share their findings.

CITIZEN-SCIENCE SPOTLIGHT: WEATHER

Humans have always been interested in the weather. It affects our moods, our work, our recreation, and even our survival. And it is notoriously difficult to predict. Citizen scientists are now helping to document and study weather from the ground up.

S'COOL (Students' Cloud Observations Online) is an educational outreach effort from NASA that uses citizen-science observations to make sure that satellite instruments are accurate. Students observe and report clouds within +/- 15 minutes of a satellite's passage, then classify and compare the ground and satellite views of those clouds. This project offers a wealth of free resources, standards-aligned lessons, and activities.

As students turn their eyes to the sky, they may begin to wonder…

- Why are some clouds puffy and others long and thin?
- What makes some clouds white, while others are grey or brown or yellow?
- How do satellites stay in their orbits?
- How do scientists predict weather and how accurate are they?

Other weather citizen-science projects: CoCoRaHS (Community Rain, Hail, Snow Network), Old Weather, Aurorasaurus, Cyclone Center

TEACHER INSIGHT

How can my students share their findings?

We suggest the following ways to present students' final product, modeling what scientists do. Of course, you may choose to do more than one of these options!

BirdSleuth Investigator

Invite students to look at *BirdSleuth Investigator*, available on the BirdSleuth web site. You may also wish to order copies of past editions of the printed magazine. We encourage students to submit many kinds of work: science papers, research reports, graphs and charts, art, photographs, field sketches, and journals. Have students print and read the submission guidelines. Students should be sure their submissions are peer-reviewed and checked by a teacher prior to submission, and should understand that (as with any scientific publication) not all work submitted can be included.

Class Newsletter

Compile the class submissions and publish your own *Science Newsletter*, to be distributed in the school and at home. Encourage students to brainstorm what they might find interesting in a publication. Students can use their imaginations and creativity to come up with a design plan and/or look at other newsletters and magazines for ideas. Additional ways students have showcased their knowledge about science include poems, songs, short stories, book reviews, surveys, and interviews. Be sure to send a copy of your newsletter to BirdSleuth at the Cornell Lab of Ornithology!

Poster Session

Have students prepare a large poster to display their work for the class, school, or open house. Graphs and other visuals can be added to make the poster attractive. Due to size limitations, posters need to be succinct summaries. While the font size must be large and readable and there may be several illustrations, all sections (introduction, materials and methods, results, discussion, and conclusion) should be included. You may wish to have students write and submit summaries for one or more of the posters they examine during the poster session.

Science Conference

Convene a conference during which students orally present their findings. You may wish to invite others to hear the presentations (the principal, next year's class, parents) and have the students prepare a PowerPoint presentation.

Science Fair

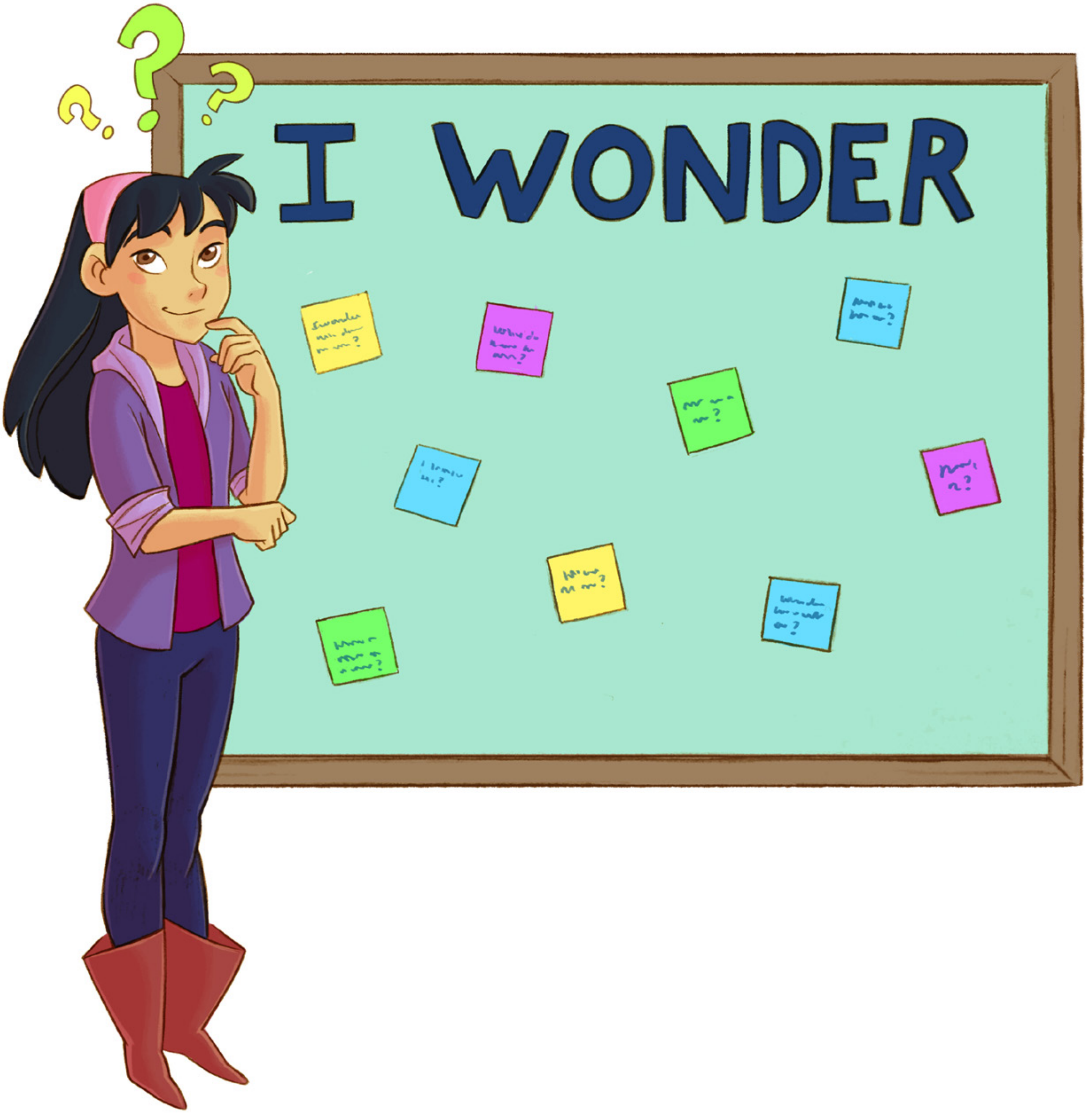
Science fairs are organized poster sessions or conventions where students share the results of their experiments and investigations in informative displays. Your school can arrange a science fair, or another school system or organization may host a fair nearby. Science fairs are often run as competitions based on the quality of the scientific research being presented.

Website or Blog

Many scientists present their work on their own websites. Students, too, can create a class website using free blog hosting. Include a page for each investigation, or simply highlight the most interesting results from each project. As with any Internet interaction, be mindful of web security and privacy: do not post student names or locations.

The Cornell Lab of Ornithology
BirdSleuth K–12

The Cornell Lab of Ornithology



Investigating Evidence

RESOURCE PAGES

The Cornell Lab of Ornithology
BirdSleuth K–12

Resource Pages

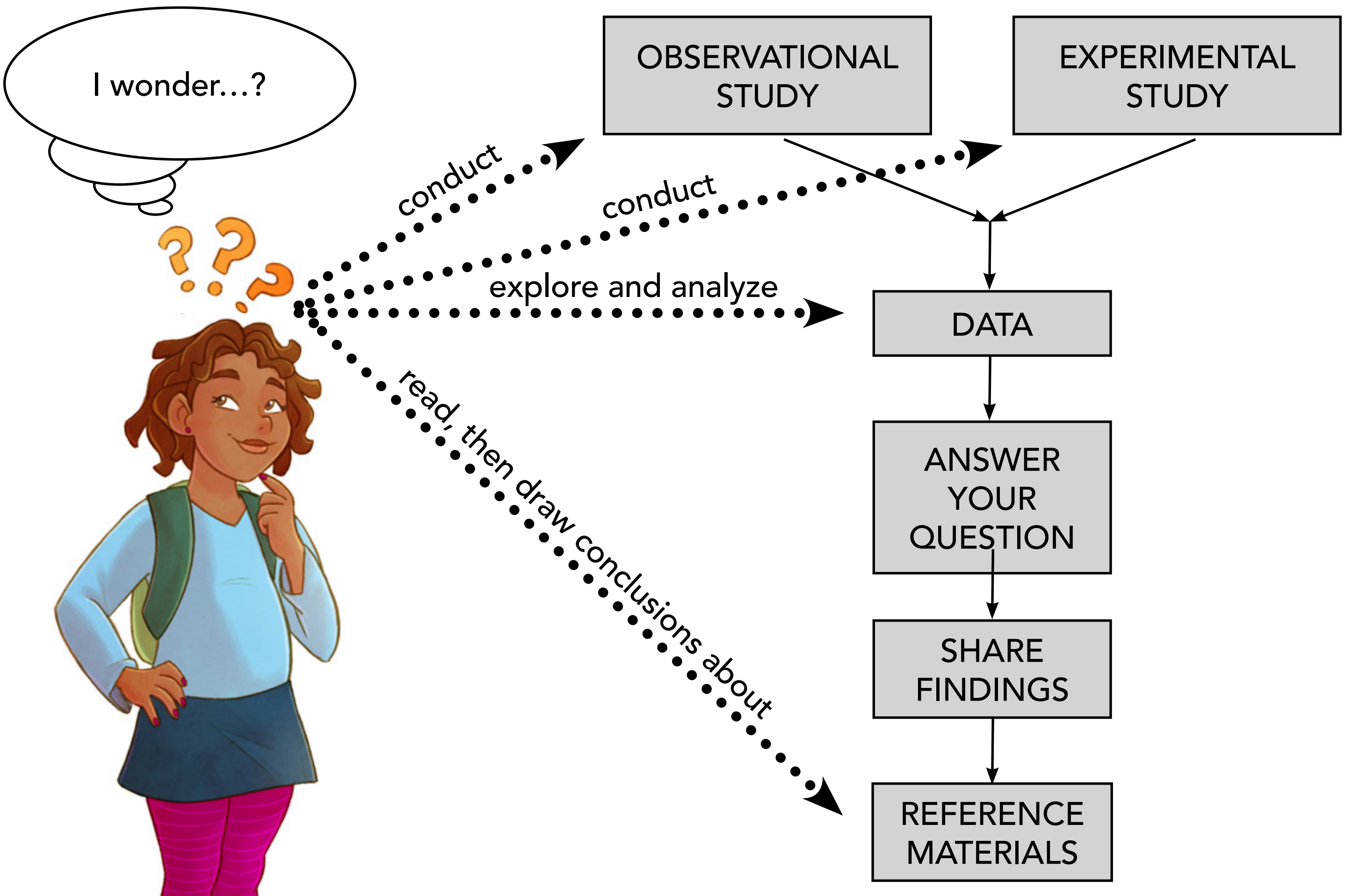
Page

Kinds of Questions

You may have already come up with some questions about your observations. Different types of questions lead to different types of research projects. You can classify questions by how you can answer them. This graphic shows four ways to answer your scientific questions.

WHAT DO **YOU** THINK?

Look at the graphic and read the paragraph in the box below. What are the four ways to answer your scientific questions?



Where will you jump into the process?

Depending on your question, you can enter the process of science at different stages. Look at the dotted arrows to see where this student scientist could jump into the scientific process. Some conduct their investigations through **experimental** or **observational** studies, some start by **exploring and analyzing data** from a database (like eBird, for example), and still others find answers by pulling together information they find in **reference materials** such as books or web sites.

Vultures: SEE or SMELL?

Vultures have an uncanny ability to find dead animals to eat. But HOW do they find their food: do they see it from above or smell it from far away? The answer to these questions was found through a series of experiments conducted not only by scientists, but also by naturalists and ordinary people!

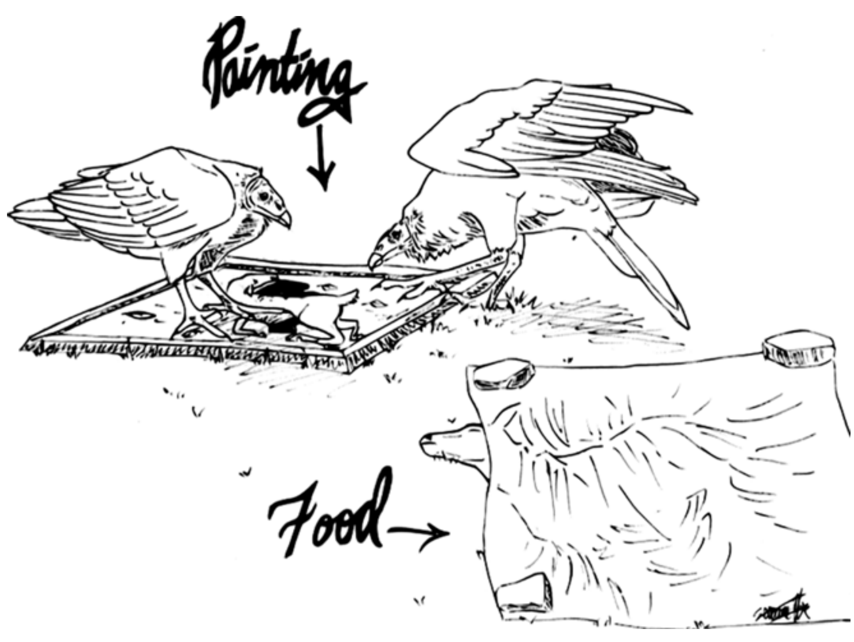
The question: How do vultures find the food they consume? Do they see it or smell it?

Back in the 1800s, people assumed that vultures could smell dead or dying animals and that this was how they found their next meal. It seemed a likely explanation: because dead things stink so much, vultures must find their meals by smelling them.

An illustrator and avid bird watcher named John James Audubon wondered if that were true. He noticed that he could get very close to feeding vultures and they would not react to him until they saw him. They didn't seem to smell him coming. Audubon decided to test how vultures found their prey. He placed a fake dead animal (an animal-shaped bag filled with straw) in an empty field and watched for vultures. One attacked the "carcass" almost immediately, and seemed puzzled by the lack of food. Audubon then placed rotting meat under some brush, making it invisible from the sky but easy to smell. No vultures came to this deliciously stinky food. He concluded that vultures must SEE rather than SMELL their way to food.

Intrigued, more researchers decided to test this theory for themselves. In 1833, Reverend John Bachman, an American naturalist, decided to continue Audubon's work. Bachman also placed smelly meat under cover to see if vultures would find it. None did. He put a painting of a dead sheep out in the open. The vultures swarmed it. He repeated this experiment fifty times with the same result. Finally, Bachman placed the painting out in the open with a pile of rotting meat ten feet away, hidden under a cloth. The vultures investigated the painting, but left without finding the real meal.

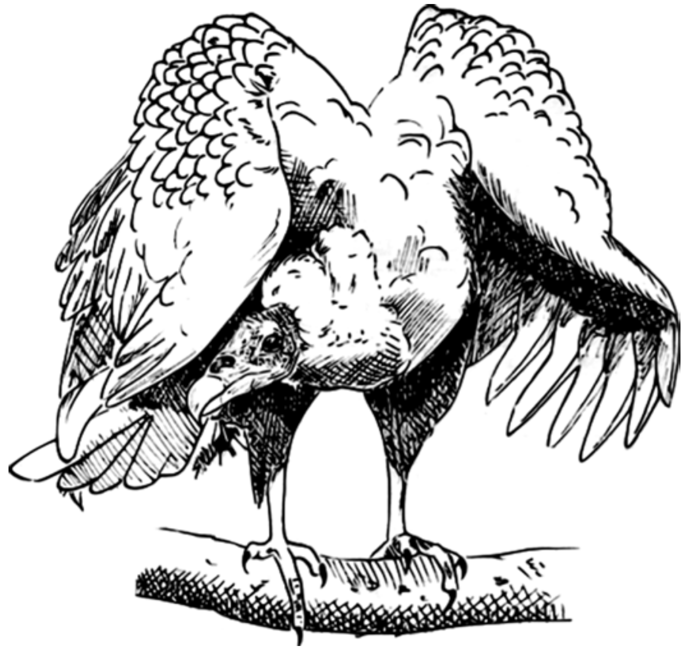
Through this series of experiments, Bachman believed he had proven Audubon's



Severine Hex

Vultures swarmed a painting of a dead sheep, but ignored a hidden real sheep.

theory: Vultures rely on sight rather than smell when finding food.



In the 1960's, Kenneth E. Stager, an ornithologist, decided to rerun some of these vulture experiments using mercaptan, an extremely smelly chemical that is released as a carcass decays. Stager became curious when a natural gas company employee told him that after the company began adding mercaptan to natural gas, Turkey Vultures were observed soaring above leaking pipelines. Stager decided to design experiments to show exactly where Audubon and Bachman had gone wrong.

First, Stager repeated Audubon's basic test of hiding a carcass to see if vultures would detect it. He put meat in cage traps and hid them. Turkey Vultures were caught in these traps. Next, he hid a carcass. Vultures appeared, flying low, searching the ground for the carcass.

Stager's most interesting experiment involved spraying mercaptan-scented gas into the air in a desert. Turkey Vultures came flocking, soaring in circles overhead. The vultures responded to the smell of decay. If decoy carcasses were present, the birds would also land. However, in his "smell only" tests, Stager noticed that Turkey Vultures would circle for about 20 minutes and then fly away. The birds would not land without seeing any decaying meat. He concluded that Turkey Vultures can use their sense of smell to find their food, but then rely on sight to find the source of the scent.

Stager and others tried to guess what was wrong with the experiments of Audubon and Bachman. It is thought that Audubon performed many of his tests on Black Vultures. It is now believed that only Turkey Vultures have a strong sense of smell. Black Vultures do not, but will follow Turkey Vultures to find food. Audubon may have mistakenly assumed that all vultures act alike. Also, he assumed all vultures prefer rotten meat, but vultures enjoy fresh carcasses. Finally, when Bachman covered the meat with canvas, he didn't take into account how weak vultures' beaks and claws are; they may have smelled the meat, but couldn't get to it through the heavy cloth. Current studies have also shown that a Turkey Vulture's sense of smell is tied to its sense of taste; they prefer eating the meat of animals that eat plants (herbivores) over those that eat meat (carnivores). That could have affected the outcome of the early experiments done by Audubon and Bachman.

Meet a Scientist – Mike Booth

Mike Booth spent much of his childhood camping in the Sierra Nevada mountains, playing in tide pools, and hiking in the redwoods. Today, Mike studies a fish species, the Sonoran Sucker, and how they interact with their river ecosystem. Many native fish populations around the world are disappearing, and when native species disappear, entire ecosystems can change. An example of this is the Gila River in Arizona, the site of Mike's research.

Mike Booth

The fish crew

Relatively little is known about the Sonoran Sucker's basic biology and how it impacts its ecosystem. Mike has a hunch that the major impact is through their feeding behavior. The stream bottom changes as fish dig in it while feeding. This behavior causes small depressions, which become habitats for other species and affect the types of organisms that can live in the stream.

Mike Booth

Sonoran Sucker

Mike tracks hundreds of Sonoran Suckers using tags that can be detected with radio antennas strung across the river. This tells him when and where the fish are active. He also looks for disturbances in the stream bed. Everything is connected to a computer which captures the data.

Mike's experiments confirm that Sonoran Sucker behavior impacts the supply of food (detritus, algae, invertebrates) in the river. Technology allows him to observe the movements of individual fish over long periods, adding a new way to understanding how fish affect streams. His data also shows that suckers regularly move large distances within the stream, implying that conservation efforts must preserve large sections of streams to be successful. Understanding the role of this important species will provide a stronger reason to conserve the fish of the southwest.

Meet a Scientist – Susan Cook-Patton

As a kid, Susan Cook-Patton fell in love with nature. She spent hours riding bikes with her father and exploring the wild places in her suburban backyard. Now, as a scientist, Susan wonders how different types of plant species interact with each other and with insects.

Courtesy of Susan Cook-Patton

Susan with bare-root plants

Plant diversity is changing. Some species that lived in one place for many, many years (native species) are disappearing. Other species that never lived in North America are moving in from other continents (non-native species). Susan wonders if it matters that we are losing some plant species and gaining others? And, if so, why?

To help answer these questions, Susan fills 150 canvas bags with soil to create 150 plots in her experimental field. Each bag is planted with native and non-native species in different combinations. Some plots have only one species. In other plots, up to seven different species are planted.

Susan carefully observes and records differences between the plots and how the plants interact with other organisms. For example, she counts the number of flowers and insects on each plant. Then, after looking at the stems and leaves, Susan removes entire plants from their soil to observe the roots. Next, she harvests sample parts of each plant and grinds them up. Back in the lab, she analyzes how much carbon and nitrogen the samples contain. Susan is particularly interested in nitrogen levels, because nitrogen tells her how well the plants are taking in nutrients from the soils.

Susan's research shows that plots containing a mixture of species use soil and water more efficiently and grow better. Plant diversity also leads to more insect diversity, but non-native plants attract fewer insects. When non-native plants are mixed with natives, the native plants produce fewer seeds. This may reduce the numbers of native species over time.

Meet a Scientist – Marita Davison

When she was 7 years old, Marita's family moved to Bolivia. She saw her first flamingos there and was amazed at their beauty. She began to wonder if anyone was studying them. After some background research in college, she learned that very few scientists around the world, and virtually no one in Bolivia itself, were focused on these impressive birds.

Courtesy of Marita Davison

Sampling at the experiment site

Marita Davison

Flamingos

Marita decided to investigate what would happen to lakes if flamingos became extinct. To do this, she fences flamingos out of particular sections of lakes. Later, Marita collects small samples of lake sediment and dries them. Back in the lab, she measures how much algae is in the samples.

Since flamingos are easily scared by people and working in these muddy areas is difficult, Marita also uses technology to collect data. From digital photos, Marita and her team find out how many flamingos are in the lakes and where they are. They combine these data with information about climate and algae to determine the effects of flamingos on the algae in the lake. Since algae is at the bottom of the food web, it is important to everything else in the ecosystem.

Marita's research shows that there is more algae in the areas fenced off from flamingoes. However, the algae is of poor nutritional value and isn't diverse. Based on these findings, Marita is convinced that flamingos should be considered a 'keystone species' in their aquatic habitats. This means that, relative to their abundance, flamingos have a very large impact on their ecosystem.

More and more people are traveling to the Bolivian Andes on vacation. This ecotourism brings a new source of income to people, but it might cause flamingo populations to decline. If this happens, wildlife around the high mountain lakes could disappear. To get the word out, Marita writes articles in scientific journals, offers workshops, and gives speeches about how to protect the flamingos.

Meet a Scientist – Anna Savage

Anna Savage thinks catching frogs is fun and exciting, but harder than it looks. She ought to know because she's been doing it since she was two years old! As a child, she caught frogs in her backyard, drew pictures of them, and put them in the kitchen sink to scare her mom.

Courtesy of Anna Savage

Anna swabbing a juvenile frog at a nature preserve

Now, as a scientist, Anna has her work cut out for her. Over the past 30 years, global frog populations have suffered severe declines and extinctions due to the fungus Bd, which causes chytridiomycosis (chytrid), a terrible skin disease. Anna wants to know why frogs from some groups are more susceptible to the Bd fungus than others.

Anna Savage

Lowland Leopard Frog caught in a net

For her research, Anna travels to a wide range of habitats, from arid deserts to forests near bodies of water, to catch Lowland Leopard Frogs during the day and night. At each site, she records air and water temperature, and GPS coordinates. A lot of Anna's work involves waiting—in the field, she has to be patient in order to catch frogs, and on some days she does not find any at all. When she does catch a frog, Anna weighs and measures it, and then takes a skin swab to determine if it is infected with the Bd fungus. The final step is to take a tissue sample by snipping off one of its toes. This will give her a bit of the frog's DNA to study.

Back in her lab, Anna extracts genetic information from her samples and loads it into a DNA sequencing machine. It takes twelve hours for this machine to provide the complete sequence of the frogs' DNA. She gets excited about this step because now she can connect the frogs she saw hopping around in the pond in Arizona to their genetic information. Anna hopes that frogs might adapt to chytrid through natural selection, creating a new generation of disease-resistant frogs.

Along with other scientists, Anna is hoping to create a database to help conservationists determine how to help infected frog populations in their areas. The biggest threat to frogs, however, is habitat loss. Anna stresses that human conservation efforts must continue to give frogs, and all the world's amphibians, a better chance at survival.

Meet a Scientist – Taza Schaming

Pocholo Martinez

Taza taking notes

Snowshoes, avalanche safety equipment, and radios are some of the gear Taza Schaming packs when she heads out to work in the Teton Mountains of Wyoming. But she is not a professional mountaineer or athlete—she is a scientist!

Recently, people have observed that Clark's Nutcrackers have almost disappeared from some of their pine forest habitats. Some scientists think that Clark's Nutcracker might be disappearing because the Whitebark Pine, one of their primary food sources, is disappearing. By studying a healthy population of Clark's Nutcracker, Taza hopes to learn what they eat, how much they move around to collect food, and how they relate to each other socially.

HHHETRICK OF CA

Clark's Nutcracker

To conduct her research, Taza first catches some birds with a net. She gently attaches identification bands to their legs, weighs them, measures their beak, wing, leg and tail lengths, and collects a blood sample. Finally, using tiny backpacks, she attaches small radios to the birds, allowing her to track their movement. This helps her learn which habitats they use, what they eat, and how big their ranges are. Taza also follows the Clark's Nutcrackers to their nests to see how many eggs they lay and how many chicks hatch. With this data, she can understand how these birds live in their environment and how their habitat affects them.

Working in the field requires patience, perseverance, and hard work. "It's crazy sometimes to realize how many different skills a field scientist needs to have," says Taza. "Not only does one need to be efficient and patient in the field, able to deal with intense weather, biting bugs, and constant troubleshooting, but one needs to be able to write well in order to obtain grants, then write up papers for publication."

Whitebark Pine continues to decline, but thanks to the work of Taza and many others, ways to restore the forest are being developed.

Meet a Scientist – Nate Senner

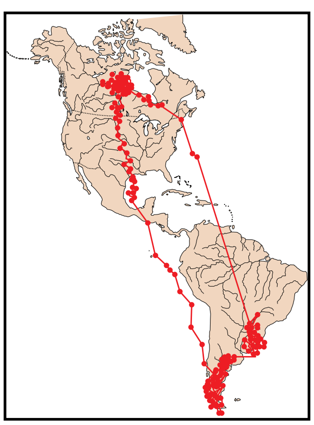
Nate Senner has been following birds since he was a little kid. Once, on a family vacation in Alaska, he walked onto the mud flats and was surrounded by huge numbers of small shorebirds that didn't seem to notice him at all. He has been hooked on birds ever since.

Courtesy of Nate Senner

Nate with Godwit

Now, he studies the small shorebird, Hudsonian Godwit, and its amazing migration (9000 miles, twice a year). Godwits hang out in groups of 70,000 birds at their northern resting site. Then they disappear for several months before arriving in South America. No one knew the path they took and where they rested along the way, but Nate Senner was determined to find out.

Nate is part of a team that places leg bands and data loggers on Godwits. The first step is the most difficult—catching at least 100 of the skittish birds. Would you believe the scientists shoot "cannon nets" in order to do this? It takes a lot of planning and precision to keep the birds safe during the process: setting the cannons in the sand, disguising the net, even camouflaging the human footsteps. Then BOOM! The net catches between 100 and 150 birds. As part of a team of scientists, Nate collects data on each bird's legs, wings, bill, weight, and DNA. Then, he places identifying bands on the Godwits' legs.



Courtesy of Nate Senner

Godwits' migration route

Nate also attaches data loggers to the birds' legs. Data loggers are small electronic devices, about the weight of a paperclip. After a year, Nate returns to recapture the birds and remove the loggers. Back in the lab, he downloads data from the devices and creates a map of the bird's migration path. With data from hundreds of birds, Nate creates maps of where the Hudsonian Godwits go when they "disappear."

Nate shares this information with other scientists, conservation groups, and governments, both in scientific journals and online. He encourages others to protect the nesting and resting areas of the Hudsonian Godwit throughout the Americas.

Annalisa's Report

The Effect of Temperature on Chickadees

by Annalisa, 10th Grade
Tualatin Valley Junior Academy, Hillsboro, OR
Mr. Kahler

Black-capped Chickadee by Caitlyn, Grade 7, Tualatin Valley Junior Academy, Hillsboro, OR, Mr. Kahler

Introduction

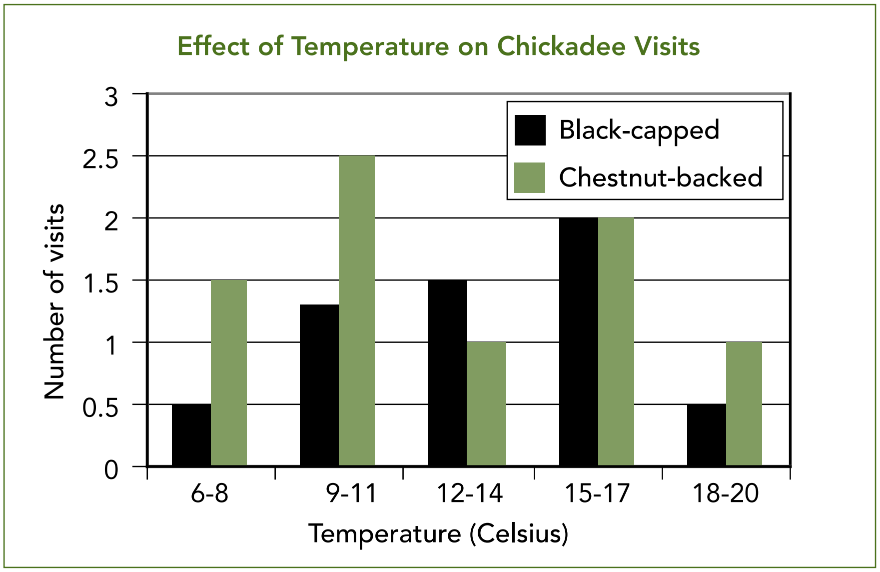
I decided to study Black-capped Chickadees and Chestnut-backed Chickadees observed at our feeding station. Both birds are found in mature forests near streams, which makes Downy Creek (near my school) the perfect haven for these active birds. I wanted to know if the temperature affected the number of birds seen eating at our feeders. I predicted that on colder days, I would observe more chickadees than on warmer days. I based this prediction on the fact that spiders and insects—the main food of these little birds—are scarce when it's cold, causing the birds to seek food from feeders.

Materials and Methods

I observed the feeders at the bird blind in the wooded area behind the school on 13 different days from November through March. At Downy Creek, we offer birds a variety of birdseed in feeders and on the ground, and suet at feeders hanging from several trees. On each data collection day, my biology class would write weather information on our bird tally sheets, walk to the bird blind, count birds, and compare data. Then, we entered the information on the web site. Each bird watch was about 15 to 30 minutes long and took place in the afternoon around 2:30 P.M.

Results and Analysis

The greatest number of Black-capped Chickadees seen on an observation day was three. The greatest number of Chestnut-backed Chickadees seen on an observation day was four. I saw these species on about half the days I watched: on five of the days, no Black-capped Chickadees were observed, and on six of the days, no Chestnut-backed Chickadees were observed. The temperature on observation days fluctuated from 6˚ C to 20˚ C (from 43˚ F to 68˚ F). I calculated an average number of visits for each temperature category and created a bar graph to see if there were any trends in the data. See my graph.



Discussion and Conclusion

It seems that temperature did not affect chickadee feeding habits at our feeders. They came and went in the same numbers on very cold days as they did on warmer ones. On a day when the temperature was 19˚ C (66˚ F), the highest observation day temperature, we saw no chickadees of either kind. Neither did we see any when it was 6˚ C (43˚ F), the lowest temperature. Looking at my graph, there was no definite pattern in my data, therefore, I must reject my hypothesis that there will be more chickadees present on colder days.

I originally thought that when the temperature was low, I would observe more chickadees than on warmer days. I believed colder days would bring more chickadees looking for food. However, the range of temperatures we had during the study was not large (43–66˚ F). None of the days was below freezing. A longer study over more temperatures might provide a better idea whether temperature affects these species' feeding habits.

Jerry Acton

Black-capped Chickadee

CDBTX

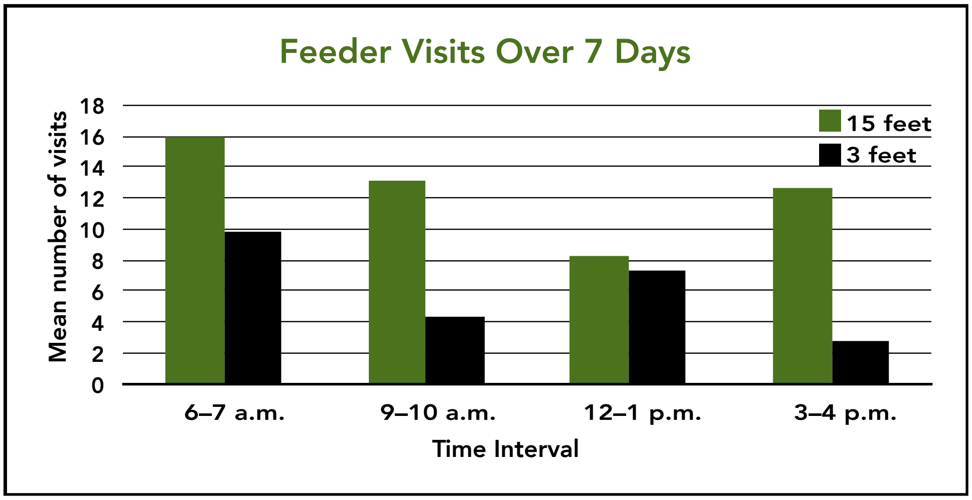
Chestnut-backed Chickadee

Hypothesis Help

Hypothesis:
A testable statement about the natural world which can be supported or rejected by experiments or observations.

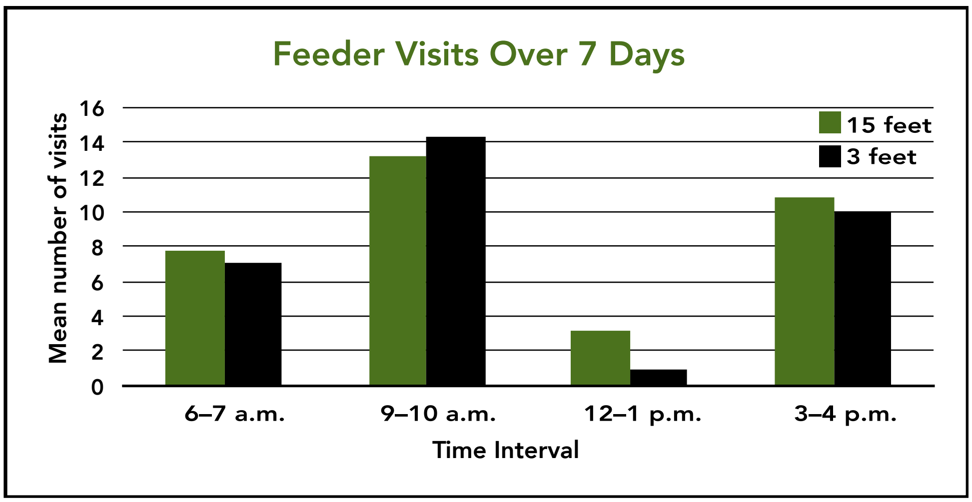
How do we turn a QUESTION into a HYPOTHESIS?

What do I wonder?	Suppose you are curious where birds that come to feeders prefer to eat—out in the open or in more sheltered places.
What do I already know?	Before you turn your question into a hypothesis, you need some background knowledge about this topic. You do some research and discover that cats can jump 10 to 15 feet and that cats are the main predator of backyard birds.
How do I turn my idea into a hypothesis?	Knowing this information might lead you to think that birds prefer eating at feeders that are out in the open because they will feel safer. Therefore, your stated hypothesis could be, "If feeders are placed at least 15 feet from trees and bushes, then more birds will visit those feeders."
How do I test my hypothesis?	Although there is more than one way to test this hypothesis, you might design a study that would involve watching two identical bird feeders with the same seed—one 15 feet from vegetative cover and one 3 feet from that same vegetative cover—and recording the number of birds that visit during specified time intervals during the day.
How do I know if my hypothesis was supported?	The data you collect can be used as evidence to either support or reject your hypothesis. Do birds visit the unsheltered feeders more often as you expected? If so, the data supports your stated hypothesis.
What if I didn't find any differences?	If your results show that birds visit the two feeders about the same, you would conclude that feeder location has no effect on feeding rates. We call this a null hypothesis, which means you could not find a pattern or relationship for the things you were testing. You would therefore reject your stated hypothesis and support your null hypothesis.
What if I found something other than what I expected?	Finally, it might be possible that the opposite is true. Your results could show that more birds visit sheltered feeders! You might then predict that more birds visit feeders near vegetative cover because they are more concerned about safety from predatory hawks in the sky instead of cats from the ground.



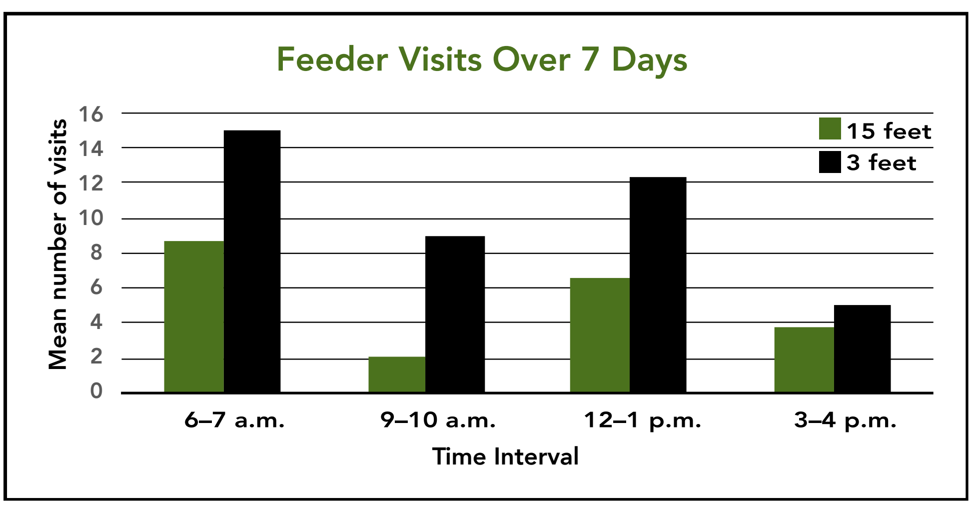
Graph 1: Hypothesis Supported

The mean number of visits seems highest for the feeders placed 15 feet from vegetative cover.



Graph 2: Null Hypothesis Supported

The mean number of visits would be about the same for both 15 and 3 foot locations.



Graph 3: Alternative Hypothesis Supported

The mean number of visits are higher for feeders placed 3 feet from vegetative cover.

Variables in Your Experiment

If you want to do an experiment, you'll have to consider variables. A variable is a characteristic that has two or more different values—it varies! For example, you might count three Turkey Vultures one day, eight the next day, and none on the third day. The number of Turkey Vultures is a variable.

When you do an experiment, always consider these three types of variables: independent variables, dependent variables, and constants:

Independent Variable

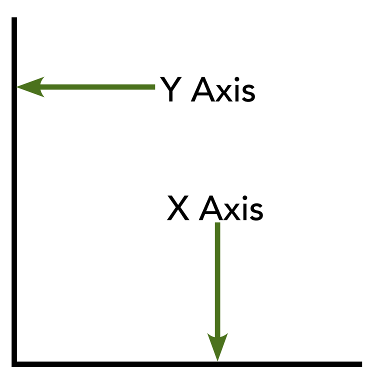
- The experimenter (you) changes this variable, or looks at a variable that naturally changes, such as temperature.
- Graph it on the x-axis.

Dependent Variable

- This variable might be affected by the change in the independent variable (you might remember: it DEPENDS on the change in the independent variable).
- This is what you measure.
- Graph it on the y-axis.

Constants

- These are all the variables that you try to keep constant, or control.



Let's look at these variables in an actual study. Allison wanted to know if birds preferred to eat at a bird feeder located in an area that was protected by trees and bushes. Allison considered three variables before she began: independent, dependent, and constants.

Independent Variable: Feeder Protectedness

Whether the feeder is protected or unprotected is what Allison changed. These are also called the treatment groups.

She put one feeder on a pole out in the open. She hung another nearby on a pole surrounded by trees and bushes. (See Figure 1.)

Dependent Variable: Total Number of Bird Visits

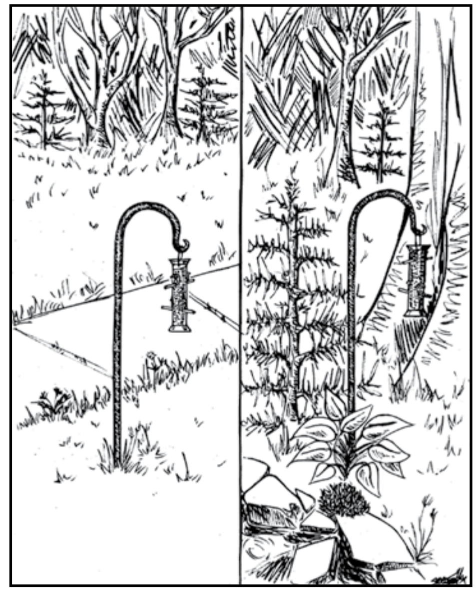
Allison measured the number of Northern Cardinals, House Finches, House Sparrows, and Tufted Titmice that visited.

Constants

Allison tried to make only one change: how protected the feeder was. She kept these things the same:

- The feeder type
- The kind of seed she used
- The feeder height
- She counted birds at both feeders at the same time (so things like the time of day, temperature, and wind speed were all the same)

These things were controlled, or held constant, so that Allison would know that any differences she saw in the number of birds that visited were due to how protected the feeder was, not caused by something like the type of feeder or the kind of seed.



Severine Hex

Figure 1. Allison put one feeder in the open, and the other in an area with cover.

When her study was complete, Allison graphed her results. Note that her independent variable is on the x-axis and her dependent variable is on the y-axis. (See Figure 2.)

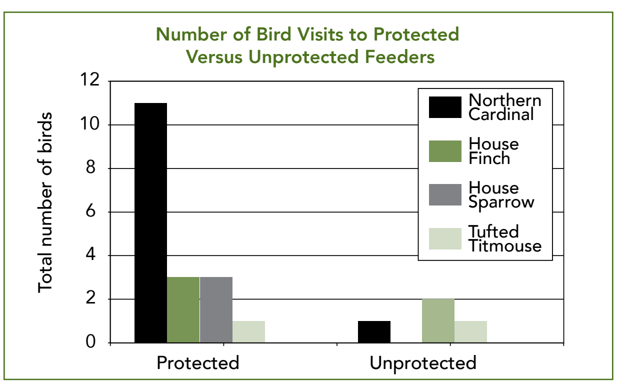


Figure 2: Number of bird visits to protected versus unprotected feeders

By Allison, 7th Grade, Bloomsburg Middle School
Bloomsburg, PA, Mr. Prosseda

WHAT DO **YOU** THINK?

Do the results of Allison's study indicate that birds prefer to feed at a protected or unprotected feeder?

Will a Fake Cat Scare Birds?

By Amy
Robert Frost School, Silverton, OR
Mrs. Rindy

Introduction

I noticed that cats in my yard had been scaring the birds away. I wondered if the birds could differentiate a fake cat from a real one. I decided to find out: does a fake cat scare birds? I measured the amount of seed the birds ate one week and compared it to how much they ate during the next week when a stuffed cat was "guarding" the feeder. I thought that for a little while the birds would be afraid of the fake cat but that eventually the birds would figure out that the cat was fake. Therefore, my hypothesis was that during the week that the cat was not "guarding" the bird feeder I would get more birds, but that there would only be a small difference in the amount of food eaten.

COURTESY OF AMY

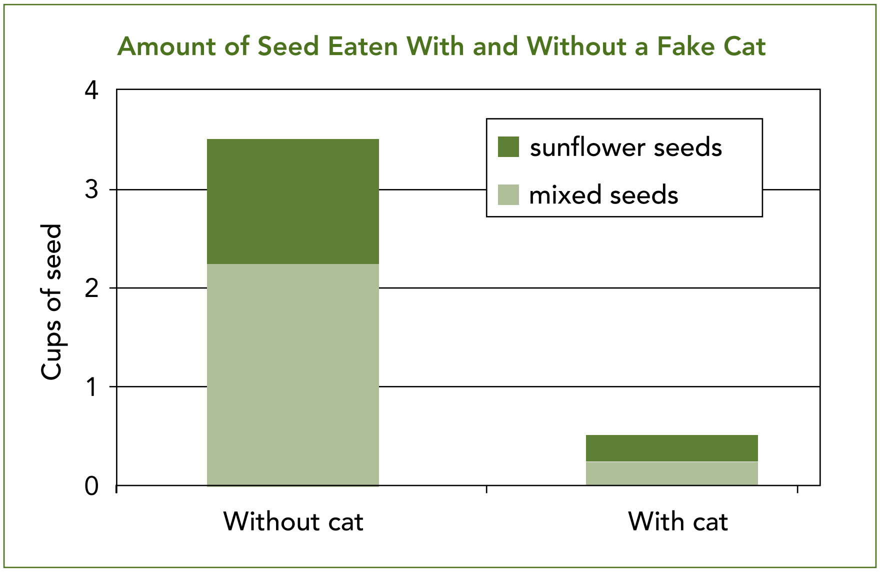
Amy wondered if a fake cat would scare away the birds. Here you can see her stuffed-animal cat "guarding" her bird feeder.

Materials and Methods

I filled two bird feeders with 2¼ cups of seed (one with mixed seed and one with sunflower seed). I hung them outside. After one week, I took the bird feeders down and measured how much seed was eaten. I got a life-size stuffed cat and propped it up in the tree close to my bird feeders (see picture). I then filled the bird feeders again with the same kinds and amounts of seed. After one week, I measured how much seed was eaten with the stuffed cat present. I compared how much seed was eaten with and without the cat.

Results and Analysis

I found out that more birds came to the bird feeders when there wasn't a "dangerous" animal around. When I didn't have the cat "guarding" the bird feeders, the birds ate all 2¼ cups of mixed seeds and 1¼ cups of the sunflower seeds (a total of 3½ cups of seed was eaten). During the week with the stuffed cat, only ¼ out of the 2¼ cups of seeds were eaten out of each of the feeders (a total of only ½ cup of seed was eaten). The birds did not eat as much birdseed when the stuffed cat was "guarding" the bird feeder. See my graph.



Amy's results (bar graph)

Discussion and Conclusion

My hypothesis was supported, but I was surprised that the birds didn't seem to eventually figure out that the cat was fake. I observed that whenever a bird did find the courage to take a quick nibble of birdseed when the stuffed cat was present, it was very jumpy and cautious, and it only stayed at the bird feeder for a moment. The birds never seemed to learn the cat was not real. My experiment demonstrated that a stuffed cat does scare birds. I wonder how long it would take the birds to discover the stuffed cat was fake. Would they ever figure out it was fake? These questions could be answered by doing another experiment in which I left the fake cat out longer.

Discuss with Your Group

1. What was Amy's hypothesis?
2. What was the independent variable in this study?
3. What was the dependent variable in this study?
4. What variables did Amy hold constant?
5. What questions or concerns do you have about her methods? Was the study well-designed?
6. What related questions do you think you'd like to answer?

Answering Your Scientific Questions

Two ways of answering your questions involve collecting and analyzing your own data—**Experimental** and **Observational** studies. The other two involve investigating the data that others have collected (**Data Exploration**) or reading reports others have published (**Reference**).

1. Experimental Questions

Sample Questions

- What would happen if we set up a birdbath?
- Will sow bugs prefer the shady or sunny side of a box?
- Do honeybees visit clover or dandelions more often?
- Does our playground noise affect birds?
- Does temperature affect the number of birds that visit our feeders?

For these types of questions, you are interested in whether some change has an effect, so you'll conduct an experiment. Experimental studies look for the effect of one variable (the thing that changes, which is called the independent variable) on another variable (the thing you measure, which is called the dependent variable). For example, one student wondered if the amount of playground noise (independent variable) affects the number of birds that visit (dependent variable). In order to be sure that changes in the dependent variable are due to the independent variable, the researcher attempts to control—hold constant—all other variables that might affect the dependent variable.

What Do You Do?

Measure your dependent variable to see if it is affected by the independent variable by collecting data on your study site. Change only one thing—the independent variable—while you hold other variables constant. Analyze your data and draw conclusions.

For example, for the question about birdbaths, you could ask: "Do birds prefer feeders with or without a birdbath?" Since you are really only interested in any effects of a birdbath, you want to be sure that the only thing you change is whether or not there is a birdbath. You want everything else, how, where, and when you count the birds, and everything about the feeder to stay the same. See Figure 1.

In this example, the presence or absence of a birdbath is the independent variable since it is the thing you change. The number of bird visits to the feeders is the dependent variable since it is the thing you measure. Notice that when you graph, the independent variable is graphed along the X-axis (horizontal axis) and the dependent variable is on the Y-axis (vertical axis).

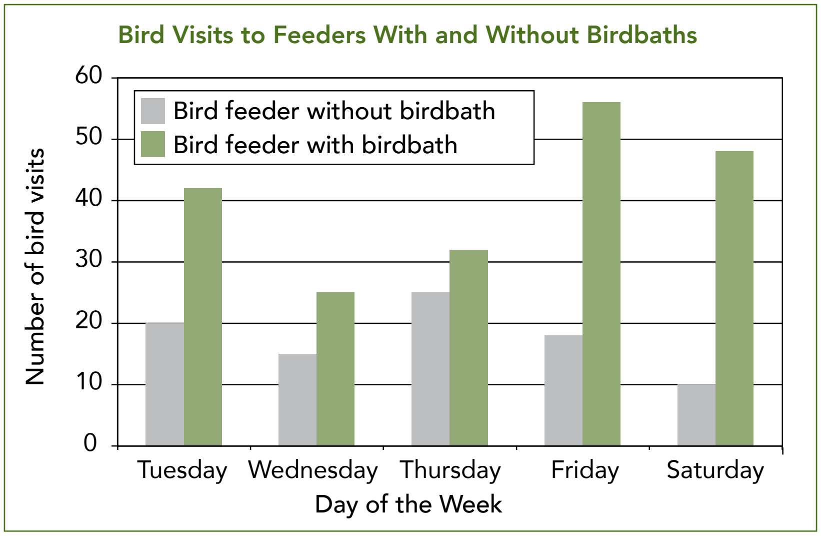


Figure 1

WHAT DO **YOU** THINK?

Does the presence of a birdbath seem to affect the number of birds? If so, how does it affect them?

For the question, "Does temperature affect the number of birds on our schoolyard?" YOU don't change the independent variable, it just naturally changes. You still try to hold everything else constant. Record the temperature (independent variable), count the birds (dependent variable), and then summarize your data, as in Figure 2.

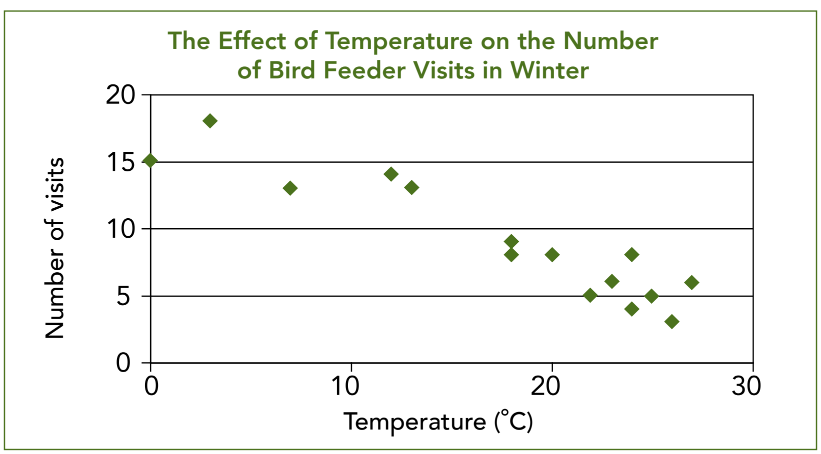


Figure 2

WHAT DO **YOU** THINK?

Does temperature affect the number of birds? If so, how does it affect them?

2. Observational Questions

Sample Questions

- How do finches behave when they visit our feeders?
- How many vertebrate species can my class find on the school yard?
- What bird is seen most often at our school?
- What birds are found around my house?

Like experimental studies, observational studies involve making observations and collecting data. But in observational studies, you don't change any variables. You just try to accurately describe what you observe. Often, questions about animal behavior lead to descriptive studies. For example, "How do birds behave when a hawk flies over?"

What Do You Do?

You might watch animals in a specified area at specified times and record what you see, then analyze this data and draw conclusions.

For example, if you wanted to explore the question, "What vertebrate animals are more common at our school?" you might look for animals at different times of day over a few weeks or months and record the kinds and numbers you see. In your scientific paper, you could tell readers how many total species you saw and which ones appeared most frequently. To help readers actually see the answer to your question, you could include a graph of the three most common species, like the pie chart found in Figure 3.

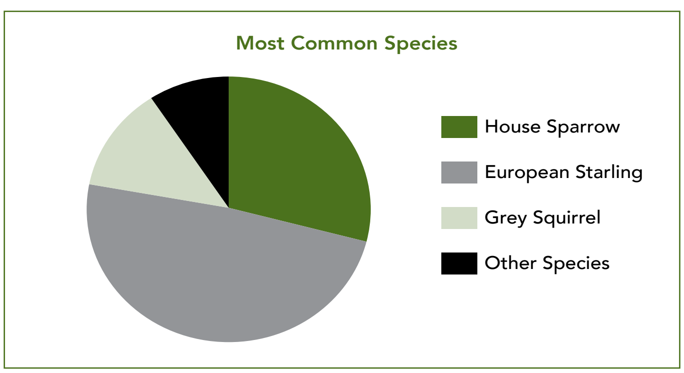


Figure 3

WHAT DO **YOU** THINK?

What is the most commonly seen species in this area?

3. Data Exploration Questions

Sample Questions

- Are American Crows seen as often in other states as they are here?
- When do lightning bugs start signalling throughout the United States?
- When do Ruby-throated Hummingbirds arrive in different parts of the country?
- When do tulips bloom in different parts of the United States?
- Which birds are most commonly reported by eBirders in my state?

Using citizen-science databases such as eBird, you can answer some big questions! The data you are using have been collected by others (and by you, too, if you have submitted data to the database!).

What Do You Do?

Access an online citizen-science database (for example, eBird, Project BudBurst, or NestWatch), and retrieve data that will help answer your question. Analyze the data and draw your conclusions.

For example, if you wanted to explore the question ,"When do Ruby-throated Hummingbirds arrive in different parts of the country?" you could look at the frequency line graphs in eBird for four states, moving south to north. The frequency graph for New York looks like this (Figure 4):

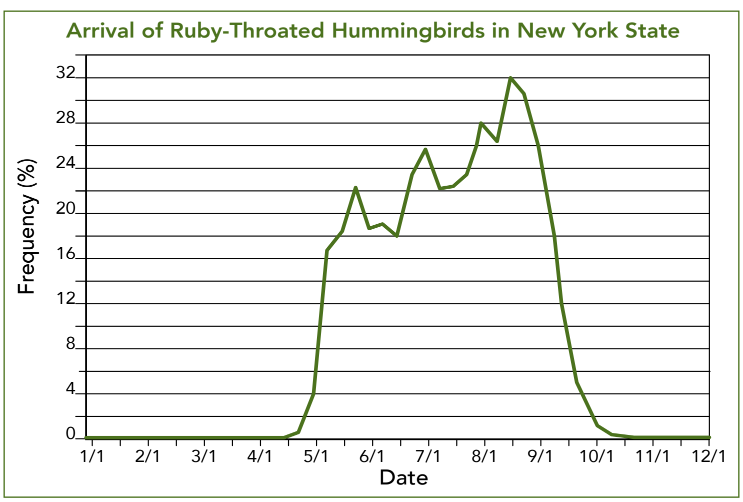
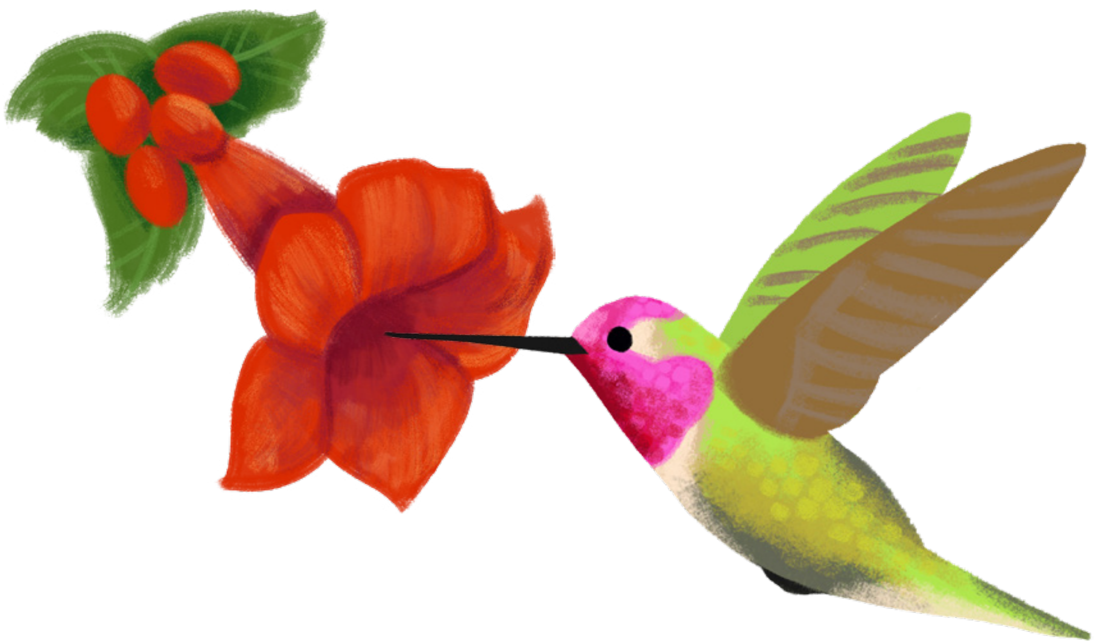


Figure 4. Data from www.ebird.org

You can see from the eBird graph that migratory Ruby-throated Hummingbirds do not begin arriving in New York until after April 15 (4/15). Look at a few other states and then summarize what you find in a table such as Figure 5.

When do Ruby-throated Hummingbirds arrive in four states?		
	State	**Arrival Date**
Further North	New York	4/15
↑	Virginia	4/1
	South Carolina	3/15
Further South	Florida	Found here year-round

Figure 5



WHAT DO **YOU** THINK?

What date do hummingbirds begin to arrive in New York? What date do they begin to leave?

4. Reference Questions

Sample Questions

- How many species of birds, mammals, and insects exist on Earth?
- What are some of the biggest survival threats facing my favorite animal?
- Do bigger birds lay bigger eggs?
- How does a bird find its way when it migrates?

Answers to questions like these may be found in sources such as books, magazines, or the Internet. However, keep in mind that a clearcut answer may not exist. For many scientific questions, further research is needed.

What Do You Do?

Identify the best available references for your topic. Read each one, take notes, and summarize the information in a well-researched answer.

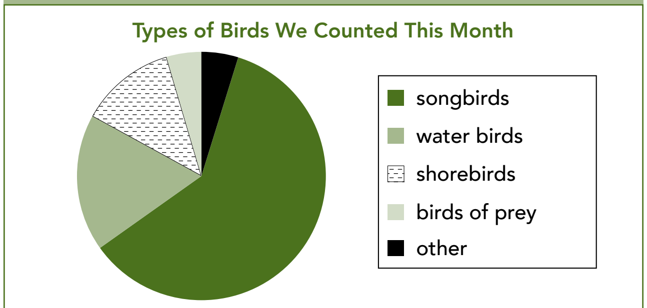
Some questions are narrow in scope and you might find the answer by looking in only one source. For example, the answer to the question, "How many species of birds breed in North America?" might be found by looking at a North American checklist of birds published by the American Birding Association, or by looking up the answer online. Other questions are broader or more complicated, and are best answered by pulling together an answer from a number of different sources. The question, "What are some of the biggest survival threats facing my favorite animal?" requires that you look up information in multiple sources and pull it all together.

WHAT DO **YOU** THINK?

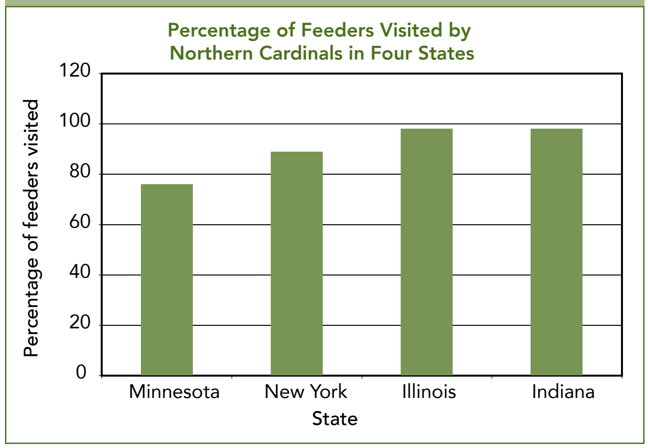
Have you ever been curious about a bird or another kind of animal and looked up information about it? Where did you look? Why might it be important to look things up in more than one place, like two different books, or a book and a website?

Graphs of Bird Data

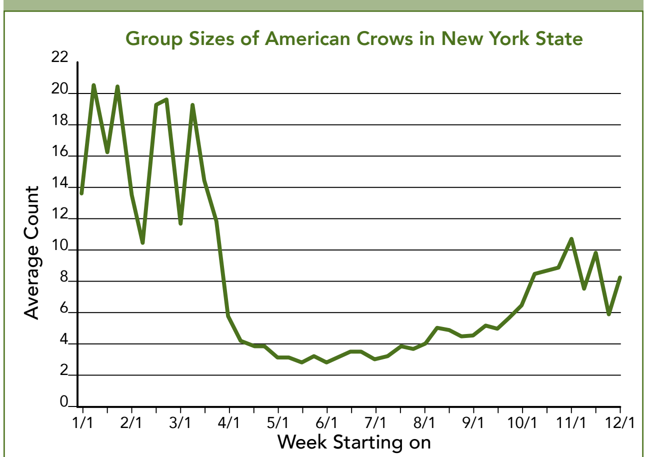
Pie Charts



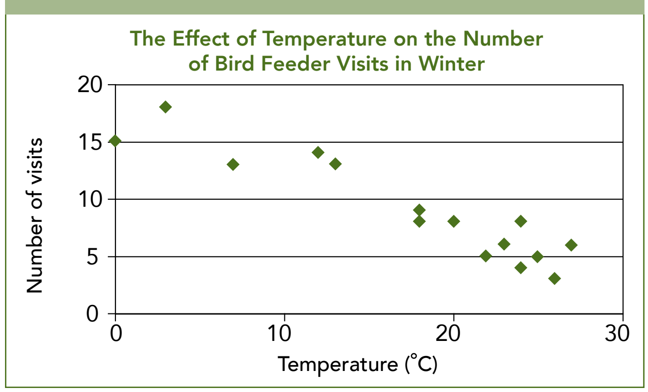
Bar Graphs



Line Graphs



Scatterplots



Graphing My Data

You've probably heard the phrase, "A picture is worth a thousand words." A well-made graph is worth a thousand words—it summarizes your data and makes it easier to see any trends in your data! Graphing is all about showing people your data visually.

There are many kinds of graphs. Not every kind of graph will be best for your data. Deciding what kind of graph to draw, and how to draw it, can require thought—which makes graphing a fun challenge! Here, you'll learn about four kinds of graphs and when to use each kind.

Big Ideas

- Your research question dictates the type of data you collect.
- The type of graph you use depends on the type of data you collect.

The key to good graph use is to match your data type to the appropriate graph type.

Graph Type	Data Type it Illustrates	Examples
Pie and Bar Charts	Categorical Data	• Kind of species • Different states or regions • Yes, no, and maybe responses
Line Graphs	Change over time	• Frequency graphs in eBird (annual) • Bird sightings over a month • Birds seen per hour over a day
Scatterplots	Relationship vetween two variables	• Bird's weight vs. wing length • Temperature vs. number of visits • Time spent singing vs. number of female visits

Pie Charts

- When you can convert data to show percentages, you can use a pie chart.
- Remember that the pieces of a pie together make 100%.

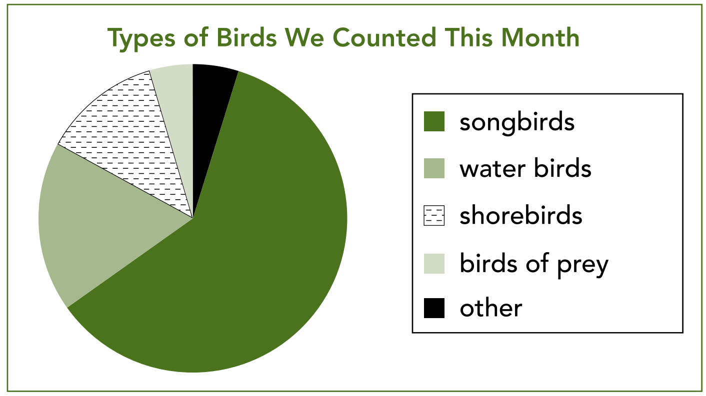


Figure 1

WHAT DO **YOU** THINK?

What is the most common kind of bird the students counted? What kind of bird was seen least often? Approximately what proportion of birds counted this month were water birds?

Bar Graphs

- Use a bar graph when there is no connection from one data point to another. (This is called categorical data.) For example, a bar graph can be used to present data from different sites.

In the example in Figure 2, students wanted to know whether Northern Cardinals are seen at feeders more often in states where the cardinal is the state bird. They hypothesized that Northern Cardinals would be seen more in states like Illinois and Indiana, where the cardinal is the state bird, than in states that chose another bird as the state bird, like Minnesota and New York.

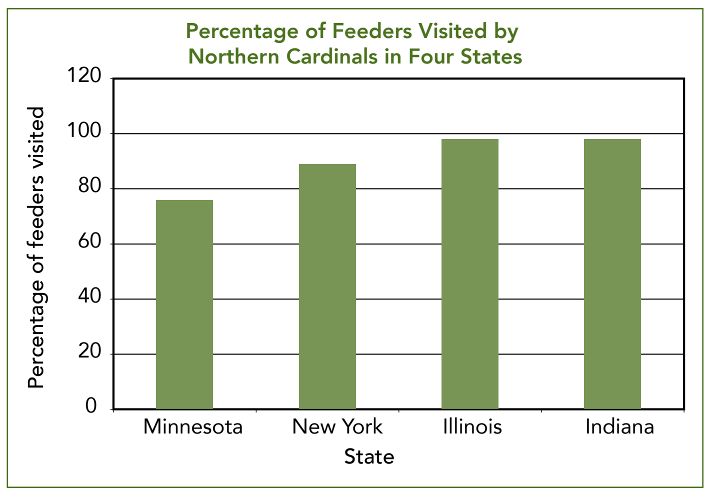


Figure 2:
Percentage of feeders visited by Northern Cardinals in four states by Kelsey, Anna, Charlotte, and Hannah, 7th Grade, Minnehaha Academy, Minneapolis, MN, Mrs. Humason

JL HIRTEN

WHAT DO **YOU** THINK?

Was the girls' hypothesis supported? Were Northern Cardinals reported more often in states that have Northern Cardinal as the state bird?

Line Graphs

- Line graphs are an excellent way to map dependent and independent variables that are both quantitative (measured with numbers). Unlike a bar graph, the data are not grouped in categories.
- Line graphs are most useful for showing whether something changes over time.
- Draw a line through the data points after you have plotted them.

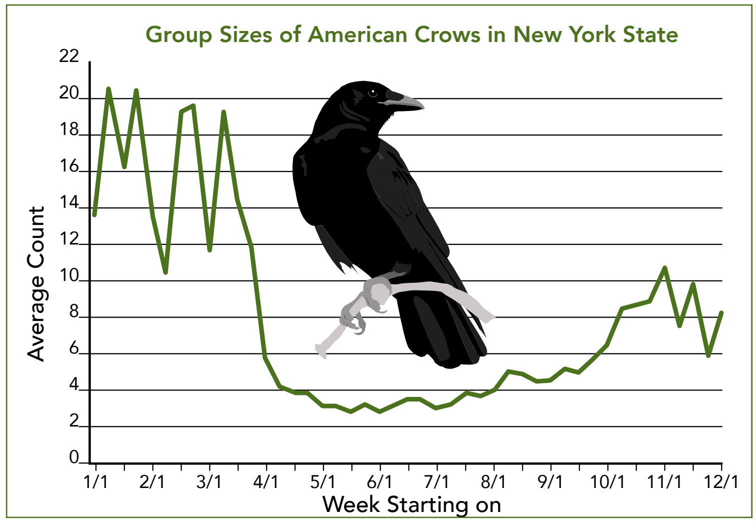


Figure 3: Group sizes of American Crows. From www.eBird.org

Susan Spear

WHAT DO **YOU** THINK?

Does the group size of American Crows seem to change during the year in New York state? If so, how does it change?

Scatterplots

- Scatterplots show at a glance whether a relationship exists between the dependent and independent variables.
- Scatterplots are like line graphs in that the dependent and independent variables are both quantitative, but you don't draw a line through every data point.
- You may wish to draw a "line of best fit" between the points to show a correlation or relationship.

Examples

Imagine you wanted to determine whether the availability of food affects the weight of nestlings. You might imagine that the more insects a mother Eastern Bluebird brings to the nest in an hour, the heavier her fledglings will be when they leave the nest. The graph in Figure 4 shows a **positive correlation**: as one variable goes up, the other does too.

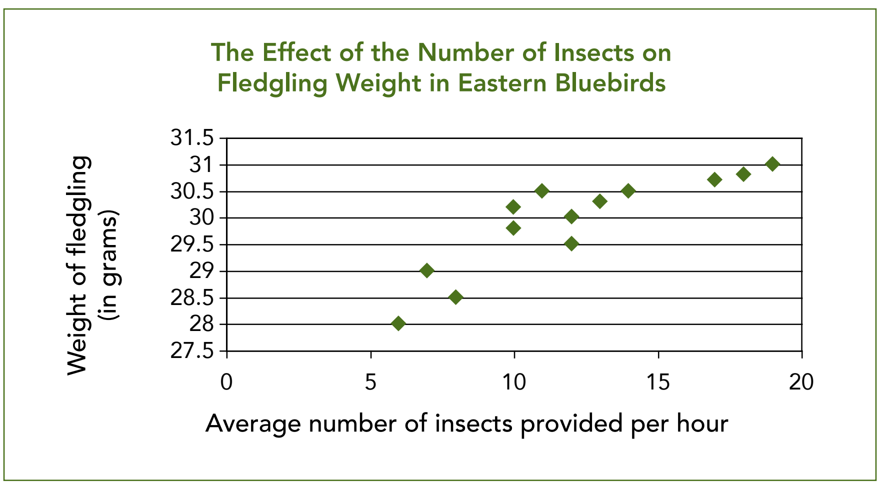


Figure 4: A scatterplot showing a positive correlation

JL Hirten

WHAT DO **YOU** THINK?

What is the range of weights of these Eastern Bluebird fledglings? In this sample, about how much does an average flegling weigh? About how many insects do the parents bring their nestlings each hour?

Some researchers have found that when it is snowier or colder, birds visit feeders more often (perhaps because they burn more energy staying warm, or perhaps because there is less wild food available, or both). If you graphed this relationship, you would find a **negative correlation**; as one variable goes up, the other goes down. See Figure 5.

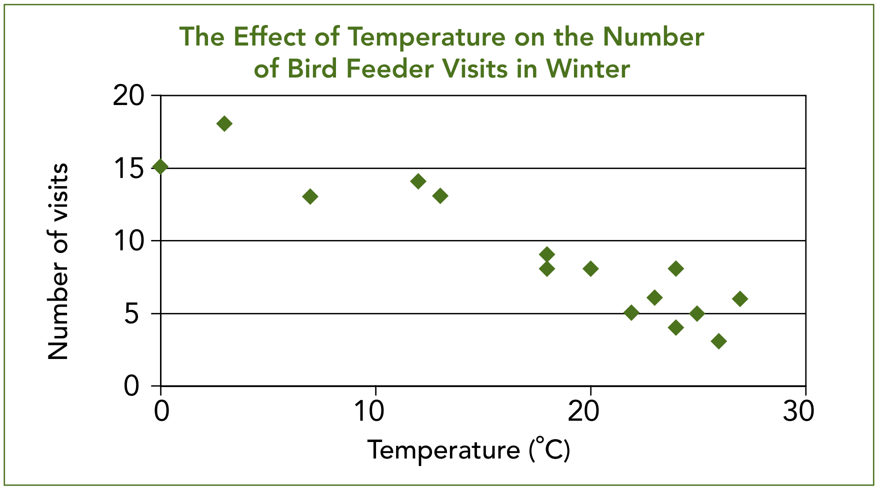


Figure 5: A scatterplot showing a negative correlation

Conclusion

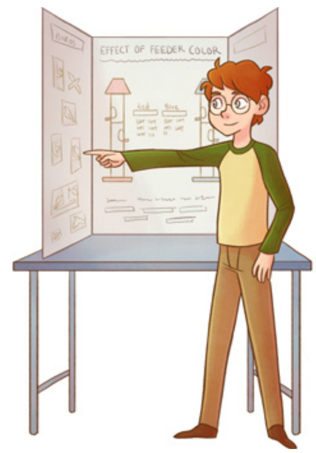
After you summarize your data in graphs, you might notice a trend in the data, or you might find no trend at all. Either will help you draw conclusions about the data in your experiment or observational study, and show others what you found, too!

Deb Felmey

Sharing My Report

Scientists write research papers or present posters so they can share their results and ideas with others. Scientific papers and posters include the following kinds of information:

- What were our questions?
- How did we do our research?
- What data did we collect?
- What do the data mean?
- What conclusions can we draw from our research?



To be sure all of this information is in every paper or poster, scientists use a standard outline for their writing.

Scientific Report Components	
Section of report	**What might be found in this section?**
Introduction	• Background information, including natural history information • Why the question was chosen or is important to study • Statement of the hypothesis
Materials and Methods	• Materials used to conduct the study • Data details: when and where data were collected, who collected them, and how • Any other methods used
Results and Analysis	• Results, including tables and graphs • How the data were analyzed (if they were analyzed) • What the data or any patterns mean
Discussion and Conclusions	• Conclusions • Alternate explanations for the results • Suggestions for improvements to the study design • Ideas for future research
References	• Any citations: web sites, books, magazines, or science reports

Table 1: Scientific Report Components Summary

Introduction

The Introduction explains why you decided to conduct your research. For example, what questions are you trying to answer? What information about previous research or existing knowledge do you have? How did this background help you decide what to do in your own research? What is your hypothesis?

Materials and Methods

The Materials and Methods section provides a clear description of exactly what you did and how you did it. For example, if you conducted a study of the birds at a feeder, what kind of feeder did you use? Where did you set it up? How often did you observe the feeder? What kinds of data did you record? You should provide enough information so other people can understand what you did and duplicate your work.

You might also describe the habitat around your study area. This information is often important in helping other scientists understand your results.

Results and Analysis

Present your data, including any charts and graphs, in the Results and Analysis section. For example, what birds did you see? How many birds did you count? What was the temperature? The Results section often contains graphs or tables that summarize the data.

The Results section should match your Materials and Methods section. That is, if you present temperature data in the Results section, the Materials and Methods section should say when and how you measured the temperature. If you explain in the Materials and Methods section that you were looking for certain species of birds, the Results section should show how many of those species you actually observed, even if the number was zero.

Finally, in the Results and Analysis section, tell what you think the results mean. For example, did the weather affect bird counts? Was one kind of seed eaten more frequently than another? Describe any patterns you see in your results, tables, or graphs. If you did statistical analysis of the data, describe it.

Discussion and Conclusion

In the Discussion and Conclusion section, report the conclusions of your study by answering the question(s) you asked in the Introduction. For example, did you discover what you thought you would find? Were the results different from what you expected? What have you learned from your analysis?

For example, if you asked questions about what kinds of food the birds in your area like, and you discovered that they prefer black-oil sunflower seeds, your Discussion and Conclusion might be about what kinds of seeds people in your area should put in their feeders.

This section is also the place to include ideas about future research studies. You may have answered the big questions you started with, but now your answers have lead you to new questions. Be sure to share your new questions in the Discussion and Conclusion section.

References

If you used any books, articles, or web sites, list them here using a standardized citation style. Any citation should include the author's name, the title of the work, the publisher, and the year of publication, as well as the specific page numbers used. If the reference is an online resource, include the URL address you used and the date you accessed it. This information helps your reader learn more about your subject and double check the background information you provided, as well as giving credit to the original authors whose work or research helped you with your project.

Once you have written all these sections, go back and check your work to see if everything is there, if it's in the right order, and if it makes sense.

The Cornell Lab of Ornithology

Misaki Ouchida

Investigating Evidence

INVESTIGATOR'S JOURNAL

The Cornell Lab of Ornithology
BirdSleuth K–12

Investigator's Journal

Page

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Name: ____ Date: ____________________________

My Scientist

What comes to mind when you hear the word "scientist?" Draw a picture of what a scientist looks like and what a scientist does.

Name: ____ Date: _____________________________

Meet a Scientist

Read one of the "Meet a Scientist" reports. Discuss it with your group and answer the questions below.

Scientist's Name: __________________________________

1. Did the scientist observe something that led him/her to ask a question? If so, what did he or she observe?

2. What did the scientist wonder?

3. What kind of information or data did the scientist collect? How did they collect it?

4. What did this scientist learn as a result of his/her research?

Name: ______________________________ Date: ____________________

Project Plan

Topic/Question: ____

____

Briefly describe the type of project you are doing (poster, presentation, *report*, etc.):

People on your production team:

____________________ ____________________

____________________ ____________________

____________________ ____________________

Who's going to do what? Remember to divide work evenly and check each other's progress!

Writer(s):

Illustrator(s):

Editor(s):

Graph Maker(s):

Teacher Approval:

____________________ __________

Signature Date

Name: ______________________________ Date: ____________________

Project Checklist

Use the checklist below to construct a timeline for each stage of your project. Remember to get your teacher's approval at each stage.

Stage of Project		Due Date	Check √ when done	Teacher initials
1.	Choose a scientific question that can be explored given the time and resources you have.		❑	
2.	Read about your topic and summarize what you learn. Write down citation information for the references you use.		❑	
3.	Develop your hypothesis.		❑	
4.	Outline your materials and methods.		❑	
5.	Do your study, collecting any necessary data and observations. You may need to make data sheets.		❑	
6.	Organize your data in tables and graphs. Analyze and/ or interpret your data.		❑	
7.	Create a first draft of your project.		❑	
8.	Peer review.		❑	
9.	Revise your work and turn in your final project. Consider submitting your work to the Cornell Lab of Ornithology.		❑	

Name: ______________________________ Date: ____________________

Project Notebook

Use this **Project Notebook** to keep track of your research project. The left hand column will help you structure your work. As you conduct your investigation, use the right hand column to take notes.

Tip: Use a pencil so you can easily make corrections.

Notes: Introduction

1. Write your scientific question.	My question:
2. Read about the topic you are studying (in books and on the Internet). Take notes in a notebook. Include complete references with your notes.	My list of references:
3a. Develop a hypothesis—a testable statement about the natural world that can be supported or rejected based on observation or experiments.	My hypothesis:
3b. If you are doing an experiment, list the variables you will consider.	My independent variable: My dependent variable: My constants or control variable(s):

Name: ______________________________ Date: ____________________

Notes: Materials and Methods

4a. Describe where you will do your investigation and what group/taxon/phenomenon you will study.	My study topic and site:
4b. Describe how you will conduct your study.	My methods:
4c. List the materials you will need.	My materials:

Name: ______________________________ Date: ____________________

Notes: Results and Analysis

5. Create data sheets to organize your findings.	Data I'll need to collect on my data sheets:
6a. Determine how you will visually present your data, (for example: line graph, pie chart, scatterplot, or bar graph). How will you label your graphs? What other figures might you want to include?	Notes about my graphs and figures:

Name: ______________________________ Date: ____________________

Notes: Results and Analysis

6b. Create a graph or graphs based on your data.	Graph sketches:
6c. Interpret your graphs and tables, or analyze your data. Are there any patterns in your data?	My data suggest:

Name: ______________________________ Date: ____________________

Notes: Conclusion and Discussion

7a. Is your hypothesis supported?	My answer to the question posed in the introduction:
7b. What scientific conclusions can you make from this research?	My conclusions:
7c. Are there alternative explanations for your results?	My ideas for other explanations:
7d. Consider problems you encountered. What could have been done differently?	My ideas for improvement:
7e. Does your conclusion raise new questions?	My ideas for further studies:

Name: ______________________________ Date: ____________________

Identifying Variables

Read these three experimental questions. For each question, underline the independent variable and circle the dependent variable. Then write a hypothesis you might test to answer the question.

Question 1: Will more birds visit our schoolyard if we put up a birdbath?

Write a hypothesis:

Question 2: Do toads call more when it is warmer?

Write a hypothesis:

Question 3: Does the type of plant wooly bear caterpillars eat impact how fast they grow?

Write a hypothesis:

Independent Variable	Dependent Variable
The independent variable may be under the control of the experimenter, like placement of a feeder or changes in seed type. Or it may be something that changes on its own, like weather or time of day. The experimenter wants to see how changes in this variable affect the dependent variable.	The dependent variable "depends upon" the independent variable. The experimenter observes or measures the dependent variable during the experiment to see if it is affected by the independent variable. The experimenter measures, but does not control, the dependent variable.

Name: ______________________________ Date: ____________________

Sample Experimental Plan

Our experimental question:

Our hypothesis:

Our null hypothesis:

Our independent variable (treatment groups):

Our dependent variable:

How we could measure the dependent variable:

Our constants (control variables):

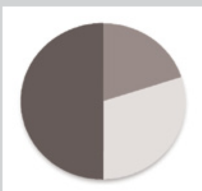
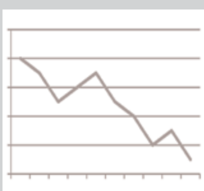
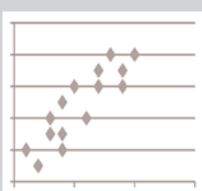
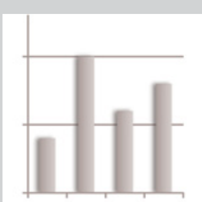
The materials we would need to conduct this study:

How we could conduct this study (our methods):

Name: ______________________________ Date: ____________________

Types of Graphs

After a class discussion about graphs, fill in the table below with a clear description of when and/or with what type/kind of data each graph should be used.

Type of Graph	When to Use this Graph
Pie Chart 	
Line Graph 	
Scatterplot 	
Bar Graph 	

Name: ____ Date: ___________________________

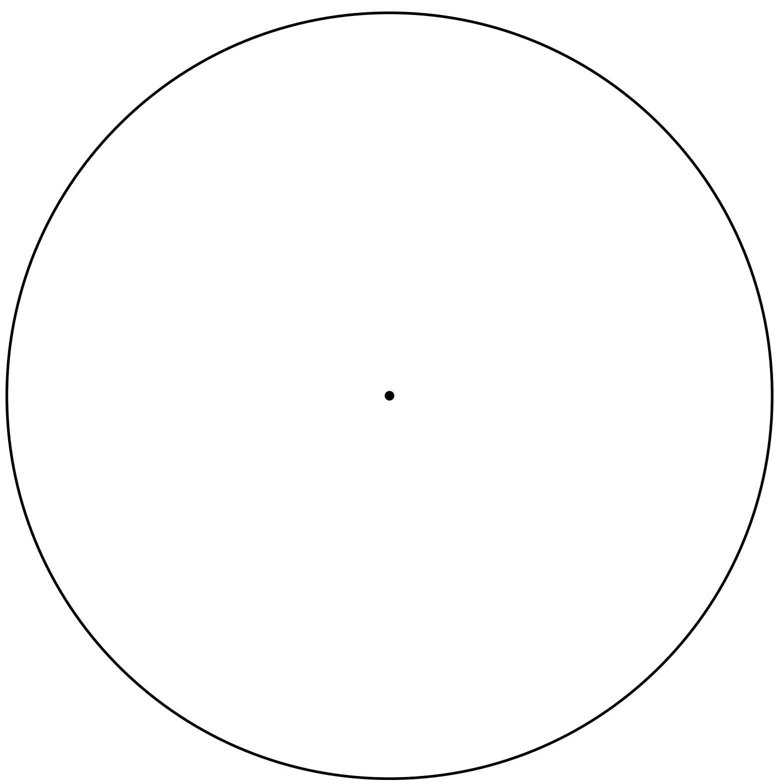
Graphing Practice

Follow along with your class to complete a pie chart, line graph, scatterplot, and bar graph. For each graph remember to include:

- Question you are trying to answer
- Title for your graph
- Labels for x and y axes (line, bar, scatterplot)
- Scale measurements for x and y axes (line, bar, scatterplot)
- Key or legend
- Data table (optional)

1. Pie Chart

Question to graph: ____



Name: ______________________________ Date: ____________________

2. Line Graph

Question to graph: ____

3. Scatterplot

Question to graph: ____

Name: ______________________________ Date: ____________________

4. Bar Graph

Question to graph: ____

Name: ______________________________ Date: ____________________

Peer Review Checklist

Name of Reviewer ______________________________ Date ____________________

Project Reviewed ____

Project Author(s) ____

Background Information

- ❑ The topic is introduced.
- ❑ The habitat and/or behavior of the species is related to the hypothesis.
- ❑ Other studies are cited.
- ❑ References are properly cited.

Suggestions for improvement:

Presenting the Hypothesis

- ❑ The hypothesis flows logically from the evidence before it.
- ❑ The hypothesis is written in the "If/then" format and can be easily investigated.
- ❑ Based on the hypothesis, what is the independent variable? ____________________
- ❑ Based on the hypothesis, what is the dependent variable? ____________________

Suggestions for improvement:

Name: ____ Date: ____________________________

Design and Reasoning

- ❑ Methods are clearly described.
- ❑ Details (such as quantities, time, location, and materials) are included.
- ❑ Each step is specific and in order.

Suggestions for improvement:

Results

- ❑ Calculations or observations are presented and summarized clearly.
- ❑ Graphs or figures are designed correctly and make sense.
- ❑ Graphs and figures are labeled.

What suggestions do you have for the results, including graphs?

Name: ______________________________ Date: ____________________

Discussion

- ❑ Language is clear and concise.
- ❑ The conclusion makes sense.
- ❑ The question posed in the introduction is answered.
- ❑ Alternative explanations for the outcome are provided.
- ❑ Possible improvements to the study are described.
- ❑ Suggestions for future research are provided.

What ideas for future research would you add?

What do you think was done particularly well in this report?