CornellLab | K-12 Education

Students as Scientists



Nature-Based Inquiry

Teacher's Guide Grades 6-12

Unit Overview

Engaging students in nature is a great way to inspire curiosity and questions! This unit will help you turn observations into investigations and encourage students to draw evidence-based conclusions.

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Students as Scientists: Nature-Based Inquiry

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Introduction

This curriculum provides lessons, slides, and handouts that will help you guide your students to ask and answer their own questions, bringing the excitement of doing real science to your classroom! The science process can be creative, fascinating, and empowering. It's more complex and more realistic than the linear, stepwise scientific method. And while the science process is complex, student investigations don't have to be. In fact, simple and straightforward investigations can engage students and support learning as well as, or even better than, complex investigations.

A team of scientists at the Cornell Lab of Ornithology (Carrie Branch, Jennifer Houtz, Monique Pipkin, Anusha Shankar, Andrew Stillman, and Benjamin Van Doren) worked together with the K-12 Education Team to illustrate the realities of the science process (Figure 1). The science process is different than the scientific method in that it is nonlinear, iterative, and overlapping, and it more clearly reflects the real process of doing science. It's organized as a flow of six parts, with communication and collaboration as central features that connect all parts of the science process. You will find a more detailed explanation of each part within the lessons.

By the end of *Students as Scientists (SAS)*, students will know that:

- The parts of the science process are interconnected, and not necessarily linear.
- You can enter the science process at different points.
- Scientific questions can be explored in different ways.
- The science process depends on communication and collaboration.

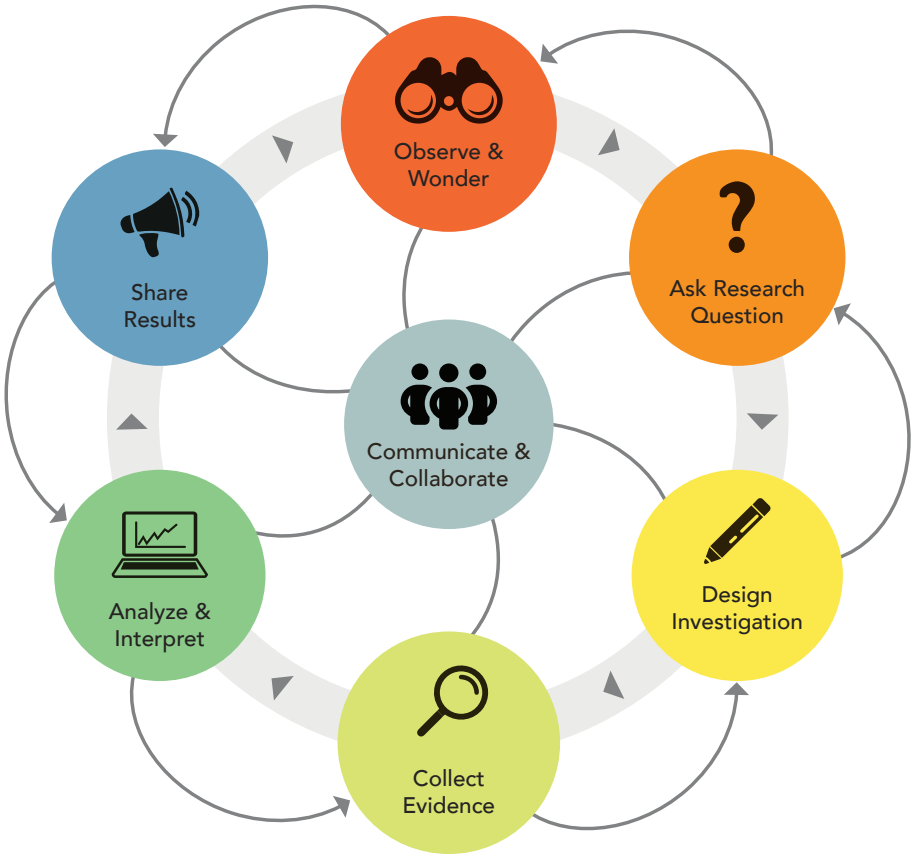


Figure 1. The science process. Original graphic designed by Jillian Ditner, adapted by Mya Thompson.

Scientific investigations are a powerful way of understanding science content and processes. This unit will help your students learn how to think and act like scientists while building their science skills. Students get to design investigations, collect evidence from various sources, develop explanations from the data, and communicate and defend their findings. The six *Students as Scientists* lessons support you in engaging your students in the science process.

Lesson 1: Explore Science

Science is a particular way of understanding the natural world through empirical evidence. Through activities and readings about real-life scientists, students consider their notions about scientists, are introduced to the science process, and identify their own scientific skills and traits.

Lesson 2: Make Observations

Scientific research often begins with curiosity and observations. In this lesson, students practice using their observation skills and learn the difference between observations and inferences.

Lesson 3: Ask Scientific Questions

Students begin asking scientific questions and discover different ways to answer them. By the end of the lesson, they have a testable scientific question they will address during the rest of the unit.

Lesson 4: Design Investigations

Designing a scientific investigation is creative and fun with many aspects to consider. Students conduct background research related to their question, develop their hypothesis, determine their variables and controls, and decide what data to collect and how to collect it. Then they put their plan into action!

Lesson 5: Analyze Evidence

To explore the data collected and answer their original research question, scientists must organize and analyze their data. Students learn practical ways to do this and then practice these skills using the data they collected.

Lesson 6: Interpret Evidence and Share Results

Science advances when scientists draw meaning from their results and clearly communicate their findings. In this lesson, students interpret their results and make reasoned claims. They learn about the different ways to share results with different audiences. After getting feedback on their ideas through peer review and making changes, they are ready to creatively share their results.

This unit provides a framework that you can customize to meet your needs. While there is a time listed for each activity and lesson, you may emphasize or remove certain activities based on many factors, including the prior knowledge and experience of your students, how much time you have, how much guidance you plan to give your students, and whether they will be conducting their investigations individually or in teams. Investigations vary greatly in length. You get to choose how much time you spend, from a week, to a semester, or an entire year (see Figure 2).

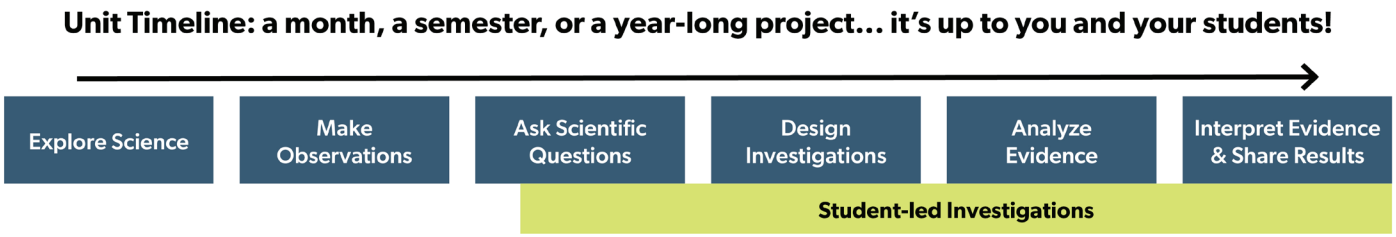


Figure 2. Conceptual timeline for teaching *Students as Scientists*.

The teacher's guide is supported by a variety of materials that you can find on the SAS resource site (www.birds.cornell.edu/k12/sas-6-12/). Download and edit them to meet your needs before printing them or sharing them digitally. Materials include:

- A Google Slideshow: Each slide contains teaching notes. If an activity has an associated slideshow, you'll find it referenced in the activity by its title.
- Resource Pages: These are student-facing resources in PDF format that include readings and images and are found at the end of this guide.
- Google Docs: a suite of curriculum resources that can be edited to meet your needs.

Student Inquiry Through Nature

Students as Scientists uses nature as inspiration for student scientific investigations. There are many ways to spark curiosity and engage students with nature-based investigations. Exploring outdoors, engaging in participatory science, watching wildlife cams, and designing a bird feeder are all good ways to make observations and generate questions. Below is a summary of each of these methods, but you can also review the Spark Guide for each topic on the SAS resource site (www.birds.cornell.edu/k12/sas-6-12/).

- **Outdoor explorations** are incredibly varied! You can start by simply going outside, wherever you are, to look and listen. You might take a walk around the schoolyard or in a nearby park or natural area. Consider visiting the same place regularly to make repeated observations and notice patterns and changes over time.
- **Participatory science** invites everyone including K-12 students, to contribute their observations of something—birds, frogs, plants, weather, the night sky—so scientists can analyze the data. Participatory science provides students with a unique connection to the science process, and they are motivated to share their data because their observations help answer real-world questions. Repeated participatory science observations are a great "question generator" to spur investigations!
- **Streaming wildlife cams** allow people to peer into the amazing and diverse world of animals 24/7. They provide accessible opportunities to watch nature unfold. Your entire classroom can observe live phenomena together, connecting to new places and new species, making observations, and asking questions.
- **Designing a bird feeder** fosters creativity and critical thinking. Plus, the birds visiting the feeders that students design and build provide a great opportunity for making observations and asking questions. You can use recycled materials and other "junk" to build feeders that are practical for birds to eat from, easy for humans to refill, and able to withstand the elements.

Setting Up for Success

Supporting Your Students as Scientists through Inclusive Teaching

Culture matters in our lives and in education, and in how students build connections to STEM disciplines. Science can be made even more engaging to students when you incorporate culturally responsive teaching. Culturally responsive teaching uses "cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant and effective for them." (Gay, pg. 36, 2018). It provides all students with learning opportunities, regardless of their race, ethnicity, gender, or first language, and it benefits everyone, including students from the dominant culture.

A first step to incorporating inclusive teaching into your classroom is to know and learn about the culture of your students. For example, you might ask students to complete an "About Me" form, meet with families, seek information on cultures through reading and other media, travel, or attending local cultural events. Demonstrating a genuine interest in each student and their culture can help establish trust, make your students feel valued, and help them develop their science skills and traits.

Inclusive teaching builds a community where everyone can flourish. This may include some or all of the goals below, some of which you may already be doing:

- Understanding your own culture.
- Understanding your own biases—we all have them—and working to counteract them.
- Creating a welcoming environment for all students.
- Knowing that students are individuals, no matter their background.
- Using student culture and diversity as an asset. For example, inviting students to share their experiences and background knowledge connected to the topics you teach.
- Empowering students to find their own answers and develop their expertise.
- Setting high expectations for everyone and demonstrating your confidence in the abilities of all of your students.
- Encouraging collaboration and communication between peers so that students are empowered to show their unique abilities, perspectives, and expertise.
- Encouraging equal time for all voices during small-group work. Making sure everyone has space and time to share their ideas.
- Telling your students you are working to incorporate their culture in your teaching. Ask them for ideas and suggestions, being transparent, and acknowledging your mistakes.

Specifically, in this science inquiry experience, you can:

- Empower students to be active participants in the entire inquiry process. For example, everyone should have a chance to ask questions, observe, write notes, track data, and report on what the group finds.
- Include families as students develop, research, and plan their investigations. Even if adults and mentors don't view themselves as "science people," everyone has knowledge and valuable perspectives to share. For example, students might interview their families or community members for their perspectives on topics.
- Allow voices that are typically not heard to take up more space. For example, when deciding on a project as a class or in small groups, rather than use a majority vote, ask for students to share their preference with you and then give more weight to those that have historically been marginalized.
- Be mindful with group assignments. Don't assign groups or partners randomly, consider each student's strengths. Allow students to have a say in the roles and responsibilities they prefer. Emphasize the value of all roles to a successful group project, including more "administrative" and more "scientific" roles.

Inclusive teaching strategies are already embedded into these resources. For example, we feature diverse scientists and provide several ideas on how students can share their results. Still, it will be important for you to consider your unique students and their needs. You will find additional inclusive teaching strategies in each lesson near the "Getting Ready" section. We recommend reviewing these tips before each lesson and incorporating at least one into your lesson. If inclusive teaching seems like a big undertaking, start small but think big—pick one goal to incorporate throughout this curriculum, then add on as you discover what works and what doesn't.

Questions to Consider Before Starting this Unit

What level of inquiry are my students able to engage in?

As the teacher, you will decide the level of independence your students have during their inquiry experience. Below are some areas to consider as you plan. Entire investigations can be designed by individual students, formed together in small groups or as a class, or you can provide more guidance at key points within the science process. It all depends on your goals, timeline, and student experience and interests.

Generally, there are four types of inquiry, with each level representing greater student autonomy (see descriptions below and Figure 3). Note that as you go through the science process, you might choose to offer your students different levels of autonomy. For example, you may allow open inquiry when students observe and wonder, but provide more structure in helping them create their datasheets.

- Confirmation inquiry—the teacher provides students with questions and procedures, and the results are known in advance. This can be a great place to start with young students.
- Structured inquiry—the teacher provides the question and procedure, but students generate an explanation with the evidence collected.
- Guided inquiry—the teacher provides the research question but students develop their own methods and explanations.
- Open inquiry—students act as scientists with a high level of independence, forming their own questions, designing and carrying out investigations, and sharing results.

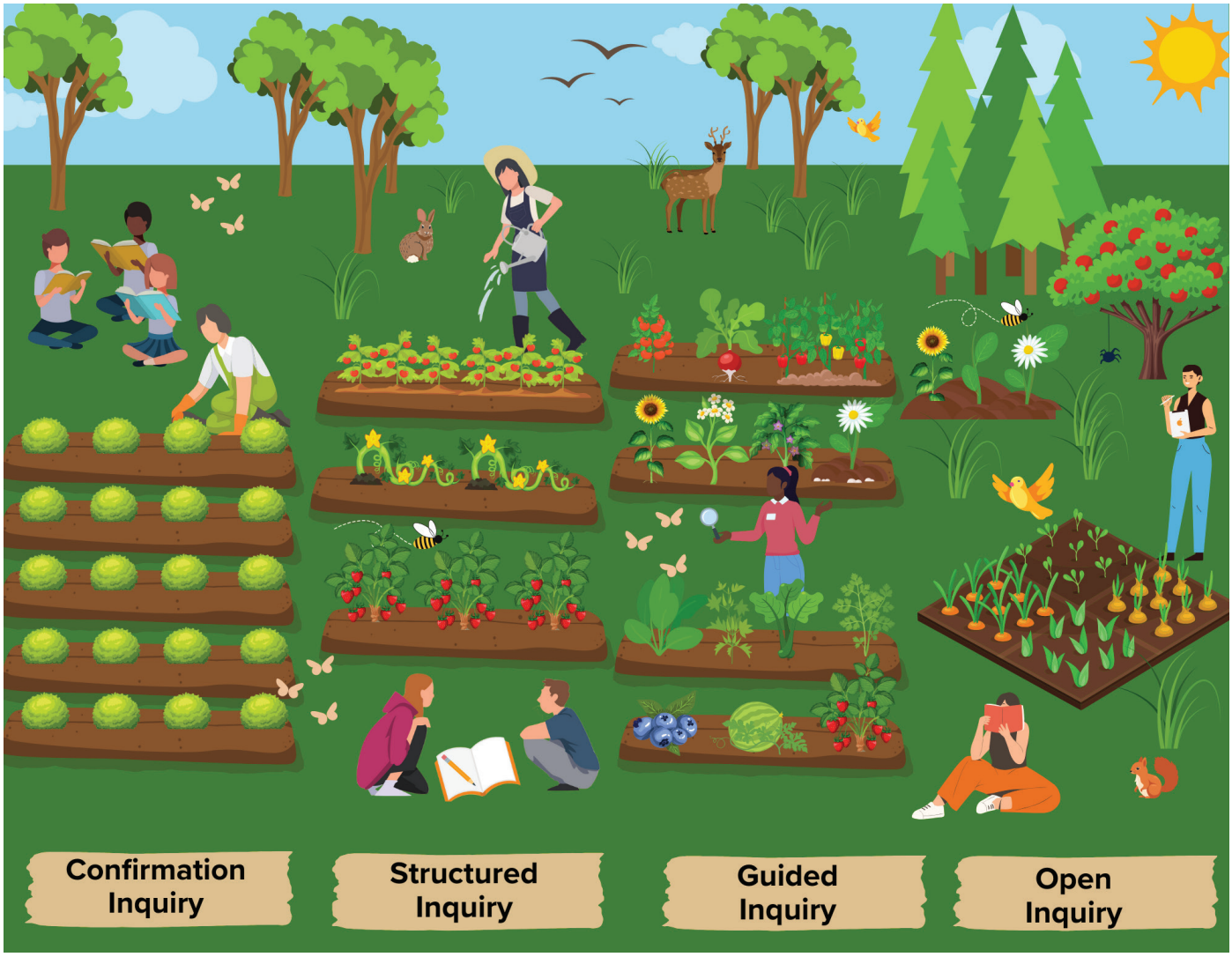


Figure 3. Types of science inquiry. Graphic by Dina Le Lagacy.

How will I focus student investigations?

You may want to constrain your students to a particular topic, taxon, or theme to help you manage their questions and investigations. For example:

- While on a nature walk, instruct students to focus their observations and questions on a particular taxon such as birds, insects, frogs, squirrels, or trees.
- Select a particular topic, such as bird feeding or nesting. A bird feeder, bird cam, or nest box can provide a great common focus.
- Address a problem or issue students see in your schoolyard or neighborhood.
- Focus on an animal species that can be observed in your schoolyard or local area.
- If outdoor space is limited, wildlife cams can be used as a focus. We encourage you to use cams that show animals in the wild rather than in captivity because animal behavior is different in the wild.
- Investigate a body of water such as a nearby stream or pond. These investigations might focus on water quality and the plants and animals found in or near the water.

How will my students conduct investigations?

Consider the resources you have available and how you will present the investigation constraints to your students. Ask yourself:

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

How will my students communicate their findings?

Depending on your context, you may choose to be explicit about how students communicate their findings or you may encourage independent selection. For ideas on how students can communicate their findings, see Lesson 6. Think about the requirements you want to establish such as:

- What length and format is required?
- Will students share their findings and presentations beyond the classroom?
- How will you assess their work?

Examples of Investigations

Here are several case studies that we have collected from experienced educators as examples.

Classroom Case Study 1: Ms. Ellwood's 7th-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 investigations on birds. She requires each group to complete a minimum of eight observations at home or school. Most students do their observations over three weeks.

Each group prepares scientific posters to display in the school's entryway so that the entire community can learn from and 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 sharing process in Ms. Ellwood's class. Using a peer review sheet, students critique each other's scientific presentations 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 has 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 concerns about individual grades on group projects, she also built 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. Further, each student group must present their investigation to the class, with each group member presenting an equal amount of content.

Classroom Case Study 2: Mr. Garcia's Research Methods high school class

Each year, Mr. Garcia's high school students complete a year-long investigation on a nature-based topic of their choosing. At the beginning of the year, he assesses student knowledge of the science process and plans the necessary scaffolding for the class. Each week during the first month of school, he invites a guest speaker who is a scientist working in the natural sciences. Mr. Garcia invites both local (in person) and virtual scientists with diverse interests and backgrounds to help expand his students' knowledge and experiences of what scientists do and who can be a scientist. He also uses the beginning of the year to explore different areas of the natural world and have students make observations. These activities include revisiting the same spot over time and making observations at different scales to broaden a student's thinking about what they might like to study.

He provides a checklist with due dates for different parts of the investigation including space to add comments and initial upon completion. Mr. Garcia reviews his students' questions, background research, variables, etc. as they proceed to check for understanding. Mr. Garcia has an individual check-in with each student to approve their question and investigation design. For the other aspects, he reviews their project notebook to assess and address their understanding of the science process and progress in their investigation.

Although students work independently on their investigation, Mr. Garcia knows that, in real life, science is a collaborative process. Students work in small teams to provide extra peer support and peer review, reviewing and providing critiques of each other's work. This helps the students in several ways: they are exposed to different ideas and ways of thinking, they practice peer review skills, and they learn to critically assess scientific reasoning and process.

Mr. Garcia teaches in a culturally diverse school and last year decided to allow students to identify their audience and choose the format of their final project. He noticed that students were more excited and invested in presenting their findings, sparking discussions about how the public interacts with science and the purpose of science in society. This requires more planning than in previous years when each student simply made a presentation to the class. As part of the final project, students were asked to address the potential real-world applications of their research. This gave students another chance to think critically about how their research, and science generally, is relevant to the world around them.

Meeting the Standards

The *Students as Scientists* curriculum will help you guide students as they investigate questions they ask about the natural world. The strength of this curriculum is not in the science content it contains (that depends on the questions your students ask), but in its applicability to any science content, as well as student engagement in the science process while building English and math skills. *Students as Scientists* 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 (NGSS)

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 *Students as Scientists* but depends on the questions being asked and answered.

NGSS Scientific Practices

1. Asking questions and defining problems - Lesson 3
2. Developing and using models - not shown explicitly, but students could use models in Lesson 5
3. Planning and carrying out investigations - Lesson 4
4. Analyzing and interpreting data - Lessons 5 and 6
5. Using mathematics and computational thinking - Lesson 5
6. Constructing explanations and designing solutions - Lessons 5 and 6
7. Engaging in argument from evidence - Lesson 6
8. Obtaining, evaluating, and communicating information - Lessons 1, 2, 3, 4, 5, and 6

Nature of Science and NGSS

Nature of science concepts are included in the Next Generation Science Standards and are also 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 and English Language Arts Common Core state standards.

References

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice* (3rd edition). Teachers College Press.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. The National Academies Press.

Lesson 1: Explore Science

Goal: **Develop students' understanding of the nature of science, including the idea that everyone has scientific skills and traits, and we use these skills and traits every day.**



Location: Indoors
Time: 150 minutes

Essential Questions

1. How does science help us understand the world?
2. Who are scientists?
3. What skills or practices do scientists use to understand the natural world?
4. What scientific skills do I have?

Students Will Know

- Scientists are people who differ in age, gender, ability, sexual orientation, and social, cultural, and ethnic backgrounds who approach the process of inquiry in similar ways.
- The science process includes observing and wondering, asking questions, designing an investigation, collecting evidence, analyzing and interpreting evidence, sharing results, and communicating and collaborating.
- Scientific traits and skills include creativity, curiosity, asking questions, planning and conducting investigations, analyzing and interpreting data, constructing explanations, engaging in arguments from evidence, communicating information, and using new evidence to revise conclusions.
- Everyone has the capacity to develop and learn scientific skills.

Students Will Be Able To

- Differentiate ways that scientists are similar and different.
- Identify skills they have in common with scientists.
- Describe at least one key feature of the nature of science: flexible thinking, discovery, and tentative nature of science.
- Explain at least three skills that scientists use and how these skills help them understand the natural world.

Getting Ready

- All curriculum resources and links are on the SAS resource site www.birds.cornell.edu/k12/sas-6-12.
- Activity 1: Who Are Scientists? (60 min)
  - Cue the "Who Are Scientists" slideshow.
  - Decide how you will facilitate sharing the "Meet a Scientist" reports and prepare accordingly.
  - Provide digital or print access to the "Meet a Scientist" Project Notebook page.
- Activity 2: What Do Scientists Do? (45 min)
  - Provide digital or print access to the "Vultures: Sight or Smell?" article (or choose to use the comic version instead).
  - Project the Science Process slides.
- Activity 3: Discuss Nature of Science (45 min)
  - Prepare a space for students to move from one side of the room to the other to show their level of agreement with each statement. Project "Nature of Science Statements" slides and/or hand out the statements for different learning styles.
  - Provide digital or print access to "#ScienceFails" Project Notebook pages.
  - Prepare to brainstorm about science and scientists.

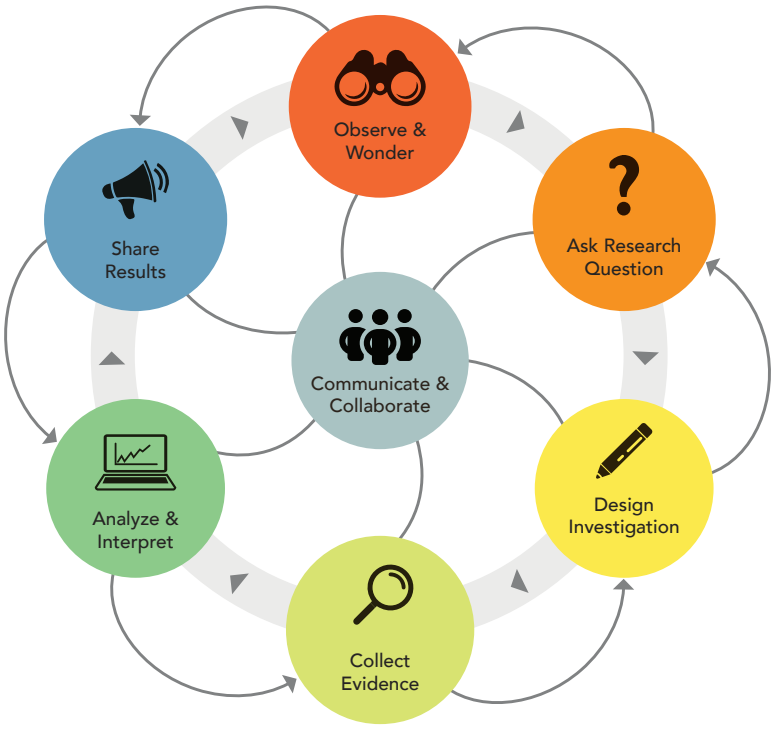
Inclusive Teaching Strategies

- Include diverse scientists in Activity 1 Who Are Scientists?, so that minoritized students in your class are represented and students of the dominant culture recognize diversity in these scientists. Remember that diversity includes both visible aspects (such as race) and invisible differences (such as country of origin, native language, disability status, sexual orientation, and socioeconomic status).
- Emphasize that science is one way of knowing and that other ways of knowing are also valid. For example, Indigenous and Eastern cultures have a deep understanding of the natural world and this knowledge was not gained through Western scientific methods.
- If you utilize the Meet a Real Scientist extension, find a scientist that your students want to know more about. If possible, invite a scientist who either reflects the cultural diversity of your class or represents a different background that expands your students' views of who can be a scientist.

Lesson 1 Teacher Background

This curriculum focuses on the science process. The science process is different than the scientific method in that it is nonlinear, iterative, and overlapping. A team of scientists at the Cornell Lab of Ornithology worked with the K-12 Education team to illustrate the realities of the science process. It's organized as a flow of six components, with communication and collaboration as central features. While these six main components are present in most science investigations, they don't occur as a stepwise progression or method.

In each lesson, we will highlight the steps of the science process emphasized in the lesson with a visual within the "Goal Box" at the top of each lesson and, if necessary, provide more explanation in the "Teacher Background" section of the lesson. In this lesson, all aspects of the science process are highlighted because students are developing their understanding of what science is and what scientists do.



The science process diagram.

Scientists: Who Are They and What Do They Do?

Students often think of scientists as people in labs who wear white coats and hold beakers of chemicals. However, this lesson emphasizes that scientists come from different cultures all over the world and work on projects indoors and outdoors according to their interests. This lesson encourages students to broaden their ideas of who scientists are and what they do.

Nature of Science

One of the most exciting aspects of teaching science is conveying how science is done and engaging students in this process of discovery. The *Next Generation Science Standards* (Appendix H) details eight aspects of the nature of science. Here are the key features of science to consider as you teach this unit:

- **Scientific investigations use a variety of methods:** Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. Scientific inquiry is guided by a common set of values including logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.
- **Scientific knowledge is based on empirical evidence:** Scientists base their explanations, arguments, and conclusions on empirical evidence. Science disciplines share common rules of evidence used to evaluate explanations about natural systems.
- **Scientific knowledge is open to revision in light of new evidence:** Most scientific knowledge is quite durable but is subject to change based on new evidence and/or reinterpretation of existing evidence. Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision.
- **Scientific models, laws, mechanisms, and theories explain natural phenomena:** Theories and laws provide explanations in science, but theories do not become laws or facts. Laws are statements or descriptions of the relationships among observable phenomena. Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and validated by the science community before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
- **Science is a way of knowing:** Science is both a body of knowledge and the processes and practices for refining knowledge. Science is one way of knowing defined by the use of empirical standards, logical arguments, and skeptical review, and there are other ways of knowing.
- **Scientific knowledge assumes an order and consistency in natural systems:** Science assumes that natural laws act the same across time and space.
- **Science is a human endeavor:** Contributions to science are made by people from cultures around the world. Scientific knowledge is a result of human qualities such as persistence, precision, reasoning, logic, imagination, creativity, intellectual honesty, skepticism, and openness to new ideas. Science is influenced by society and society is influenced by science.
- **Science addresses questions about the natural and material world:** Science limits its explanations to systems that lend themselves to observation and empirical evidence, and not all questions can be answered by science. Scientific knowledge indicates what can happen in natural systems but not what should happen. Instead, the latter involves ethics, values, and human decisions about the use of scientific knowledge.



Activity 1 Who Are Scientists?

Project the collage of scientist images in the slideshow. Start by asking "Who is the REAL scientist?" and allow the students to make guesses and explain their thinking. Reveal that all are scientists and go through the slides sharing their brief biographies.

Everyone benefits from seeing diverse scientists and creating a more inclusive vision of who can do science. Plus, students gain an understanding of what science looks like in the real world. Your students already have ideas and misconceptions about who scientists are and what they do. Assess their current ideas by asking and discussing:

- Who are scientists?
- What do scientists do?
- What skills do scientists have?
- What scientific skills do you have?
- Are you interested in being a scientist? Why or why not?

Read and discuss the "Meet a Scientist" reports.

- 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 and allow them time to read. Invite them to discuss the scientist with their group and answer the questions about the scientist's work on the "Meet a Scientist" page in the Project Notebook.
- Have each group briefly describe their scientist to the rest of the class. Ask each group to share:
    - What does the scientist study, and what did you find interesting about it?
    - What has the scientist discovered, and what are their future plans?
- After each group has reported, discuss the following questions as a whole class, or in a partner share:
    - What does each of these scientists have in common? (*Possible answers include asking questions, collecting data, studying nature, and understanding the Earth/conservation.*)
    - How does the work of these scientists differ? (*Possible answers include studying different animals, working outside versus inside, and traveling to and living in different locations around the country and in other parts of the world.*)
    - What skills do you think these scientists have that help them understand the natural world? (*Possible answers include curiosity, enthusiasm, attention to detail, persistence, adaptability, precision, logic, and willingness to change their minds.*)

Share with students that in this unit, they will explore who scientists are and what they do. They will also plan and conduct a scientific study, becoming scientists themselves.



Activity 2 What Do Scientists Do?

Present the problem: Vultures eat smelly, dead things. Scientists wondered, "How do they find their food: by sight or by smell?" Ask the students: How do you think scientists might find the answer to this question? After a brief share-out, either as a class, in small groups, or individually, have students read the "Vultures: Sight or Smell?" article and/or look at the Vulture Comic (*note: if using the comic alone, then some questions below are not relevant*). Then ask the following questions:

- **How did Audubon answer his question?** (*Audubon designed two experiments using a fake dead animal and camouflaged stinky meat to see if vultures used sight or smell to find food.*)
- **Could Audubon have used reference materials or asked someone else for the answer to his question? Why or why not?** (*Reference materials at that time probably all stated that vultures found their food by smelling it. If Audubon used only those references, he would not have learned something new. Audubon was likely the first person to do this kind of experiment. This was before the internet, so even if someone had conducted this study, it may have been difficult for Audubon to know about it and be able to access the results. If most people believed that vultures found their food by smelling it, he would not have learned something new if he asked other people or consulted references of the time.*)

Share the science process diagram and tell the students that a group of scientists developed this diagram to help explain how they do science. Divide students into pairs and give them time to study the diagram and answer the question, "What do you think the scientists were trying to show us about science?" If students struggle to read the diagram, encourage deeper discussions with questions such as:

- Why do you think Observe and Wonder is at the top?
- What do you think the arrows represent?
- Why do you think Communicate and Collaborate are at the center?

Invite students to share any conclusions and questions that came up in their partner discussion. Summarize that doing science is not a simple linear progression, but iterative and at times messy, with scientists needing to go back more than one step or start over completely. Also, note the importance of communication and collaboration throughout the process. Finally, make the point that the science process almost always leads to new questions to explore.

After discussing the science process, take time as a class to explore and connect the "Vultures: Sight or Smell?" article to the components of the science process. You can use the following questions to guide the discussion.

- **What did Audubon and Stager observe and wonder about how vultures find their food?** (*Audubon noticed that he could get close to vultures as long as they did not see him and wondered, if they could smell so well, why didn't they fly away? Stager wondered where Audubon and Bachman had gone wrong because there was strong evidence that Turkey Vultures found food by smell and yet Audubon and Bachman had evidence that vultures found food by sight. If all vultures found food in the same way, then someone must be wrong.*)
- **How did Stager design his experiments to test his question?** (*He used similar but more thorough methods than Audubon. He hid meat in cages rather than just under a bush and he confirmed that it was Turkey Vultures and not Black Vultures that were finding the meat. He also repeated the experiment using a decoy deer and real deer. Additionally, he tested what the gas company engineer had reported to further understand how Turkey Vultures use their sense of smell.*)
- **What conclusions were shown to be inaccurate with additional testing?** (*When Audubon and Bachman interpreted their data, they concluded that vultures find their food by sight rather than smell.*)
- **Why is it important that Audubon, Bachman, and Stager shared the results of their studies?** (*By publishing their findings, they made it possible for others to learn about, question and/or confirm findings, and build upon their research.*)
- **Bachman confirmed Audubon's findings. Do you think that Bachman was unbiased in his research? Why or why not?** (*We don't know for sure what, if any, bias Bachman introduced into his studies and we have evidence for Bachman being both biased and unbiased. We know he was motivated by his desire to silence the Audubon critics. But he also repeated the experiments extensively and even tried a new experiment.*)
- **Based on the readings or your own observations, what do you wonder?**

Share with students that: 1) experiments are repeated to ensure that the results are valid; 2) scientific ideas, knowledge, and conclusions can change as new evidence is collected; and 3) scientific knowledge grows and changes.

Teacher Tip: Discussing the Intersection of Science and Society

Science, history, and culture are inherently tied to each other. It is important to consider how these elements interact. We may like to think that science can be removed from the influence of culture and society, including prejudice and injustice, but it cannot. As we designed this curriculum, we considered whether or not to include John J. Audubon and his investigations of vultures. In addition to being a naturalist who impacted the history of birding and conservation with his experiments and drawings of birds, Audubon had numerous flaws. For a period of time, Audubon owned slaves. Moreover, in his journals, he recounts a time when he returned runaway slaves to their captors. Recent research has uncovered that he plagiarized a drawing of a bird and named it Washington's Eagle—a fake bird species he concocted—in order to sensationalize and publicize his work in Europe.

We share this information to encourage you to consider delving into challenging discussions with your students. Should scientists' work and accomplishments be separate from their personal lives? What considerations should teachers and students make as they study scientists and other people with dubious pasts? Should organizations avoid using discoveries or experiments that were conducted in questionable ways or by people with questionable histories? What consequences might come from either decision? Taking time to introduce your students to the complexities of science invites everyone to develop critical thinking skills.



Activity 3 Discuss Nature of Science

In this activity, you will introduce students to nature-of-science concepts and uncover misconceptions about what science is and how scientists work. Play a "moving vote" game with a continuum—one side of the room indicating strongly agree, the other side of the room indicating strongly disagree, and in between being for agreeing or disagreeing but not strongly. After each statement, ask a few students to state why they chose their vote; allow students to change their position if their peers' reasoning changed their minds.

- **Scientists use their senses.** (*Scientists do use their senses to make observations and collect evidence. They often use tools to enhance their senses, such as microscopes, sound meters, and binoculars.*)
- **You can learn everything about science by reading books or looking on the internet.** (*While you can learn things about science in books and on the internet, there are many new scientific discoveries that can be made by making observations, doing experiments, and testing ideas in new ways. Ask your students to give examples of new scientific discoveries.*)
- **Scientists are creative in the questions they ask and the ways they figure out the answer.** (*Part of the fun of science is being curious and creative. Oftentimes, scientists invent new instruments and new methods to explore their questions.*)
- **Scientists collect data and information.** (*There are many kinds of data that scientists collect. For example, they might observe and make notes about plants or animals, collect numerical data during experiments, measure things in the environment, or analyze data collected by citizen scientists.*)
- **Scientists are collaborative.** (*Scientists often get ideas from each other and share their own experience and research with others. Many early-career scientists are mentored by experienced scientists, and scientists often work in teams.*)
- **As new scientific information, evidence, or data comes to light, scientists may change their minds about their recommendations.** (*Scientists modify their ideas and recommendations in light of new evidence and develop new ideas as they work. For example, in changing treatments or recommendations in medicine, solutions in environmental conservation, or understanding about our solar system as technology advances.*)
- **An observation or experiment often leads to new questions.** (*Scientists often ask new questions as they discover new information.*)

- **Scientists should keep their ideas to themselves so they do not get stolen.** (*An important aspect of science is sharing ideas, but sometimes scientists do need to keep some information private, such as individual medical information.*)
- **Scientists must be honest and ethical.** (*In order for society to trust the findings that accompany science, scientists must honestly and ethically conduct their research and report their findings. However, science has been used, and continues to be used, to support racist, sexist, ableist, and ageist practices.*)
- **Science impacts our lives every day.** (*Science and society interact and influence one another. Ask your students to provide examples.*)
- **Science is always unbiased.** (*It is impossible for science to be completely unbiased because scientists are human. In fact, science has been used in the past in discriminatory ways. However, the scientific field has methods and tools that limit bias, scientists strive to be objective, and they use peer review as a way to limit bias. Most scientists are ethical and strive to be unbiased but as with all fields, some scientists will make bad choices and choose to use science in discriminatory ways.*)
- **Scientific knowledge is both reliable and subject to change.** (*Having confidence in scientific knowledge is reasonable, and also scientific understanding changes in light of new evidence or a better understanding of prior evidence.*)
- **Science is a way of knowing.** (*Science is just one way of knowing and uses empirical standards, logical arguments, and skeptical review as its standard for judging knowledge. Indigenous and Eastern cultures have a deep understanding of the natural world and this knowledge was not gained through Western scientific methods.*)
- **Science has a set of tools and methods that must always be followed.** (*Scientific investigations use a wide variety of tools and methods depending on the question being asked. However, science is guided by a common set of values such as logical thinking, precision, objectivity, replicability, etc.*)
- **Scientific contributions have been made by people throughout history and from around the world.** (*Scientists exist in every country, throughout history, and come from all different backgrounds.*)
- **Scientists always succeed.** (*Scientists do discover new information and find solutions to problems but they also often discover what doesn't work. This may be considered a failure in other areas of life, but it is an important part of the work done in science.*)

Have them read and then answer the questions from the "#ScienceFails" worksheet in the Project Notebook.

As a class, generate a list of traits about science and scientists. You may wish to brainstorm ideas on chart paper or virtual whiteboard, or other platforms for later reference. Ask questions such as "What is science?" and "What do scientists do?" and "What skills and traits do scientists have?" Your list might include:

- 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 support or refute their claims and answer their questions.
- 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 and ideas.
- Scientists are flexible in their thinking. They get to change their minds when there is new evidence to back up their claim.
- Scientists are curious—they do not assume that they know everything, instead, they remain curious even about things they know well.

Ask:

- What traits and skills do you have in common with scientists? (*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 skills and traits illustrated by the scientists in the "Meet a Scientist" reports?

Lesson 1 Assessments

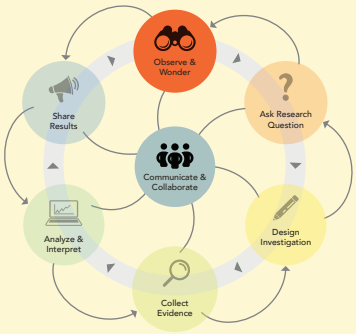
- Give students time to reflect on what they've learned about scientists and their practice and skills. Ask them to write a response to the question: What skills or traits do I have in common with scientists? What scientific skills do I want to develop?
- Now that students have a more complete picture of science and scientists, ask how their thoughts have changed. Give them an opportunity to reflect on their learning either through journaling or verbally. Questions to pose:
  - How have your ideas about scientists changed?
  - What has changed about your understanding of science?
  - Are you interested in having a career as a scientist? Why or why not?
- Revisit the opening discussion by showing the "Who are Scientists?" images again. Ask:
  - Is there any way to tell from a picture who is a scientist? Why or why not?
  - What new ideas did you learn regarding who scientists are and what they do?

Lesson 1 Extensions

- **Meet a Real Scientist:** Invite a professional scientist to visit your class. You can find a scientist by contacting your local nature center, state park, or wildlife refuge; at your local college or university; by enlisting a former student or a parent of a student; or by reaching out to a local business. If you are having trouble finding a local scientist, there are several programs to facilitate connecting students to scientists (see SAS resource site). Ask the scientist to talk both about their work and their lives outside of work. Brainstorm some possible questions in advance of the visit.
- **Explore a Relevant Science Story:** Brainstorm as a class, in small groups, or individually about a science story that is local or personally relevant. If you can not think of a local example, consider the following ideas:
  - Scientists changed their recommendations on how to prevent the spread of COVID-19 based on new evidence.
  - DDT was banned when scientists realized the negative impacts it had on birds of prey.
  - Scientists now believe that most dinosaurs had protofeathers thanks to new fossil evidence.
- **Making New Discoveries:** Science is a growing body of knowledge. Invite students to research a recent scientific discovery or any kind of cutting-edge science. You might suggest topics such as climate change, COVID-19, new species discoveries, new fossil evidence, space exploration, little-known Earth environments such as the deep sea, or under-studied plant and animal taxa.
- **Most Important Scientist:** Have each student decide who they think is the most important scientist. Encourage students to write a "Meet a Scientist" report, or create a slide deck or a podcast about that scientist, and share about the scientist and why they chose that scientist. Compare and contrast the scientists and the reasons why their work is important. Discuss: What do these scientists have in common, and how are they different? Which scientific fields are represented? What, as a group, do we think was important about their work?

Lesson 2: Make Observations

GOAL: **Develop students' abilities to observe while attending to the differences between inferences and observations.**



Location: Indoors and Outdoors
Time: 100 minutes

Essential Questions

1. Why is making observations important in science?
2. What are different ways to make observations?
3. What is the difference between an observation and an inference?

Students Will Know

- Observation and curiosity are foundational to scientific investigations and being a scientist; everyone can develop these skills.
- An observation is something you directly experience with your senses: what you see, touch, hear, smell, or taste.
- An inference uses prior knowledge to develop an explanation about something you've observed.

Students Will Be Able To

- Make and record careful observations about a phenomenon.
- Make and record observations at different scales.
- Explain the difference between an observation and an inference.
- Categorize statements either as an observation or an inference.

Getting Ready

- All curriculum resources and links are on the SAS resource site www.birds.cornell.edu/k12/sas-6-12.
- Activity 1: Introduce the Wonder Wall (15 min)
  - Project the science process diagram slide.
  - Create a space for the Wonder Wall and have sticky notes available. See Teacher Background for explanation and ideas.
- Activity 2: Observe a Phenomenon (15 min)
  - Determine which phenomenon you will use and be prepared to make a list of observations that you can use later in this lesson.
  - Provide digital or print access to the "Class Observations" Project Notebook page.
- Activity 3: Observe at Different Scales (40 min)
  - Select an outdoor space on your school grounds or local green space to complete the "See the Big Picture" and "Take a Tiny Hike" activities.
  - Cut 3-foot long pieces of yarn or string, enough for one for each student.
  - If available, provide students with hand lenses and binoculars to make observations at different scales.
  - Print the "See the Big Picture" and "Take a Tiny Hike" Project Notebook pages and provide a clipboard for each student.
- Activity 4: Observation Versus Inference (30 min)
  - Pick an image, video, or wildlife cam from the SAS resource site to teach about observation vs. inference.
  - Provide digital or print access to the "Observation vs. Inference" Project Notebook page.

Inclusive Teaching Strategies

- Invite students to design the Wonder Wall.
- Invite your students to choose a phenomenon or provide feedback on the phenomenon you select. Pay attention and give more weight to the suggestions from those voices that have been minoritized and silenced.
- Don't dismiss inferences, familial knowledge, or colloquialism just because it does not match up with scientific knowledge or your own prior conceptions. Instead, ask clarifying questions and attend to the cultural background of your students.
- When taking students outside for Activity 3 Observe at Different Scales, ensure that everyone can participate, attend to cultural differences in how the outdoors is utilized, and establish expectations and guidelines for outdoor time. If you are looking for guidance around using the outdoors as a learning space, download the "Spark Student Curiosity with Outdoor Exploration" from the SAS website.

Lesson 2 Teacher Background

Scientists are professional observers! They use their curiosity and observation skills to ask questions about the natural world. A scientist's research may be inspired by a variety of things, including societal needs, observation of a phenomenon, a new discovery or technology, curiosity about how something functions, or the desire to solve a problem. You can help students investigate personally relevant topics by inspiring them to critically observe their surroundings, explore their environment, and discover the natural world with all their senses and the tools available to them.

Students need time and space to wonder so they can think about what they notice and begin to ask questions that will lead them to plan and carry out an actual investigation of their own design. A short walk around your schoolyard or local park, during which students are encouraged to explore their surroundings using all their senses, can awaken curiosity. Nature provides many opportunities for observation. For example, which of these experiences might you have access to at your school?

- Watching birds visiting a feeder
- Looking under a rotting log
- Looking up at the sky
- Viewing a wildlife cam
- Observing pollinators on flowers
- Searching for insects on plants
- Watching ants work

The Wonder Wall

During this unit, you'll lead students through a scientific investigation. To accomplish this, students need to begin thinking like scientists. Scientists are constantly making observations and asking questions about the world around them. The Wonder Wall provides a place to collect and display student questions that you can revisit, answer later, or turn into investigations. When questions 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, save them on the Wonder Wall. Designate a space for your Wonder Wall and encourage students to write their questions on sticky notes and post them there. If wall space is tight, you can create a roll-up board using bulletin board paper or consider a trifold board. It's important that students have access to the board to add questions as they come up during the day or during instruction.



Over time, the Wonder Wall will provide a wealth of ideas that can form the basis of student-led investigations. Students will want to return to questions that they are genuinely interested in. Questions like, "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?"

Teacher Tip: Add Your Own Questions

Add your own "I wonder" questions to the Wonder Wall. You'll be contributing to the classroom community, modeling skills, and demonstrating that we are all lifelong learners.

Observation Versus Inference

Have you ever experienced a student who confidently declares something like, "Look, those squirrels are kissing!" or "That bird is telling the others how to get home"? It can be tricky to decide how to respond. Sometimes your instinct may be to correct them and say what YOU think is happening. Other times, you may be tempted to simply support their enthusiasm and say "Maybe!" Yet one of the most powerful things you can do to inspire more curiosity is to turn experiences like this into an exploration of observation and inference. It's a great way to encourage a sense of wonder about the natural world and to hone our ability to observe it closely.

People automatically create explanations for what they encounter. Often these explanations go beyond what we can observe and enter the realm of inference. Observations are what you experience directly with your senses (what you see, hear, taste, touch, or smell). Inferences are explanations you make about what you observe, often based on previous knowledge and experience. Inferences make assumptions about purpose, intent, motivation, or emotion—like the squirrels that may be romantically involved.

There are many possible explanations or inferences you might make about a situation that you observe. Both observations and inferences lead to hypotheses and research questions. When you hear "Those birds are fighting!" you can ask students to make more observations and generate other inferences. Guide your students to continue making observations so that they can determine which explanations are more likely: that's what scientists do!

Lesson 2 Activities



Activity 1 Introduce the Wonder Wall

Have students reflect on what they learned in the previous lesson about the nature of science. Project the science process diagram slide. Point out that all components of the scientific process are equally important, but we can see Observe & Wonder at the top. Ask:

- Why do you think Observe & Wonder are at the top of the diagram?
- Why do you think observation is an important skill for scientists?
- Is observation an important skill in other careers or other parts of life? Why or why not?

Share that many important scientific discoveries began with curiosity. Just like Audubon and Stager wondered about how vultures find their food, when we are observant and curious, we can discover amazing things about our world. Observation is an important scientific skill that can be strengthened through practice. Throughout this lesson, students will have the opportunity to practice their observation skills.

Introduce the Wonder Wall and the goals you have for the student investigations. Moving forward in the unit, regularly encourage students to add questions to the Wonder Wall and give them time to make observations related to their topics of study.



Activity 2 Observe a Phenomenon

Use phenomena to elicit careful observations from students. Choose your phenomenon and then have students

create a list of as many observations as they can using as many senses as possible, using the "Class Observation" page from the Project Notebook. Possible phenomena include:

- A photo or video of an animal (links on SAS resource site)
- A live wildlife cam (links available on SAS resource site)
- A natural item or living thing. You may wish to choose a simple item (rock, branch, leaf) or a more complex system (plant, aquarium, classroom pet).
- An interesting object in the schoolyard or nearby greenspace, such as a tree, bird feeder, or garden.

Create a list of student observations. Have each student take a turn sharing an observation. Challenge them to share a new observation until they run out of ideas. Hold onto this class list because it will be used later in the lesson.



Activity 3 Observe at Different Scales

Share with students that in order to both ask good questions and find answers, a scientist often observes and asks questions about phenomena from different scales. Lead a quick discussion about how scale matters by asking questions such as:

- How would observations of the Earth change if we were to observe it from a satellite image, from an airplane, on the ground, or through a magnifying glass?
- What would you miss if you only completed observations from a single scale?

Invite your students to complete two different types of observations around your school campus or local greenspace. Provide each student with a clipboard and copies of the "See the Big Picture" and "Take a Tiny Hike" Project Notebook pages. For both observations, encourage students to use drawings, words, and numbers to record their observations and to use as many senses as they can (sight, sound, touch, smell, but not taste).

- **See the Big Picture.** Have students sit or stand in a spot and zoom out, making big-picture or large-scale observations about everything around, looking high and low, and making a complete 360-degree turn around the spot. Have them note the weather, and anything else that gives context to the area. Optionally, provide binoculars.
- **Take a Tiny Hike.** In the same spot as they completed the "See the Big Picture" activity, give each student an equal length of string. Have them lay out their string and make as many small-scale observations as they can along that string, observing very closely along the string for a zoomed-in perspective of the world. Optionally, provide magnifying glasses.

Afterwards, invite students to compare and contrast their observations from these two activities. Ask:

- What kinds of details do you notice when up close? Far away?
- What differences did you notice between the two scales?
- What would you have missed if you only completed large-scale or small-scale observations?
- Why might it be important to make both kinds of observations?
- Are there questions or situations when one scale may be more appropriate for making observations?
- What questions do we have to add to the Wonder Wall?



Activity 4 Observation Versus Inference

As humans, we automatically create explanations for what we encounter. Often these explanations go beyond what we can observe and enter the realm of inference. It's ok to make inferences, but we must be able to distinguish between inferences and observation. It can be powerful to invite students to step back and think about what they have inferred so they can start thinking about alternate explanations. This step back can help generate

hypotheses based on early observations and inferences. It can be enlightening to think about how often your brain is spontaneously putting together a story.

Provide students with an image, video, or wildlife cam from the SAS resource site. Invite students to describe what they observe. As they provide answers, challenge students to limit their responses to only things they can directly sense (see or hear, in this case). Reinforce that these are observations.

Next, ask students to explain what is happening in the picture or video based on what they see and what they already know. For example, the birds are escaping a predator; the birds at the feeder are fighting over the seed; the moth has spots on its wings that look like eyes to scare off predators. Reinforce that these explanations are inferences and that they are using their prior knowledge to make them.

Have them practice identifying the statements on the "Observation vs. Inference" Project Notebook page as either an observation or inference.

After they have practiced, have students evaluate the class list of observations from the "Class Observation" list in Activity 2, and place each item from this class list into either observation or inference categories in the Observation vs. Inference table. For each inference, have the students cite any evidence they have for their explanation. Note that just providing evidence or reasoning may not mean an inference is accurate or true. You may need to correct their understanding of what is an observation or an inference even at the explanation stage. But also remember to attend to cultural knowledge and use that as a resource—don't dismiss this type of knowledge.

Lesson 2 Assessments

- Give students time to reflect on what they've learned about observation. Ask them to write a response to the question: What tips would you give a friend who wants to become a better observer?
- Present an image, a video, or .GIF and have students generate a list of observations and inferences.

Lesson 2 Extensions

- **I Choose This:** Take students outside and ask them to point out an object from nature. Give them the chance to share with a partner, small group, or the whole class, why they chose their object. Others might be surprised they chose the same object as someone else but for different reasons, which senses they used to choose their object, or why objects were meaningful to each other. Encourage students to share their observations of the object with each other.
- **Nature Journaling Over Time:** Going outside for repeated observations over time can lead to rich questions. Provide your students with time to write a nature journal weekly or monthly. You may wish to encourage them to find "sit spots" or places where they can return to make observations over time. How do their observations change with time? For more information on outdoor explorations see the SAS resource site.
- **Create a Mystery Box:** The mystery box should be a container that students cannot see through, such as a box with hand holes in the side or a paper bag. Place natural objects (feathers, shells, natural sponges, bones, or a piece of fruit) inside the mystery box and challenge students to use their sense of touch to try to identify the object. Touching an unknown object that you cannot see can make some students very nervous, so you may wish to only challenge volunteers and emphasize that the objects inside the box cannot harm them and are not living. Have students reflect on the experience of observing without the sense of sight. Was it intimidating? Was it challenging to describe and interpret what you touched?
- **Paying Close Attention to Everyday Items:** Start by choosing something that the students see every day but likely have not studied or just pass by without noticing it. For example: your desk, school gymnasium, a display case or board near your room. Then have them write down what they remember about it. Have students share what they remember. Did anyone remember something that no one else did? Did anyone remember something differently? Share that when we are familiar with something, we often stop noticing or seeing it, but scientists must try to avoid this and stay curious even about things they know well.

LESSON 3: Ask Scientific Questions

GOAL: **Develop students' abilities to ask scientific questions, and identify ways to answer those questions.**



Location: Indoors and Outdoors
Time: 120+ minutes
(Note: This lesson includes time for observations and question development, which can take additional time.)

Essential Questions

1. What types of questions do scientists ask?
2. What are the characteristics of scientific questions?
3. How and why do scientists refine questions to ones they can address with an investigation?

Students Will Know

- How to develop scientific questions based on their observations.
- Scientific questions can be answered using a variety of methods, including looking at reference material, exploring and analyzing existing data, conducting an observational study, and conducting an experiment.
- Scientific questions are those that are testable and can be answered empirically.
- Scientists refine their questions by ensuring that they are testable, meaning that they are specific, measurable, achievable, relevant, and temporal (SMART) while also being safe and ethical.

Studentsw Will Be Able To

- Ask scientific questions that arise from careful observation of phenomena.
- Evaluate a question to determine if it is testable by using the SMART method and if it is safe and ethical.
- Choose a testable, safe, and ethical question to explore through their own investigations.

Getting Ready

- All curriculum resources and links are on the SAS resource site www.birds.cornell.edu/k12/sas-6-12.
- Activity 1: Brainstorming Questions (15 min)
  - Prepare the same phenomenon as you used in "Observe a Phenomenon" (Lesson 2, Activity 2).
  - Prepare sticky notes for students to record questions they brainstorm.
- Activity 2: Ways to Answer Scientific Questions (20 min)
  - Cue the "Ways to Answer Scientific Questions" slide.
  - Decide how you will sort Wonder Wall questions and prepare enough copies for your method.
- Activity 3: Time to Wonder (20 min + extra for observations and question development)
  - Decide the level and topic(s) for student investigations (review the curriculum introduction for additional background information).
  - Choose and lead an activity or activities related to your investigation topic so students have time to make observations and brainstorm questions they might like to investigate.
  - Provide digital or print access to the "I Wonder List" in the Project Notebook.
- Activity 4: Refining Scientific Questions (45 min)
  - Cue the "Tools of Science: Testable Question" video from the slide deck or the SAS resource site.
  - Cue the "Creating a Testable Question" slides and review the notes section.
- Activity 5: Choose a Testable Wonder Wall Question (20 min)
  - Determine any constraints for student investigations, especially time and materials.
  - Prepare the observational and experimental questions from your Wonder Wall for students to refine into SMART testable questions.
  - Provide digital or print access to the "Testable Question" page in the Project Notebook.

Inclusive Teaching Strategies



- Take notice of what your students are curious about and work together to turn those interests into Wonder Wall questions.
- If possible, allow students to choose their own research question. If you choose to do investigations as a class or in small groups, pay attention to students who have been minoritized and silenced.
- Consider how students' non-scientific, but personally interesting questions, can be turned into scientific questions. For example, in her book *Braiding Sweetgrass*, Robin Wall Kimmerer described how she wanted to know why asters and goldenrod look so beautiful together but was told it was not a scientific question. In fact, this question can be expressed as a scientific question about symbiotic relationships or habitats, for example, "Why do asters and goldenrod often grow together in meadows?" (The answer that Kimmerer discovered through scientific research was that when they grow together, they are a more attractive target for bees and by growing together both plants receive more pollinator visits.)

Lesson 3 Teacher Background

Inspiring Questions

Questions are an essential part of science. Scientific questions are those that can be answered empirically by direct observations or with scientific tools. Students need meaningful opportunities to explore the environment to inspire questions based on their observations. Here are some tips from teachers who have used nature to spark student inquiry:

- **Model asking questions.** Ask questions as you observe. Turn your statements about what you see into questions. For example, you might observe that a bird is holding a worm. You might ask, "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 student inquiry, leads to even more questions, empowers students to find answers, and provides a space for them to be an expert.

Refining Scientific Questions

Curiosity and wonder may open up ideas that are broader than a student can successfully investigate. Help your students be successful by narrowing down their research questions to one that will fit their time, space, resources, and abilities. Scientists know from experience that often the first step in developing a good research question is to narrow down their question to one they can answer. While they may start with a broad question such as "Why are there more birds in my yard on different days?" they will evaluate and refine the question. One method is to use the acronym SMART:

Specific — Does my question have only one defined answer?

Measurable — Can the question be answered with results that I can measure?

Achievable — Do I have the resources to do this investigation in the time that I have?

Reasonable — Is the question worth asking?

Timely — Does this question relate to a specific time?

A SMART testable question may be: "How does the temperature affect the number of birds visiting my feeders from 6:30 a.m. to 7:00 a.m. from October through December?"



Activity 1 Brainstorming Questions

Remind students that curiosity is the heart of all scientific discoveries and that each of them already has this skill through observing and wondering. Invite students to observe the same phenomenon you used in Lesson 2, Activity 2, but this time they will ask questions about the phenomenon. Either individually or in small teams, encourage students to ask as many questions as possible for 5–10 minutes, recording each question on a sticky note. Have students write their questions exactly as stated, without discussion or attempting answers. At the end of the time, ask individuals or teams to each share one question. Add these questions to the Wonder Wall.

Teacher Tip: Question Building

If your students need support in developing their own questions, have them build questions by using:

- *Question starters:* does, how many, what is the relationship between, when, what percentage of, where.
- *Measurements:* hours of light, amount of water, number of, weight, volume, height.
- *Topics:* schoolyard animals, food preference, plants, water quality.



Activity 2 Ways to Answer Scientific Questions

Ask students to share ways they think scientific questions might be answered. Then, project the "Ways to Answer Scientific Questions" slide, using the graphic and notes to introduce the four ways people answer scientific questions:

- **Reference Materials:** 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 Existing Data:** You will find and analyze data that other people have collected to answer these questions. (For example: Which bird species are usually seen in the county I live in during the month of December? This question can be answered using data from participatory projects such as eBird, where people worldwide share their bird observations.)
- **Observational Studies:** To answer these kinds of questions, you need to collect data as you observe the natural world. (For example, if you are curious about the water quality of a stream near your school, or want to know if different species of birds behave differently, you can observe these things and collect data yourself.)
- **Experimental Studies:** To answer these kinds of questions, you will design an experiment and collect data based on a variable that you have changed. (For example, if you are curious about whether the birds in your backyard will eat more of one kind of seed, you can put out different seeds and collect data on how much of each type of seed the birds eat.)

Next, have the students sort the questions from the Wonder Wall into the four ways of answering questions individually, in small groups, or as a class.

Teacher Tip: Ways to Answer Questions

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 social science questions. Examples of survey questions include, "What animal is the favorite of the ninth-grade students?" and "How many sixth graders have a bird feeder at home?" If students mention asking someone who knows the answer, you may wish to liken that to reference material questions. Whether the resource is written or a person, the source must be a reliable source of information.



Activity 3 Time to Wonder



If you are allowing students to choose the topic they are investigating, give them time to consider what they want to investigate. Upon approval of the topic, give them time to make observations and pose questions about it. Encourage them to post as many questions as possible about their topic to the "I Wonder List" in their Project Notebook. If they are having trouble coming up with observational or experimental questions, have them pair up to help each other generate 3–5 of these kinds of questions on that topic. You may also want to use the question-building ideas provided in the Teacher Tip Box at the beginning of this lesson.

Alternatively, introduce the topic you've chosen as a focus of the student investigations (such as questions generated while participating in a participatory project; observations of birds, insects, or a local stream; or a local issue or problem your students would like to address). Inspire Wonder Wall questions by engaging students in observations and experiences related to the topic you've chosen (such as a nature walk, participating in a citizen-science project, watching a bird cam, or other opportunities to observe phenomena in or out of the classroom). Invite students to post as many questions as possible to the class Wonder Wall.

If feasible, allow your students to make observations and ask questions over a period of time, not just during one class to give time for additional observations and reflections. Allow them to continue posing and posting relevant questions to the "I Wonder List" Project Notebook page or Wonder Wall as time and space allows.



Activity 4 Refining Scientific Questions

Share with students that all four of the types of questions they learned about earlier are scientific questions. However, we'll focus on testable questions that can be answered by conducting an observational or experimental investigation on the topic or topics you've identified.

Show the video "Tools of Science: Testable Questions," which showcases how a team of scientists refined their testable questions using the acronym SMART. After watching the video, ask:

- Why wasn't Dr. Kim's original question testable? *(There were too many ways to answer the question; there were too many possible answers; it was too broad; it was a good starting point but it was not specific enough to find an answer.)*
- What did these scientists do to refine their question? *(They made sure the question was testable given their subject and the time and resources available. They did this by using the SMART acronym.)*

Show "Creating a Testable Question" slides to further explain the SMART way to create a testable question. After sharing the slideshow, ask:

- Do you think all aspects of the SMART technique will be equally important as you think about doing your own investigations? Why or why not?
- Why is it important to consider the health and safety of ourselves, our environment, and the living things that might be impacted by our studies?

To practice developing SMART questions, pair students and distribute any observational and experimental Wonder Wall questions; it's ok for more than one pair to have the same question. Have each pair refine the original question into a SMART testable question then share their original and SMART questions with the class. Provide feedback about the refined question, including safety considerations.



Activity 5 Choose a Testable Question

Now that students have practiced refining a scientific question, remind them that they will be completing an entire investigation themselves. Share any constraints that are applicable to your class (for example, the length of time they have to complete the investigation, if it must be completed on school grounds or if they can conduct it elsewhere, if they are allowed to supply their own resources or must only use those resources that are provided by the school).

With these constraints in mind, have each student or group choose or develop a research question they would like to investigate. Students should use the "Testable Question" Project Notebook page and the SMART acronym to revise their question into a testable question. (Note: In Lesson 4 they will have another chance to revise this question after they have learned about variables and conducted background research. So although they'll write their question now, it will not be finalized or approved until later.) Explain that the rest of the Project Notebook will be explored in the next lesson.

Lesson 3 Assessments

- Review each student's "Testable Question" Project Notebook page to assess their competency of refining a question into a scientific question.
- Have students select a scenario and write a paragraph outlining at least three possible safety considerations and at least two possible ethical considerations for a scientific study, for example, a scientist who wants to research:
  - a highly endangered butterfly in the remote forest
  - the impact of human-generated ocean noise on migratory whales
  - how prairie plants and animals respond to controlled burning of the prairie
  - the social life of chimpanzees
- Present an image, video, or natural object. Have students generate a list of questions and identify which way each question could be answered (i.e. reference materials, analyzing existing data, observational study, or experimental study).

Lesson 3 Extensions

- **Rank Top Questions:** Have each group choose their top three questions from the Wonder Wall. They will need to define "top," whether it will be defined as the most interesting, the best for conducting an investigation, or some other definition. Each group will present to the class their top three questions and the reasons they were chosen.
- **Question Sort:** Take the class outside for a "question walk" in nature, and have them write down as many questions as they can. Then sort the questions into the four ways to answer questions (observational, experimental, reference, existing data).
- **Look It Up:** Have each student pick a science question that they are curious about and can use reference materials to answer. Have them create a podcast, develop a poster, or write a report to share what they've discovered.

Lesson 4: Design Investigations

GOAL: **Develop students' abilities to design a scientific investigation that answers a testable question.**



Location: Indoors and Outdoors

Time: 240+ minutes

(Note: this lesson includes students' background research, designing their own investigation, and data collection, which can take as much time as you'd like.)

Essential Questions

1. How do scientists design investigations to answer testable questions?
2. What is the role of background research in designing an investigation?
3. What methods and tools do scientists use to collect data?

Students Will Know

- Background research using reliable resources, and careful planning are the foundations of a well-designed scientific investigation.
- How to plan a well-designed scientific investigation to answer a testable question, which includes conducting background research, developing a hypothesis, identifying variables and controls, choosing materials and methods, and collecting evidence.
- Methods and tools used in a scientific investigation vary depending upon the question being asked and the evidence being collected.

Students Will Be Able To

- Design a safe scientific investigation based on a testable question that includes:
  - background research;
  - a hypothesis;
  - variables (independent, dependent, and controls);
  - materials needed;
  - methods and tools for collecting evidence.

Getting Ready

- All curriculum resources and links are on the SAS resource site www.birds.cornell.edu/k12/sas-6-12.
- Decide the scope and format of the investigations, for example:
  - Will students work as a whole class, in groups, or individually to address a question?
  - What is the investigation timeline? How will this impact the scope of the questions students have time to address?
  - What is the final format that students will use to share their work? You can find options for formats in "The Many Ways to Share My Investigation" list found on the SAS resource site. Review the list and offer your preferred formats so students can choose.
- Activity 1: Read "The Effect of Temperature on Chickadees" (15 min)
  - Provide digital or print access to "The Effect of Temperature on Chickadees" article for each student.
- Activity 2: Explore the Project Notebook (30 min)
  - Develop a plan for how students will get their investigation plans approved.
  - Provide digital or print access to the Project Notebook.
  - Develop a rubric to assess their final projects.
- Activity 3: Conducting Background Research (20 min + additional time for background research)
  - Determine what level of scaffolding you will give students on acceptable sources for their background research.
  - Decide if your students will do background research in or out of class.
  - Provide digital or print access to the "Practicing Background Research" and "My Investigation: Background Research" Project Notebook pages.

- Activity 4: Understanding Variables (20 min; more if using the optional article)
  - Optional: Prepare to give the "Lesson 4 Pre-assessment Quiz" to assess what your students know about variables.
  - Review the teaching notes for the "Variables in a Science Investigation" slideshow and cue the slides for students.
  - Optional: Provide digital or printed access to the "Variables in Your Science Investigation" article.
- Activity 5: Developing a Hypothesis (35 min)
  - Review the teaching notes for the "Hypothesis Help" slideshow and cue the slides for students.
- Activity 6: Investigation Design (60 min)
  - Review the teaching notes for the "Designing a Science Investigation" slideshow and cue the show for students.
  - Provide digital or print access to the "Will a Fake Cat Scare Birds?" article.
- Activity 7: Designing Their Own Investigation (60+ min, depends on the investigation)
  - Provide digital or print access to the Project Notebook pages: "My Investigation: Hypothesis", "My Investigation: Variables", "My Investigation: Location and Materials", and "My Investigation: Methods."
  - Review each of the above Project Notebook pages to ensure that your students have designed a reasonable investigation and have the tools, measuring devices, and data sheets needed to collect their data.
- Activity 8: Putting Ideas Into Action! Collecting Evidence (time varies, depending on the investigation)
  - Decide how long students will have to collect data and if they are collecting it during or outside of class time.

Inclusive Teaching Strategies



- At this stage of planning, it can be helpful for students to know the format of their final project. If possible, allow students to choose how they'd like to share their work.
- Family and community members can provide expertise and insight. Invite your students to gather information from parents/guardians, grandparents, and community members as part of their background research. For example, students could ask their elders what the local environment was like when they were kids.
- Empower students to determine their research approach and design.

Lesson 4 Teacher Background

In this lesson, you will guide your students through a science investigation, including conducting background research and setting up a plan for collecting evidence that will answer their testable question. Don't try to make this perfect for your students. An investigation that doesn't go as planned is just as valuable in the learning process. Let students take the lead, experience challenges, and make adjustments. Real scientists do this all the time!

Background Research from Reliable Sources

An important part of designing an investigation is understanding what is already known. During this lesson, students will do background research on their question. It is important that they use reliable (thorough and unbiased) sources when conducting their background research. Such sources can include peer-reviewed journal articles and books; nonfiction books; governmental resources; and magazine, news, and website articles from well-established and unbiased publishers.

Wikipedia's extensive content often makes it a great place to begin the research process. However, because anyone can edit a Wikipedia article at any time and the editors are anonymous, it's difficult to assess its reliability or credibility and should not be used as an authoritative reference. A better idea is to use Wikipedia as a jumping-off point to get some background information and discover related topics. Then, use the list of references at the bottom of the article to search for reliable sources.

If your students need practice in doing background research, you may wish to use the Practice Background Research extension or look at the SAS resource site to discover other teaching resources about reliable sources.

Hypothesis

The concept of developing a hypothesis can be difficult to understand. You may have heard the word hypothesis described as an educated guess, but too often people focus on the word *guess* instead of the word *educated*. Scientists usually develop a hypothesis based on their knowledge of a topic, often after many years of learning about their research topic. A hypothesis is based on prior knowledge and background research, not just hunches. A hypothesis is a testable statement about the natural world that can be supported or rejected based on evidence or data collected during experiments or observations. Students should be able to state why they believe their hypothesis may be true.

A hypothesis is a reasoned and informed explanation that:

- is written after background research, but before conducting the investigation;
- is tentative in nature (it can either be supported or rejected through research);
- is both possible and plausible;
- will guide the investigation of the cause or correlation between variables;
- is not written to just confirm 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;
- points to the kind of data that 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, but can be supported or rejected by evidence.

Confusion between the terms hypothesis and prediction is also common. Predictions are stronger than guesses because predictions rely on data and research to reason what might happen in the future. A well-written hypothesis goes further by proposing why something will happen, which helps suggest an investigation design.

You may be familiar with the "Claim, Evidence, Reasoning" method in K-12 science. How and where does this fit into the science process? Oftentimes, the words hypothesis and claim are incorrectly used interchangeably. A hypothesis is a potential answer to a question. A claim is based upon the evidence collected during the investigation. A hypothesis is written before an investigation begins, while a claim is made after data is collected as part of interpreting evidence. Claim, evidence, and reasoning are used in interpreting data and are all part of the argumentation practice. In fact, multiple claims may be made while interpreting evidence, but there can only be one hypothesis.

One standard way to write hypotheses is to use the "If…then…because" 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 helps to clarify the relationship between the variables and to make the student's reasoning clear. For example, an If/then/because hypothesis might look like this: If feeder birds prefer higher fat seeds in the winter, then they will eat more of the Brand X bird seed mix than the Brand Y bird seed mix, because the Brand X bird seed mix contains 10% crude fat and the Brand Y bird seed mix contains 5% crude fat.

Because forming hypotheses can be difficult for students, here is another way to help them. It is often easier for students to consider what they think will happen or what they expect to observe, based on prior experience. You

can help students go beyond expectations to generate hypotheses by providing sentence starters for them to fill in: "I expect to observe A because B." For example, "I expect more birds will eat the expensive seed because it has more fat and protein," or "I expect more squirrels to choose peanuts without shells than with shells because they are easier to eat." To make a hypothesis, simply restate your expectation into a statement, such as "More birds will eat the expensive bird seed mix because it has more crude fat and protein than the cheaper bird seed mix," or "More squirrels will choose peanuts without shells than with shells because they are easier to eat."

A Well-Designed Investigation

A well-designed investigation generates meaningful data that can be used as evidence to make reasoned arguments. A well-designed investigation:

- starts with a testable question (Lesson 3);
- includes background research to inform writing a plausible hypothesis;
- identifies the independent, dependent, and control variables;
- has a dependent variable that is measurable using appropriate tools and methods;
- changes only the independent variable so evidence/data can be attributed to that change and not to another variable;
- ensures that the investigation effectively measures the dependent variable and collects enough data to explore the question;
- avoids bias in the design, the data collected, and the interpretation of the data; and
- avoids harming ourselves, others, and the environment.

Collecting Evidence

Once the investigation is planned, a scientist begins collecting data, also called evidence. Evidence can take many forms: quantitative (number) measurements, qualitative (descriptive) data, direct observations, and data collected by others. Oftentimes, scientists use many different types of evidence. During this lesson, students will carry out the investigation they designed and collect their data. While collecting evidence, students may find they need to modify their investigation design further. It is also possible that while carrying out the investigation, a new discovery, question, or observation is made that leads to a new research question, a modification to the design of the current investigation, or the need to develop a whole new investigation design. This is a normal part of the science process.

Classroom Case Study

Discussing the Investigation Plan

Ms. James teaches an 8th-grade class in rural New York. They conducted a bird feeder study as a class. Before beginning, she invited small groups to brainstorm how they thought the study should be designed. She invited groups to share their ideas.

The first group explained, "We would make two identical feeders from soda bottles and fill one with one kind of mixed bird seed and the other with a more expensive brand of mixed bird seed. 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 contains more of their preferred seed types.

She asked the rest of the class what they thought about the plan to have 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.

She asked the other groups if they considered this in their plans. One student said that their group planned to hang the feeders in different trees, but all in the same area. The discussion was lively about whether that was acceptable. In the end, the group decided not to change their plan, but to make sure other things (such as 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. One group suggested that it was better to weigh or measure the amount of seed remaining, rather than just the number of bird visits because 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 bird seed, then they will eat more of the expensive seed because it contains more of the preferred seed types." Everyone was excited to start investigating!

Lesson 4 Activities



Activity 1 Read "The Effect of Temperature on Chickadees"

Distribute "The Effect of Temperature on Chickadees" article to each student or group. Give students 5–7 minutes to read the report. Direct them to pay attention to the section headings (indicated in bold) and the information contained in each section.

After students have finished reading, lead a discussion to highlight Annalisa's investigation process by asking questions such as:

- What did Annalisa wonder?
- What was her hypothesis? What experience or knowledge led to this hypothesis?
- What did she conclude, and what evidence did she use to support that conclusion?



Activity 2 Explore the Project Notebook

Share that, like Annalisa, students will take part in a complete scientific investigation that begins with one of their questions (which was chosen in Lesson 3 but may still be revised).

Doing an investigation requires planning and organization. Ask students to look at the "Project Checklist" in their Project Notebook and review the process they will use throughout the unit. Review the 11 stages of the project:

1. Develop a testable question that can be explored given the time and resources you have. *(Chosen in Lesson 3 but revisable)*
2. Conduct background research by reading about your topic and summarizing what you learn. Write down notes and citation information for all the resources you use. *(Note: you may need to revise your SMART testable question based on your research. Lesson 4)*
3. Determine your variables. *(Note: review your SMART testable question to make sure your variables are included. Lesson 4)*
4. Develop your hypothesis. *(Lesson 4)*
5. Outline your materials and methods. *(Lesson 4)*
6. Conduct your study, collecting data and/or making observations. *(Lesson 4)*
7. Organize, visualize, and analyze your data. *(Lesson 5)*
8. Interpret your data, make claims, and evaluate if your hypothesis was supported, rejected, or partially supported. *(Lesson 6)*
9. Create the first draft of your final project. *(Lesson 6)*
10. Complete peer review. *(Lesson 6)*
11. Revise your work based on the peer review and turn in your final project. *(Lesson 6)*

Explain the process for getting their investigation plans approved. Share your expectations for their final project and the rubric you will use to evaluate their work. Assign due dates for each of the above steps and have students record them in their "Project Checklist."

Then explore the rest of the Project Notebook. This will be their guide to ensuring that all parts of the investigation are carefully planned and carried out. If they are working in teams or as a class, ask them to complete "Team Project Plan" from the Project Notebook before they begin their investigation.

Teacher Tip: Safety Considerations

Before approving a project plan, make sure your students have considered safety. Are there any issues with methods (location, access, etc.) or the materials (power tools, chemicals, sharp items, etc.)? Will any animals, plants, or habitats be harmed? Will the investigation attract unintended predators or pests?



Activity 3 Conducting Background Research

Share with students that when scientists have questions or have made an interesting observation, they use their own knowledge and do background research to see what is already known. This helps them design a good study (see Teacher Tip Box: Background Research). Scientists also share this background research, usually written in the introduction of a scientific paper or poster, so they keep careful notes regarding what they've found.

Ask students where they might look if they wanted to learn about a particular species of animal, for example, to find out where it lives, what habitat it prefers, and what it eats. *(Possible answers include watching the animal, watching a video, listening to a podcast or interview, looking online, reading a book or article, finding a field guide, or asking an expert, which can include their own community members—don't dismiss a grandparent or other adult's knowledge.)*

Review how to write citations. Challenge students to work individually or in small groups, to search for information on any animal they are interested in using at least three trusted sources (ideally, using online and printed resources). You may wish to recommend acceptable sources and sites (read more about Wikipedia as a resource in the Teacher Background section of this lesson). Use the "Practicing Background Research" page from the Project Notebook for them to record their findings and answer the following questions.

- What resources did you use? (*Encourage them to cite their sources on the worksheet in the same format they should use for their own investigation.*)
- What did you learn about the animal?
- Do you think all sources are equally reliable? Can you trust everything you read? Why or why not?
- Did anyone find conflicting information between sources? What did you do?
- What makes some resources better than others? *(For example: current or up-to-date, unbiased, reliable, or based on a trusted source.)*

Discuss answers and ideas as a class.

Give students time to conduct background research for their own investigation and have them fill out the "My Investigation: Background Research" page of their Project Notebook. (Note: have students complete most or all of the background research prior to moving on to the next activity because the more the students know before writing a hypothesis, the more informed and plausible their hypothesis will be.)

Teacher Tip: The Importance of Background Research

One teacher described a struggle she had in her classroom. Her students were interested in building good nest boxes for birds. They voted on which local bird they wanted to build a box for, and the kids selected the Mourning Dove. They designed and built nest boxes for that species, but unfortunately, no doves visited the nest boxes, despite being in the area in the spring and summer. The teacher was later surprised to learn that Mourning Doves simply do not use nest boxes because they are not cavity-nesting birds. A bit of research would have led to a more successful study and great discussion about the nesting preferences of birds.



Activity 4 Understanding Variables

If you want to assess what students already know about variables, consider using the "Lesson 4 Pre-assessment Quiz." Present the "Variables in a Science Investigation" slideshow to emphasize the importance of the different kinds of variables in an investigation. If your students need additional examples of variables, have them read the "Variables in Your Science Investigation" article.



Activity 5 Developing a Hypothesis

Use the "Hypothesis Help" slides to teach about what a hypothesis is and to give practice writing hypotheses. Revisit the working definition that your class developed in the first slide of the slideshow and make changes if needed.



Activity 6 Investigation Design

Present the "Designing a Science Investigation" slideshow to teach the basics of designing an investigation.

Provide access to "Will a Fake Cat Scare Birds?" for each student. Divide students into small groups or partners and have them read the article and discuss the questions at the end of the report.

- What was Amy's hypothesis? *(If a fake cat is placed next to a bird feeder, then fewer birds would visit the feeder.)*
- What was the independent variable in this study? *(Fake cat or no fake cat.)*
- What was the dependent variable in this study? *(How much birdseed is eaten during a week.)*
- What variables did Amy control? *(Time frame, kind and amount of seed, location, bird feeders.)*
- What methods and tools did Amy use? *(Tools: measuring cups, bird feeders, two types of birdseed; life-sized stuffed cat. Methods: measured amount of birdseed before and after the week without a stuffed cat and again before and after a week with the stuffed cat, comparison of volume of birdseed.)*

Invite several students to share out from the group discussion, then continue the discussion by asking:

- **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 anything else in her yard, such as real cats, other predators, people, or other disturbances, may have impacted the experiment. She didn't describe if the weather was similar across the two weeks when she conducted her 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 or evidence to determine the strength of the support.)*
- **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, 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 friendly stuffed bird or a stuffed bunny, would it have scared the birds? Was it the cat or just the fact that something new was there?)*
- **Was the study well-designed?** *(Opinion based; see preceding points and the Teacher Tip Box: Was Amy's Experiment Well Designed?)*

Teacher Tip:
Was Amy's Experiment Well Designed?

Many factors might have affected the number of birds that ate from 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. We also don't know if there were any real cats present during the experiment. Remember, it was seeing cats in her yard that led her to do her experiment.

Collecting more data and evidence will generally make a study better. More data helps show trends. Adding another variable to the experiment would also strengthen the design. For example, adding a stuffed bird for a week would show whether it was simply a new object that scared the birds away or if the birds were reacting to the presence of a stuffed cat.

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



Activity 7 Designing Their Own Investigation

Invite students to write a hypothesis for their investigation in their Project Notebook on the "My Investigation: Hypothesis" page. If they haven't already, have students identify their independent variable, dependent variable, and control variables and add them to their Project Notebook. Give students time to finish planning their investigation by filling out the following pages in their Project Notebook: "My Investigation: Variables," "My Investigation: Location and Materials," and "My Investigation: Methods."

Make sure students have chosen materials that are available. Check their data sheets for clarity and completeness. Carefully consider the impacts to and safety of students, animals, and the environment. See Teacher Tip box: Safety Considerations. We suggest regularly checking student progress throughout this activity and the remaining activities of this unit to provide support and encouragement.



Activity 8 Putting Ideas Into Action! Collecting Evidence

It's time for your students to put their ideas into action! During this part of the unit, students collect their data (e.g., making and recording observations, collecting accurate and precise measurements) that will be used as evidence to make claims. Depending on the original question, students might need 20 minutes, 20 hours, or 20 days to collect enough evidence to aid them in their arguments. Be sure that:

- students have enough time either in or out of class to gather the necessary data;
- data is being collected accurately;
- if there are unforeseen problems, corrections are made and documented, and, if necessary, the data collection period is extended.

Lesson 4 Assessments

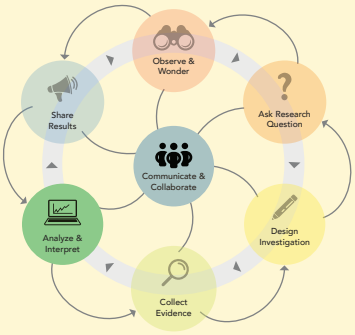
- Review each student's Project Notebooks after each independent activity.

Lesson 4 Extensions

- **Background Research Stations:** To help students better understand the idea of reliable resources and being critical consumers of information, set up stations with different background resources for the same bird species. Station 1: A video, podcast, or popular science/newspaper article. Station 2: All About Birds website. Station 3: Wikipedia. Invite students to spend about 10 minutes at each station to watch, listen to, or read the source and write down notes just as they would for their own background research, including citing the source. Once they've gone through each station, ask the following questions:
  - How did the information differ between sources?
  - If information was different between sources, how do you decide which source(s) to use?
- **Sample Size:** Have the students collect data at their table/group (height, hair color, favorite food, etc.), then collect the same data for the class, and finally collect data from the whole school—how do the results compare? What is the value in having a larger sample size? What kinds of biases could be in data when the sample size is small that may not be in a large sample size? What is an appropriate sample size for a dataset? What impacts the sample size of a dataset?
- **Correct Citations:** Introduce citation formats for their final project references. Pick an appropriate reference format (APA, MLA, etc.) and have your students write a citation for any/all of the following: a book, a book chapter, an exact quote, a video, a website, a magazine or journal article, and personal communication.

Lesson 5: Analyze Evidence

GOAL: **Develop students' abilities to create graphical displays and analyze data collected during a scientific investigation.**



Location: Indoors
Time: 120+ minutes
(Note: students will need additional time to analyze their own data.)

Essential Questions

1. How do scientists decide how to analyze data?
2. How are patterns and relationships in data discovered?

Students Will Know

- Diagrams, graphs, tables, charts, maps, and statistics are different ways to visualize and analyze data to explore the answers to a question.
- Analyzing data helps scientists identify the patterns and relationships within the data they collect.

Students Will Be Able To

- Create grade-appropriate graphical displays and analyses of their data.

Getting Ready

- All curriculum resources and links are on the SAS resource site www.birds.cornell.edu/k12/sas-6-12.
- Activity 1: Creating Graphical Displays from Class Data (30 min)
  - On chart paper, create three graphical displays: a pre-drawn map of the US or world and two XY charts/plots.
  - Decide what student-focused questions you will use for each graphical display. See the activity for suggestions or you may choose an alternative that is more relevant to your students.
  - Provide enough stickers or sticky notes for each student to have three data points to place on the maps and plots.
- Activity 2: Choosing Appropriate Graphical Displays and Analyses (90 min)
  - Provide digital or print access to the resource "Choosing Graphical Displays and Analyses," modifying if needed.
  - Decide whether you can work with a math teacher or if you need to prepare and teach grade-appropriate analyses and math lessons.
  - Review and project the "Exploring Graphical Displays and Analyses" teaching slides. *Please note that this slideshow includes graphical displays and discussions of analyses (descriptive and statistical) that are appropriate for experienced high school students; if you are teaching middle school or less experienced high school students, you may need to delete/edit some slides or content.*
  - Prepare practice data and activities for data analysis. We recommend using the data analysis program used in your school or by math teachers to help reduce the learning curve for your students. If your school does not already have data analysis programs, see the SAS resource site for options.
- Activity 3: Analyzing Their Own Data (varies)
  - Provide digital or print access to the resource "Choosing Graphical Displays and Analyses," modifying if needed.
  - Provide digital or print access to the Project Notebook "My Investigation: Data Analysis," modifying it if needed.
  - Provide digital or print access to the Project Notebook "Graphical Display Checklist."

Inclusive Teaching Strategies

- During Activity 1, choose questions that are relevant to and inclusive of all your students. Be mindful of using questions that might be problematic for any of your students (for example, consider avoiding questions about family structure or topics that have a financial component).
- During Activity 2, when your students are exploring and analyzing data, allow them to choose datasets that are interesting to them.
- During Activity 3, give time in and out of class for students to create graphical displays and analyze data so that you can guide student learning while also providing opportunities for them to succeed on their own.

Lesson 5 Teacher Background

Understanding raw data can be hard. So, after collecting data, scientists organize it. Going through the data helps ensure it is accurate—no missing or wrong information. Organizing it also makes it easier to see and study the data. In this lesson, you will use a slideshow to explain data organization and later students will organize the data they collected.

After data is organized, it is ready to be analyzed. A scientist (or student-scientist) analyzes data by creating tables, graphs, charts, maps, models, and diagrams, or doing mathematical calculations and statistics. This helps uncover patterns and relationships within the data. Sometimes there are no obvious patterns or relationships–that's ok. No pattern or relationship is an answer too!

In this lesson, we cover different types of graphical displays and analyses that you can do with different kinds of data using a slideshow and handouts. Depending on your students, you could dig deeper into mathematical and statistical analyses, but we do not cover that in detail within this curriculum. We encourage you to collaborate with the math teachers in your school as you teach this lesson, if needed. At the end of the lesson your students will analyze their own data.

Lesson 5 Activities



Activity 1 Creating Graphical Displays from Class Data

In this activity, you'll collaboratively create graphical displays with class data. First, hang large sheets of paper around your classroom as laid out below. Then, hand out sticky notes or stickers, enough for each student to place their own data point on each sheet. Demonstrate how you want students to mark their responses for each graphic.

- Map of your state, the United States, or the world, depending on your students.
  - Question suggestions: Where were you born? What place would you most like to visit?
- Bar chart with the x- and y-axes labeled appropriately.
  - Question suggestions: Which superpower would you choose: invisibility, flying, being able to read minds, superhuman strength, or teleportation? How do you most like to connect with your friends: social media, talking on the phone, texting, or in person?

- Scatterplot with x-axis labeled appropriately.
    - Question suggestions: How many kilometers/miles away from school do you live vs. how long does it take for you to get to school in the morning? What is the amount of time you sleep each night vs. the amount of time you spend on a screen outside of school time?

Once everyone has added their data to all the sheets, start a class discussion about one of them, giving the students a few minutes to study it, and ask:

- How does your data compare to that of your classmates?
- What patterns do you notice? What might be influencing these patterns? (*One example could be, the mode of transportation - walking, cycling, bus, train, car - could be influencing the patterns we see in the scatter plot of distance vs. time to get to school.*)
- What suggestions do you have to make this graphic easier to understand? (*For example, are the key, axis labels, and titles clear, accurate, and descriptive?*)

Continue the same process for all graphical displays. Afterwards, wrap up the discussion with these questions.

- How might these patterns change if we included data from the whole school?
- Do you have any questions about these graphics? What are you curious about?
- When have graphical displays been useful in your everyday life?



Activity 2 Choosing Appropriate Graphical Displays and Analyses

With so many options for visualizing and analyzing data, it can be hard for students to decide which to use and when. Present the "Exploring Graphical Displays and Analyses" slideshow and provide access to the "Choosing Graphical Displays and Analyses" resource for them to reference and use during the slideshow.

Upon completion of the slideshow, invite your students to practice analyzing data by creating tables, graphs, charts, and maps using your school's data analysis program and practice data sets.

Teacher Tip: Analyses

We do not include how to teach specific statistical calculations or mathematical computations in this curriculum. Instead, it focuses on helping students build data analysis skills without specific computations. However, the NGSS standards expect students to be able to include mathematical and computational thinking in their scientific work. Therefore, we encourage you to collaborate with the math teachers at your school to guide your students' mathematical and statistical calculations and thinking, if needed.



Activity 3 Analyzing Their Own Data

First, have students look at their own investigation data and organize it using your school's data analysis software. Once it is organized, have them consider which graphical displays and types of analyses could be used to make sense of their data. There may be several graphics, descriptive analyses, or statistical calculations that are appropriate. You may want to ask your students to generate multiple graphics to decide which ones explain the story best. You may require your students to complete specific analyses of their data, such as averages or best-fit with a correlation coefficient. Remind them to consider all the different graphical displays and analysis techniques they've learned. Scaffold this process by having students complete the Project Notebook pages "My Investigation: Data Analysis" and review the "How do I choose what graphics and analyses to use to explore my data?" reading, which will guide them in picking suitable visuals for the data and the question they studied.

After they have filled out the Project Notebook pages "My Investigation: Data Analysis," invite the students to share their ideas and choices with a partner. The partners should listen to each other's reasoning and see if these planned graphics and analyses make sense for what they want to explore in the data. Invite students to modify their plans based on the discussion.

Finally, review the "My Investigation: Data Analysis" Project Notebook pages to assess each student's understanding of their planned data analysis and provide support as needed. Then invite students to analyze their own data, either in or out of class. After students have completed these first drafts, have pairs of students review each other's graphical displays by using the "Graphical Display Checklist" in the Project Notebook. Encourage students to make revisions, if needed.

Lesson 5 Assessments

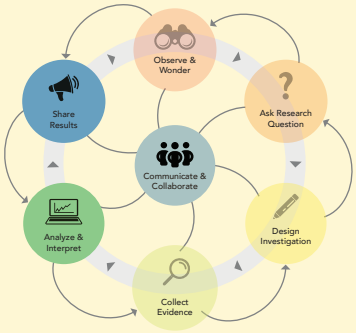
- Use the "My Investigation: Data Analysis" and "Graphical Display Checklist" Project Notebook pages to assess students' data graphics and analyses.
- Have your students determine problems with each of the images provided in the "What's wrong with this picture?" resource.

Lesson 5 Extensions

- **Play Data Games:** There are many online and in-person data games. Check out our favorites on the SAS resource site and choose one or more to play.
- **Explore eBird Data:** The Cornell Lab of Ornithology's participatory science databases are a great resource for data analysis. 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 and click the "explore" tab. For additional support, consider purchasing the grade-appropriate *eBird Explorers* kit (see the SAS resource site for links) to help students contribute to and use the eBird database.

Lesson 6: Interpret Evidence and Share Results

GOAL: **Develop students' abilities to effectively interpret evidence and communicate the results of their investigation to others.**



Location: Indoors
Time: 205+ minutes

(Note: this lesson includes time for developing a rough draft, conducting peer review, and creating the final project, which can take as much time as you'd like.)

Essential Questions

1. How can data be used to make claims and evaluate hypotheses?
2. How do scientists communicate results?
3. How does peer review support the science process?

Students Will Know

- Claims and arguments are informed by background research and developed from the data that is collected, analyzed, and interpreted.
- Data analysis and interpretation are used as evidence to support or reject a hypothesis.
- When scientists share their results, they include details about their background research, what they studied and how they studied it, and what they learned.
- The intended audience impacts how results are shared.
- Constructive feedback can improve science projects.

Students Will Be Able To

- Describe what the observed patterns and/or relationships in data means for the broader context or phenomenon.
- Construct claims and arguments based on valid and reliable evidence, scientific ideas, and principles.
- Determine whether they can support or reject their hypothesis and use evidence to explain their reasoning.
- Effectively communicate, in a grade-appropriate manner, the results of their investigation to a target audience.
- Incorporate constructive feedback into their final project.
- Give constructive feedback to peers.

Getting Ready

- All curriculum resources and links are on the SAS resource site www.birds.cornell.edu/k12/sas-6-12.
- Activity 1: Interpreting Data to Make a Claim (90 min)
  - Cue the slideshow "Interpreting Data to Make a Claim." Print the slides to hand out to groups so they each have an example visualization to interpret in their group or gather your own examples. The answer key is found on the SAS resource site.
  - Provide digital or print access to the Project Notebook page "Interpreting Data Practice."
- Activity 2: What's The Story? Interpreting Data and Making Claims (60 min)
  - Provide digital or print access to the Project Notebook page "My Investigation: What's My Story?"
- Activity 3: Decide Your Communication Strategy (30 min)
  - Decide options for final projects. If needed, modify "The Many Ways to Share My Investigation" to list only those options you want to make available to your students.
  - Provide digital or print access to "The Many Ways to Share My Investigation."
- Activity 4: Prepare a Draft Project (varies)
  - Have check-ins with the students while they are working on their rough draft.

- Activity 5: Introduce Peer Review (15 min)
  - Optionally, show the "Peer Review Tips" video found on the SAS resource site.
- Activity 6: Conduct Peer Review (10 min + time for students to complete the peer review).
  - Provide digital or print access to the Project Notebook pages "Peer Review Checklist."
- Activity 7: Complete and Share the Final Project (variable)
  - Prepare the time and space for students to share their final projects.

Inclusive Teaching Strategies



- Provide example data and visualizations that are relevant to your students.
- When students interpret their data, attend to everyone's culture. Ask clarifying questions instead of dismissing explanations, ideas, and arguments.
- Today, scientific results are communicated to diverse audiences through many channels. The challenge of expressing technical information to a wide audience can be empowering and fun. Encourage students to consider different ways of sharing their findings and messages with audiences that matter to them. Encourage ways to share beyond your classroom (for example, to higher and lower grade levels, to adults such as families or local community groups, and to audiences in a student's first language).
- Take time to co-develop the rubric for peer review. Ask students to consider how they prefer to give and receive feedback.
- Peer review can be a source of miscommunication and hurt feelings. Rather than randomly assigning students for peer review, take into account culture and personalities so that peer review can be constructive.

Lesson 6 Teacher Background

In this lesson, students will continue working on the analyze and interpret aspect of the science process, focusing on interpreting data for activities 1 and 2. The last five activities of this curriculum involve sharing results. As with all activities, communication and collaboration are important but are really highlighted in activities 3 through 7.

Interpreting Data

Once your students have analyzed their data, it's time to interpret their data. Interpreting data is the sensemaking portion of the science process. Interpretation brings together background knowledge, scientific principles and reasoning, and the data collected during the current research. Scientists then use evidence to make claims and support their claims through reasoning. It is through this interpretation process that scientists will evaluate whether their hypothesis was supported or rejected. In the same way, students will use evidence to make a claim and back up their claim using reasoning that includes background research and scientific principles, and evaluate their hypothesis.

Sharing Results

Communication and collaboration are fundamental to the science process. Scientists commonly collaborate with peers during their investigations, which often leads to new ideas and questions. Authentic scientific research also undergoes peer review by multiple qualified scientists who offer valuable feedback before results are shared with the wider scientific community. Scientific findings are frequently shared with the public. Sharing scientific research can improve public health, inform policy, solve common issues or problems, and generate new knowledge.

Now it's your students' chance to present their discoveries to broader audiences! There are several creative ways for sharing results, and you can explore different options in "The Many Ways to Share My Investigation" article. Typically, students will include background research, their hypothesis, study design details, data analysis and interpretation, claims, and graphical displays. Encourage students to consider how their research findings can benefit others. While traditional reports and posters feature sections such as introduction, materials and methods, results, and future research sections, alternative ways of sharing results may follow different structures.

Lesson 6 Activities



Activity 1 Interpreting Data to Make a Claim

Begin by presenting the slideshow titled "Interpreting Data to Make a Claim." Start with the first slide to introduce the concept of data interpretation. Then, as a class, practice data interpretation using the next slide, which features the research question: "Will the presence of a fake cat change how much seed is eaten by birds?"

Next, divide your students into groups and give each group one example graphic from the slideshow. Encourage students to carefully examine their graphic and complete the "Interpreting Data Practice" section in their Project Notebook. Have each group present their example and interpretation to the class. If misinterpretations occur, help students arrive at better interpretations.

Return to the slideshow and present the slides "What is a Claim?" and "How to Use Evidence to Make a Claim and Support a Claim with Reasoning." Guide your class through the example on "Will the presence of a fake cat change how much seed birds eat?"

Conclude the slideshow by sharing the last two slides about hypotheses. Sometimes students think they have "failed" if their stated hypothesis is rejected. Ask:

- How might you feel if the evidence led you to reject your hypothesis?
- If your hypothesis is rejected, should you conclude you have done something wrong? Why or why not?

During these discussions, remind students that any outcome of any well-designed scientific study contributes to our understanding of the world. Therefore, any result is valuable, even if a hypothesis is rejected. Studies aim to explore and understand the natural world, not to prove hypotheses right or wrong.



Activity 2 What's The Story? Interpreting Data and Making Claims

Now that your students have practiced interpreting data and making claims supported by evidence and reasoning, it's time for them to apply this process to their own investigations. Begin by introducing the Project Notebook worksheet titled "My Investigation: What's My Story?" Instruct them to complete this worksheet, emphasizing that they will use this work in their final project.



Activity 3 Decide Your Communication Strategy

Remind students that scientists communicate the significance of their studies by explaining why and how they matter. Traditionally, scientific findings are shared in peer-reviewed journals. These technical articles have specific requirements, and the target audience is fellow scientists. However, in today's world, scientists present their findings in additional ways, such as infographics, news articles, talks, podcasts, videos, and social media.

Hand out "The Many Ways to Share My Investigation" to each student. Each project type can effectively convey the story of an investigation, but the medium and the intended audience differ. Divide students into groups, and ask them to identify their intended audience, the language style (formal vs. informal), and possible visuals for each format. Invite students to record their ideas to refer to when they work on their final project.



Activity 4 Prepare a Draft Project

Consider having your students begin their final project with an outline, a storyboard, or sketches. Review these initial ideas and provide feedback. Afterwards, allocate time, whether in class or outside of it, for students to use their data and notes from their Project Notebook to prepare their first draft.



Activity 5 Introduce Peer Review

Remind students that after scientists write their articles, they don't immediately get them published. Instead, they share their work with other experts who review it and provide suggestions for improvement. This process is known as peer review. Peer review ensures that a scientific study's methods, data, results, and claims are evaluated by knowledgeable experts to confirm that the results are well-structured, logical, reproducible, reasonable, and ready to share. It ensures that the research and findings are high quality.

While peer reviewers offer suggestions for improvement, it's important that their critique is constructive. Lead a discussion on how the peer review process can be a positive one. Make a list on the board titled "What makes a good peer review?" and add adjectives and ideas suggested by the class (your list might include adjectives such as respectful, helpful, kind, thoughtful, specific, encouraging, creative, honest, clear, readable, reasonable, and useful). You may also want your students to begin their reviews with a positive, truthful comment, make suggestions for improvement, and ending with a different positive, truthful comment. Optionally, you can show the "Peer Review Tips" video found on the SAS resource site.



Activity 6 Conduct Peer Review

Invite students to peer review each other's project. Pass out the "Peer Review Checklist" from the Project Notebook and review it with the class. The peer review process may vary depending on the types of projects each student or group has created. For example, some groups may present their work to their reviewers, while others might quietly listen to a podcast through headphones. If possible, encourage them to write peer reviews for more than one project.

When the reviews are complete, let the reviewers give their "Peer Review Checklists" back to the scientist. Encourage students to thoughtfully consider the feedback they have received and incorporate all reasonable suggestions into the next draft of their project.



Activity 7 Complete and Share the Final Project

Invite students to revise their projects, incorporating any valuable suggestions provided by their peer reviewers. You can guide this revision process by asking them to:

1. describe how they have addressed the suggestions made by their peer reviewers; and
2. explain any review comments that they choose to reject, emphasizing that it's acceptable to do so as long as they can provide a reason for their decision.

Once their revisions are complete, students are ready to share their findings with a wider audience. Depending on the chosen format of their projects, have them present their investigations to the appropriate audience in a suitable setting.

Lesson 6 Assessment

- Review their "My Investigation: What's My Story" Project Notebook pages to check for understanding, reasoned claims and arguments, and the evidence used to support their claims prior to them completing the final project.
- The final project will be the assessment for this lesson.

CornellLab | K-12 Education

Students as Scientists



Nature-Based Inquiry

Resource Pages Grades 6-12

Students as Scientists: Nature-Based Inquiry

Resource Pages

Meet a Scientist Reports 1

Vultures: Sight or Smell? Article 13

Vultures: Sight or Smell? Comic 16

The Effect of Temperature on Chickadees 18

Variables in Your Science Investigation 20

Will a Fake Cat Scare Birds? 22

Amelia-Juliette Demery
Evolutionary Biologist
Ph.D. Cornell University

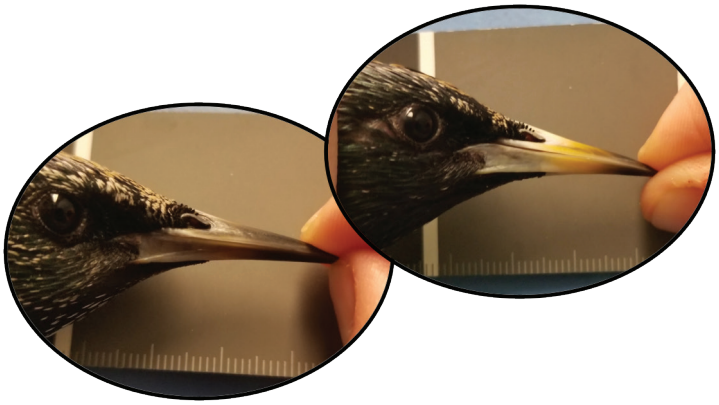


Amelia with a specimen from the Cornell University Museum of Vertebrates. Photo courtesy of Amelia-Juliette Demery.

When Amelia-Juliette Demery was young, she watched the Animal Planet TV show with the famous zookeeper and conservationist, Steve Irwin. She was so inspired by him that she decided she wanted to work outdoors and teach others about nature too.

As a scientist, Amelia is curious about why animals look the way they do, and how their looks change over time. Early in her career, she studied how fence lizards in urban and rural places look different. Now she studies birds and how their beaks have evolved. Beaks can communicate health, dominance, and even sex appeal.

Amelia studies the European Starling, a common bird found in the same environments as humans. While most bird beaks do not change color during their lifetime, European Starling beaks do. Their beaks are bright yellow during the breeding season and darken the rest of the year. To figure out how and why these changes occur, Amelia studies these birds in a lab so she can control the conditions in which they live. For example, in one experiment, she changed the amount of sunlight they received to see whether it affected beak color. Take a look at the photos (on the next page) from Amelia's experiment. How did the beak change during the experiment?



Left: European Starling's beak on day 0 of Amelia's experiment.
Right: European Starling's beak on day 63 of the experiment.
Photo credit: Amelia-Juliette Demery.

There are many things that could make bird beaks change color. Amelia studies sex hormones, environmental changes (such as sunlight and food), and neurobiology as their beak color changes. Amelia has discovered that beak color changes are not due to sex hormones, and she now wonders if genetic factors are causing the changes.

Beyond color changes, Amelia also studies how beak shape is evolving among distantly related birds, specifically birds in the tanager family. She found that more than half of the tanagers were evolving towards similar beak shapes. The problem is that these physical changes in beak shape have not kept up with the changes in the food available to tanagers. Climate change and other human influences have caused food availability to change rapidly, while beak evolution takes longer. This could lead to a mismatch between the physical ability of a bird to eat the food available to them. It is important to understand physical evolution in order to understand a bird's ability to adapt to climate change. Understanding evolution could help us protect these tanagers in the face of climate change.

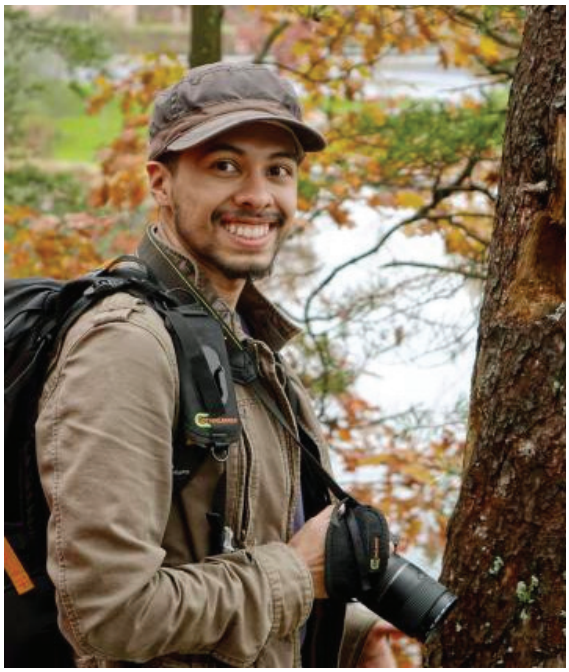
In addition to her scientific research, Amelia is passionate about making research safer and more inclusive for scientists from all backgrounds. She recently wrote a manual with her friend and fellow scientist, Monique Pipkin, to promote safe and inclusive fieldwork. Their manual is being used to improve conditions for women and minoritized scientists across the country.

To learn more about Amelia's work, explore:

- Cornell University Student Spotlight: Amelia-Juliette Demery.
  gradschool.cornell.edu/spotlights/student-spotlight-amelia-juliette-demery
- Women in STEM Series – Amelia-Juliette Demery, Ph.D. Student.
  www.birds.cornell.edu/k12/amelia/
- Distantly Related Tanagers Independently Evolve Similar Beaks.
  newscenter.sdsu.edu/sdsu_newscenter/news_story.aspx?sid=79101

Sebastian Alejandro Echeverri

Ecologist/Evolutionary Biologist
Ph.D. University of Pittsburg



Sebastian taking photos of wildlife.
Photo credit: Yusan Yang, AAAS.

When you hear the word conservation, you might not think of spiders. Sebastian Echeverri is trying to change that. He is a scientist, science communicator, and wildlife photographer who studies spider behavior. While many people are afraid of spiders, they are an important predator and play a key role in controlling insect populations. By helping people understand and appreciate spiders and their behaviors, he advocates for their conservation.

Sebastian was captivated by the "sick dance moves" that male jumping spiders use to attract mates. During his Ph.D. program, Sebastian studied how these colorful spiders get their audience's attention when performing their animated courtship dances. Jumping spiders can only see color with the eyes on the front of their heads; the eyes on the back of their heads can only see in black and white. But unexpectedly, the male jumping spider starts his courtship dance behind the female spider. Why? Sebastian discovered that these males wave their legs to grab her attention, and then she turns around to see him in all his glory!

Sebastian continues to study spiders and make new discoveries. Currently, he studies tarantulas. Even though all spiders have eight eyes, scientists have long believed that tarantulas don't use their vision much. Sebastian noticed that arboreal (tree-living) tarantulas have larger eyes than terrestrial (ground-living) species. Why? He's not sure but has discovered that this evolution in eyesight happened when some tarantula species moved from living on the ground to living in trees.

Like insects, spider populations are declining in total numbers and in species diversity around the globe. Maybe you won't have more than 20 pet spiders like Sebastian, but by understanding spiders, their cool behaviors, and the way they've evolved, we can make better decisions for saving them.

Sebastian is also passionate about using humor and entertainment to engage everyone in learning about nature. He is co-host of the weekly podcast *BBC Earth* where he invites you to listen, laugh, and learn about the natural world. He helped design the curriculum for *Crash Course: Zoology* that will take you on a rapid and deep dive into the wonderful world of animals. Plus, Sebastian has been a guest on the podcast *Ologies*, where he got to talk about those "sick dance moves" of the jumping spider. Sebastian proves that science isn't boring or lonely.





Sebastian conducting fieldwork. Photos courtesy of Sebastian Echeverri.

To learn more about Sebastian's work, explore:

- Scientist Sebastian Echeverri treats spiders with the dignity they deserve. www.aaas.org/membership/member-spotlight/scientist-sebastian-echeverri-treats-spiders-dignity-they-deserve
- Sebastian A. Echeverri, Ph.D. www.spiderdaynightlive.com
- Co-host on the *BBC Earth Podcast*. www.bbcearth.com/podcast
- Guest on *Ologies Podcast* about jumping spiders. www.alieward.com/ologies/dancingspiders
- Designing the curriculum for *Crash Course: Zoology* on YouTube. www.youtube.com/playlist?list=PL8dPuuaLjXtNRgJI4gHRLFtOD_r4hfJaF

Rhiannon Kirton
Wildlife Biologist
M.S. University of Western Ontario



Rhiannon outdoors.
Photo courtesy of Rhiannon Kirton.

Rhiannon grew up in Australia and England and loved all types of animals. When she was younger, she dreamed of being a veterinarian. Although she especially liked large carnivores (such as bears, tigers, and wolves), many of these animals are feared by most people. In high school, Rhiannon was determined to change the way people view wolves–they are often written about as bad or evil animals. She spent several days closely observing wolves at a local wildlife park to help understand and protect them.

In college, Rhiannon got to study many different animals. Her research allowed her to travel and study animals all over the world: Tasmanian devils, fruit bats, black-footed ferrets, grizzly bears, birds, antelope, prairie dogs, salmon, sturgeon, bats, frogs, and others!

Today, Rhiannon is researching how hunting impacts deer behavior. Hunting is an important part of deer management in North America, but little is known about its impacts on deer behavior. She uses the GPS positions of white-tailed deer to learn more about their habitat use and movement in response to predators, especially hunters. Studying how human activity changes deer behavior will help wildlife biologists make better population management decisions.

Outside of school and work, Rhiannon enjoys hiking, camping, fly fishing, hunting, exploring new places, and learning about the native people whose lands she spends time on. She also believes it is important to show and promote diversity in outdoor recreation spaces. She does this by being part of Black Birders Week and a representative for several outdoor recreation brands.



Rhiannon releasing a Tasmanian Devil (left) and collecting data on fish (right).
Photos courtesy of Rhiannon Kirton.

To learn more about Rhiannon's work, explore:

- Rhiannon Kirton.
  rhiannonkirton.com/
- Rhiannon Kirton: Zoologist.
  www.pbs.org/wnet/nature/blog/rhiannon-kirton/

Mei Lin Neo
Marine Ecologist
Ph.D. National University of Singapore



Mei Lin Neo collecting samples at the beach. Photo courtesy of Mei Lin Neo.

On a 45-minute boat ride to an uninhabited island off the coast of mainland Singapore, Mei Lin Neo saw her first giant clam in the wild. At the time, she was a student researching giant clams in the laboratory, but she found that seeing them in the wild was truly amazing! As the other survey volunteers asked her all about the giant clam, she discovered how much she enjoyed sharing her knowledge of science and marine life. Her excitement for the animal has earned her the nickname "Giant Clam Girl."

Mei Lin was introduced to marine science as an undergraduate student during a visit to the St. John's Island National Marine Laboratory. Meeting the marine scientists and seeing sealife up close sparked her interest in ocean life. She got involved in oceanic research as soon as possible and joined a research team before she even knew how to dive! Mei Lin believes in learning as you go… you shouldn't let obstacles get in the way of your dreams.

Whales, dolphins, and other charismatic ocean creatures often get the most attention. Mei Lin is hoping to get more people to see that all sea creatures are amazing. Today, Mei Lin works as marine ecologist and science communicator living in Singapore. She wants to get people excited about her research and the giant clams she loves. She does this by showing how vital giant clams are for the reefs. For example, clams in the coral reef make up an important building block for the reef, adding shape to the seabed and serving as a nursery for many animals. Clams also serve as a food source and shelter for other sea animals. They filter the water around the reef.

Giant clams are an endangered species and Mei Lin wants to save them. She has worked to breed and raise young clams that will eventually be placed into reefs in the wild. Her current research focuses on improving restocking techniques for endangered marine species including cowrie snails and sea urchins. Because many people don't get a chance to peer into the murky ocean waters, Mei Lin is passionate about "bringing the seas closer to people."

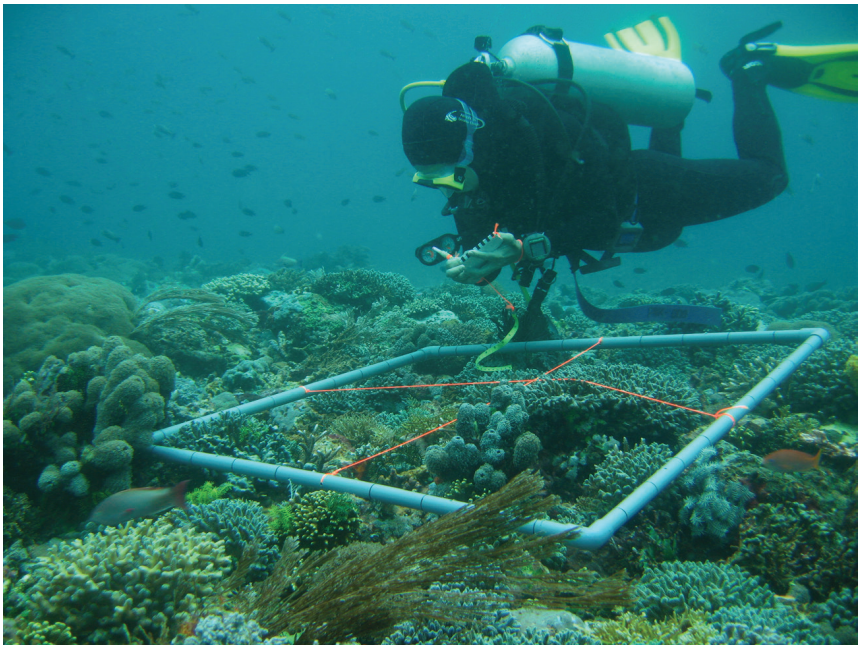


Mei Lin is holding a giant clam currently housed at the St. John's Island National Marine Laboratory.
Photo credit: Denise McIntyre.

To learn more about Mei Lin's work, explore:

- Mei Lin Neo.
  meilin5giantclam.wordpress.com/about-me/
- Asia's rising scientists: Neo Mei Lin.
  www.asianscientist.com/2016/06/features/asias-rising-scientists-neo-mei-lin-nus-giant-clams/

Tries Blandine Razak
Coral Reef Ecologist
Ph.D. University of Queensland



Tries collecting data on a coral reef site.
Photo credit: Sangeeta Mangubhai.

Tries (pronounced Tree-Yes) Blandine Razak is a marine biologist in Indonesia—a country made up entirely of islands in Southeast Asia. Growing up in a land-locked city, Tries only learned to swim at age 17 when she decided to study marine biology. She fell in love with coral reefs while swimming alongside sea turtles and vowed to dedicate her life to reef conservation. Now, Tries works to understand how coral reefs in Indonesia can be restored and protected.

Coral reefs are an important habitat for many fish and other sea creatures. Human activities, such as agriculture and fishing, can pollute waters and damage coral reef ecosystems. For example, blast fishing is a destructive practice that uses explosives to stun or kill schools of fish so they can be easily collected. This often destroys the surrounding habitat, including coral reefs that are so important for fish and other sea life.

Restoring coral reefs isn't easy. Corals must overcome many odds to survive. They start as tiny and highly sensitive larvae that can get swept away in the ocean before finding a place to grow. Larvae must find a substrate–or a material they can attach to—so they can grow. Even if larvae are able to find a good substrate, that location might not meet the other conditions it needs to survive. Plus, different coral species may need different environmental conditions.

Tries dives to various coral reef sites to measure conditions such as the water temperature, current, and clarity of the water. These conditions determine whether each coral species thrives or dies. Warmer ocean temperatures caused by climate change slow down the growth of the corals. Tries also uses satellite images and other technology to map out where coral reefs have been destroyed. In these destroyed ecosystems, she is studying how to stabilize the rubble and recreate better conditions for new coral.

Saving coral reefs is difficult and expensive, but numerous individuals and organizations worldwide are engaged in reef restoration efforts. Tries contributes to these efforts by assessing various reef restoration projects in Indonesia and understanding what makes a successful restoration program. Her love of the ocean, along with her scientific training and knowledge, allows her to be part of this amazing conservation effort.



Tries (second from the right) and her team out at sea.
Photo courtesy of Tries Blandine Razak.

To learn more about Tries' work, explore:

- Indonesia leads the way in restoring coral reefs, scientists say.
  www.aljazeera.com/news/2021/11/2/indonesia-leads-the-way-in-coral-restoration
- Tries Blandine Razak, Ph. D.
  www.pewtrusts.org/en/projects/marine-fellows/fellows-directory/2021/tries-blandine-razak

Peter Soroye
Conservation Biologist
Ph.D. University of Ottawa



Peter enjoys photographing the natural world. Photo courtesy of Peter Soroye.

Peter Soroye is a conservation scientist focused on saving bumblebees. He grew up surrounded by nature in Ontario, Canada. But it was a summer of studying butterflies as a research assistant that sparked his love for pollinators. Butterflies and other insects are small but play an important role in plant reproduction because they spread pollen, fertilizing plants along the way. Cute, buzzy, and fuzzy, bumblebees caught Peter's attention and he focuses his research on preserving them.

During the last 50 years, bumblebee populations have drastically decreased. Studies suggest that climate change is a key reason for the decline. As temperature and weather patterns change, plants and animals struggle to survive in their habitats. As a result, living things may go extinct or shift their range to areas where resources or conditions are better.

Peter and his research team investigate how bumblebee populations are affected by temperature. The team compared where 66 bumblebee species live now and where they lived 100 years ago. They found that bumblebees left areas that became hotter. Both the number of species in an area and the number of individual bees decreased as places grew warmer. Researchers believe the bumblebees either died or were forced to move elsewhere. Peter used this information to develop a computer model that predicts the changes in bumblebee populations.

Identifying at-risk populations is important for the survival of the species. Peter's research helps us better understand the impacts of climate change on bumblebees and what we can do to help. He suggests that you can help bumblebees by planting trees and shrubs that create cooler areas that protect bumblebees from the heat. You can also plant native, flowering plants to feed pollinators.



Peter with a tray of bumblebees. Photo credit: The University of Ottawa.

To learn more about Peter's work, explore:

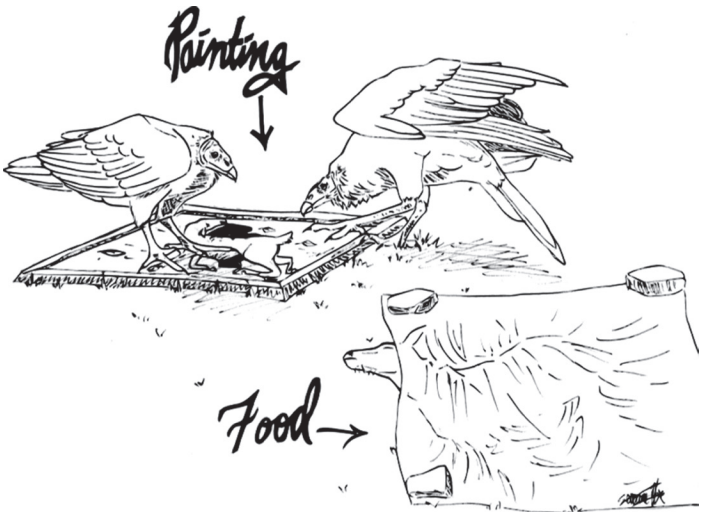
- Peter Soroye.
  www.petersoroye.com
- Taking the sting out of bumblebee extinction.
  www.youtube.com/watch?v=LdVbeKe9SjE
- Five black conservationists making change in the world.
  thestarfish.ca/journal/2020/08/five-black-conservationists-making-change-in-the-world

Vultures: SIGHT 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 answers to these questions were discovered through a series of experiments conducted not only by scientists but also naturalists and ordinary people!

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 birder named John James Audubon wondered if that were true. He noticed that he could get very close to 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 stuffed a deerskin with straw and placed it in an empty field and watched for vultures. Vultures attacked the "carcass" almost immediately and seemed puzzled by the lack of food. He repeated this experiment many times. Audubon next placed rotting meat under some brush, making it invisible from the sky but easy to smell. No vultures ever came to this deliciously stinky food. He concluded that vultures must SEE rather than SMELL their way to food (Waddell, 2011; Stager, 1964).



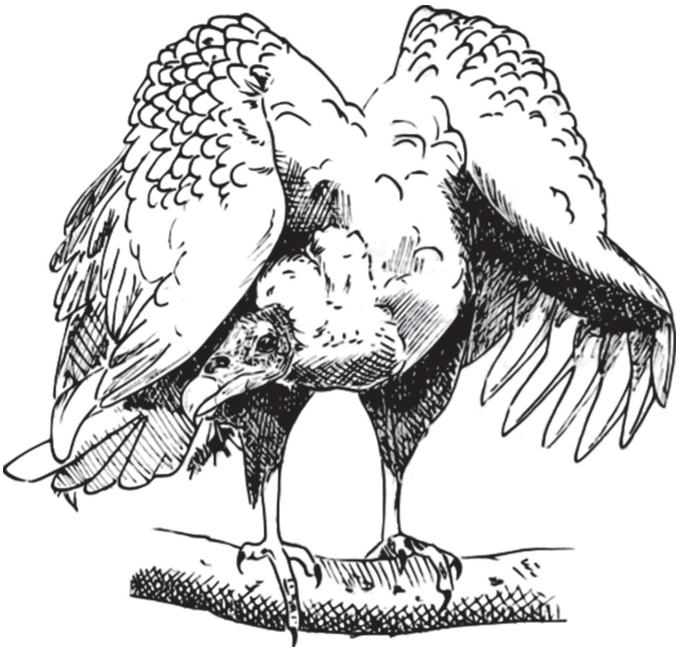
Severine Hex

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

Audubon's claims were met with much criticism. In 1833, Reverend John Bachman, an American naturalist and friend of Audubon's, decided to repeat Audubon's experiments, hoping to silence the critics. Bachman also placed dead animals and meat scraps from a butcher under brush to see if vultures would find it. None did. He then put a painting of a dead sheep out in the open. The vultures found it almost immediately. He repeated this experiment 50 times with the same results. Finally, Bachman placed the painting out in the open within 10 feet of the previously placed animals and scraps. The vultures investigated the painting but left without finding the real meal. Through this series of experiments, Bachman believed he had validated Audubon's experiments: vultures rely on sight rather than smell when finding food (Waddell, 2011).

In the 1960s, Kenneth E. Stager, an ornithologist, raised concerns about how Audubon and Bachman's experiments were conducted and the conclusions they made. Stager also found that other scientists had made claims about vultures that were not supported by evidence and had made unverified assumptions. Stager decided it was time to complete more rigorous testing (Stager, 1964).

Stager put meat in cage traps and hid them, ensuring they were not visible from above or from any other vantage point. Turkey Vultures were caught in these traps. He placed a taxidermied mule deer out in the open; Turkey Vultures circled and saw it but never landed. Then he replaced the decoy with a real carcass and Turkey Vultures rapidly appeared and began landing and feeding once they also smelled it (Stager, 1964).



Severine Hex

Another interesting experiment conducted by Stager involved emitting ethyl mercaptan gas into the air. This idea was given to him by a gas company engineer who, as early as the 1930s, introduced pungent ethyl mercaptan into odorless natural gas pipelines to locate leaks. The ethyl mercaptan drew Turkey Vultures to the exact locations of such leaks and thus the leaks could be located. So Stager also released ethyl mercaptan into the air and, as expected, Turkey Vultures came flocking, soaring in circles overhead and homing in on the source but rarely landing. It turns out that ethyl mercaptan is emitted from decomposing animals, suggesting that the Turkey Vultures were responding to the smell of decay. Through these multiple experiments, Stager concluded that Turkey Vultures use their sense of smell to find their food, and then rely on both smell and sight to find the source of the scent (Stager, 1964).

So, where did Audubon and Bachman go wrong? It is thought that Audubon and Bachman were mostly attracting Black Vultures rather than Turkey Vultures with their experiments, especially based on their descriptions of the aggressive behavior of the vultures. It is now known that Black Vultures are more aggressive than Turkey Vultures. We also now know that of North American vultures, only Turkey Vultures have a strong sense of smell. Black Vultures will follow Turkey Vultures to find food, but do not use smell to locate it. Audubon seems to have mistakenly assumed that all vultures act alike. He also assumed all vultures prefer rotten meat and that the more rotten the better. But a 1986 experiment by David Houston showed that Turkey Vultures prefer fresher carcasses (Kirk and Mossman, 2020). Also, 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. Vultures must start eating a carcass through an orifice or soft spot, or wait until another animal has opened it up, or until the animal has decayed enough so that the vulture's beak or talons can break through the skin (Kirk and Mossman, 2020).

Though the debate about Turkey Vultures and Black Vultures and their sense of smell is settled, discoveries about the sense of smell in other birds continue. In the past, the role of smell in birds had mostly been dismissed because their olfactory bulbs and nares (nostrils) are often not well developed. But thanks to curious scientists, we are learning that despite these small sensors, some birds do use their sense of smell. Dr. Bernice Wenzel, Dr. Gabrielle Nevitt, and Dr. Danielle

Whittaker are some of the scientists who have studied how other birds make use of their sense of smell. They have studied everything from how seabirds use their sense of smell to find food (Dr. Nevitt), to the role of scent used in mate choice by Dark-eyed Juncos (Dr. Whittaker), and to the electrical response that occurs when more than 100 different species of birds get a whiff of something (Dr. Wenzel) (Averett, 2014). And so the science process continues with new questions being asked and new discoveries being made all the time.

Sources:

Averett, N. (2014). *Birds can smell, and one scientist is leading the charge to prove it.* Audubon. Retrieved February 4, 2022, from www.audubon.org/magazine/january-february-2014/birds-can-smell-and-one-scientist

Do vultures find dead animals by smell or by tracking predators or scavengers on the ground? (No date). All About Birds. Retrieved February 4, 2022, from www.allaboutbirds.org/news/do-vultures-find-dead-animals-by-smell-or-by-tracking-predators-or-scavengers-on-the-ground/

Turkey Vulture: Life history. (No date). All About Birds. Retrieved February 4, 2022, from www.allaboutbirds.org/guide/Turkey_Vulture/lifehistory#food

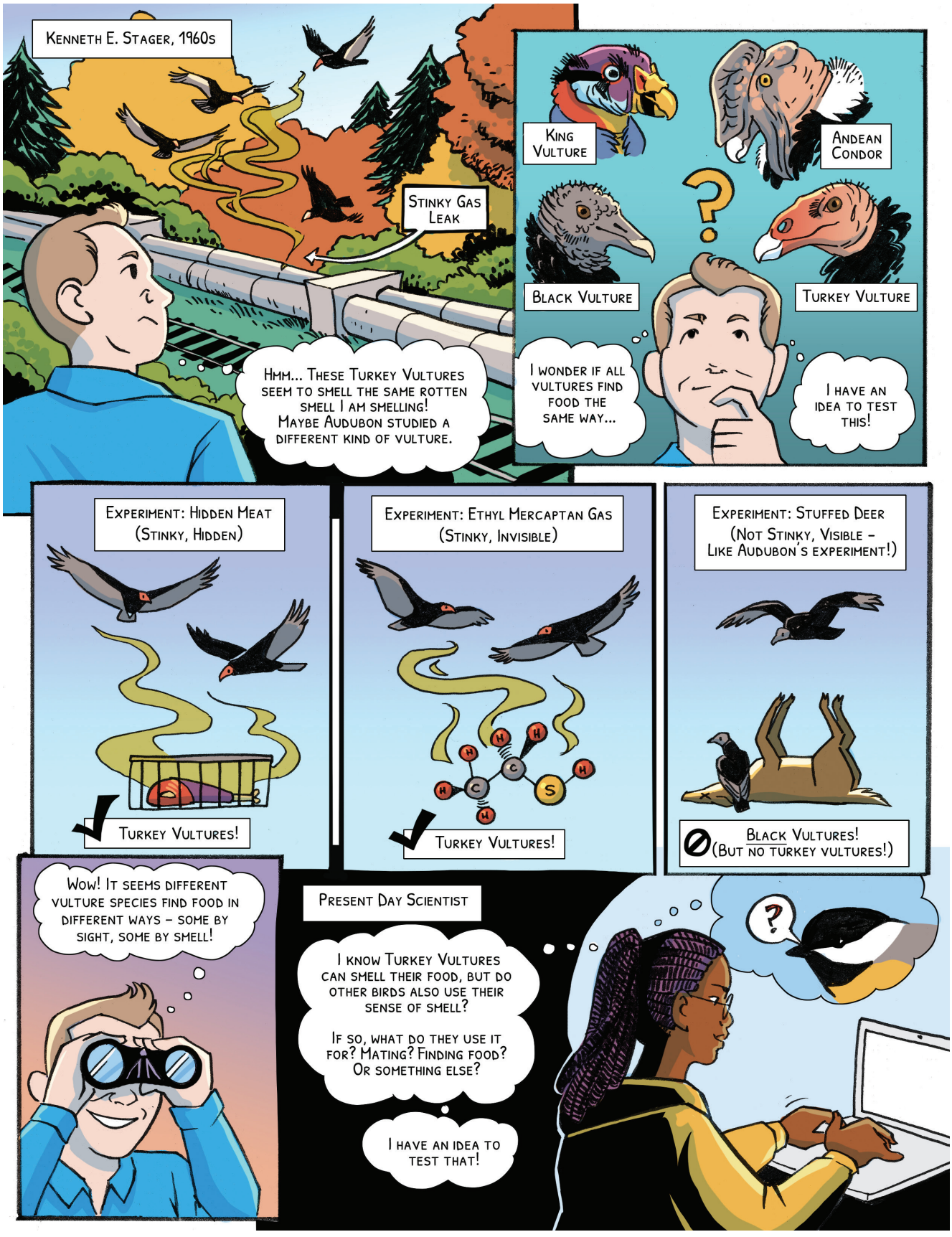
Kirk, D. A. and M. J. Mossman (2020). *Turkey Vulture (Cathartes aura), version 1.0.* In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. doi.org/10.2173/bow.turvul.01

Stager, K. E. (1964). *The role of olfaction in food location by the Turkey Vulture* (*Cathartes aura*). Contributions in Science, No. 81, June 30, 1964.

Waddell, G. (Ed.). (2011). *John Bachman: Selected writings on science, race, and religion.* University of Georgia Press.



Comic illustrated by Virginia Greene



Comic illustrated by Virginia Greene

The Effects of Temperature on Chickadees

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

Introduction

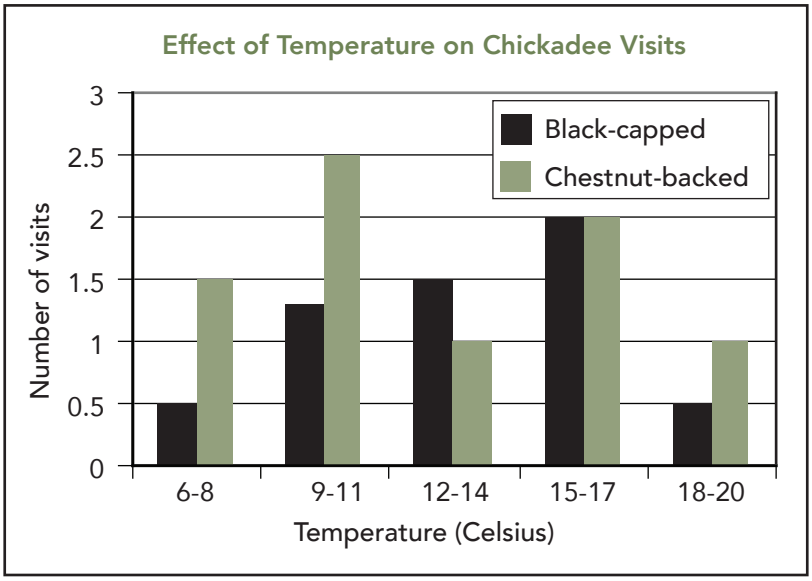
I decided to study Black-capped Chickadees and Chestnut-backed Chickadees observed at our feeding station. Both birds are found in mature forests near streams, which makes Downy Creek (near my school) the perfect haven for these active birds. I wanted to know if the temperature affected the number of 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

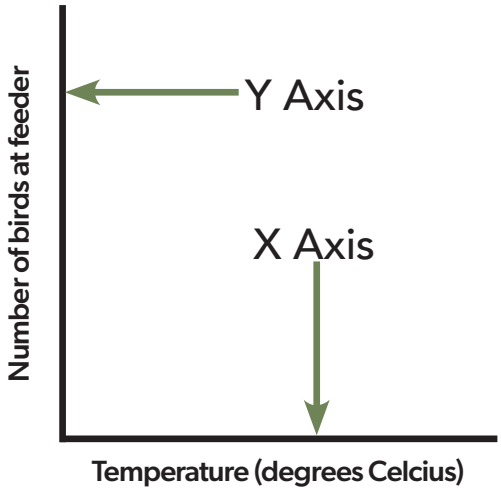
Variables in Your Science Investigation

If you want to do an investigation, 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 5 Turkey Vultures one day, 12 the next day, and 1 on the third day. The number of Turkey Vultures is a variable.

When you do an investigation, always consider these three types of variables: independent variable, dependent variable, and control variables.

Independent Variable

- The investigator (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.

Control Variables

- These are all the variables that you keep the same 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 control variables.

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.)

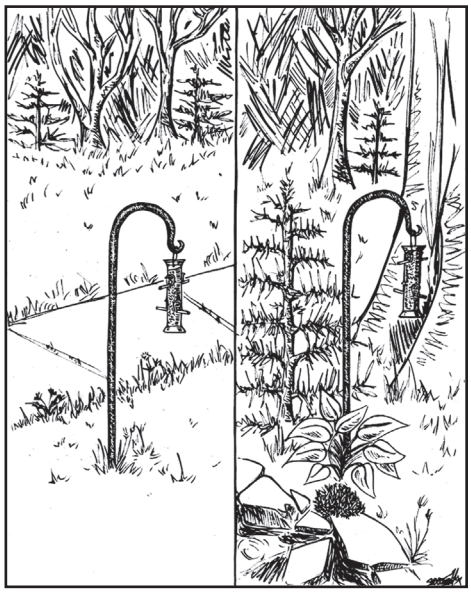


Figure 1. Allison put one feeder in the open, and the other in an area with cover.

Dependent Variable: Total Number of Bird Visits

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

Control Variables:

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 such as the time of day, temperature, and wind speed were all the same)

These things were controlled, or kept the same, 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 such as the type of feeder or the kind of seed.

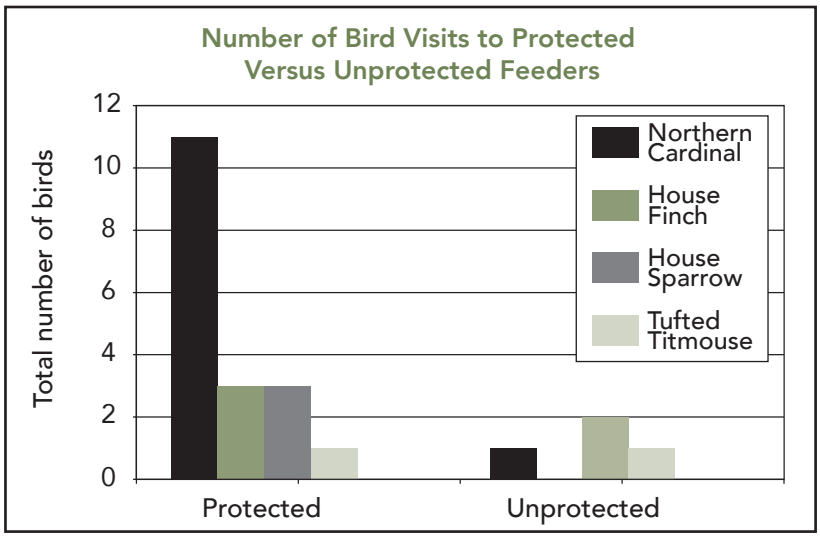


Figure 2. Number of bird visits to protected versus unprotected feeders.
By Allison, 7th Grade, Bloomsburg Middle School
Bloomsburg, PA, Mr. Prosseda

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.)

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



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.

Introduction

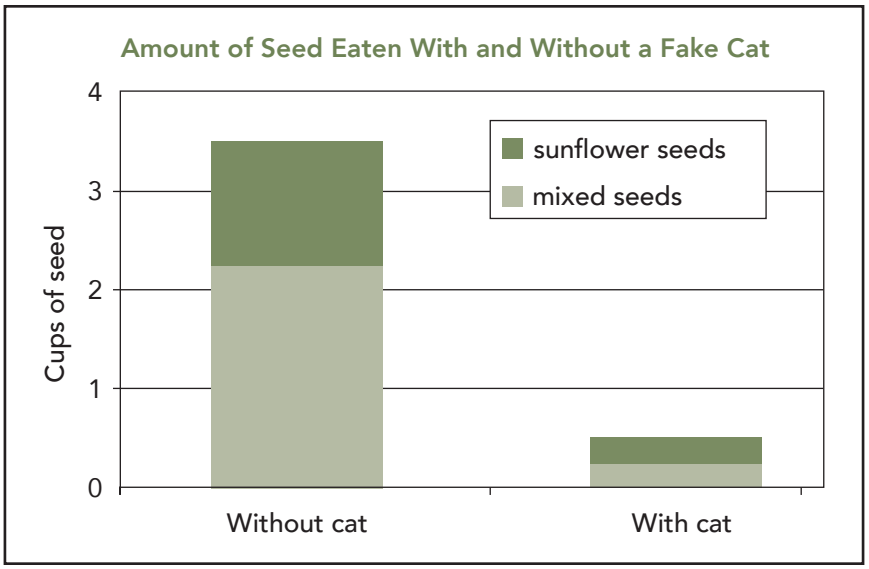
I noticed that cats in my yard had been scaring the birds away. I wondered if the birds could differentiate a fake cat from a real one. I decided to find out: does a fake cat scare birds? I measured the amount of seed the birds ate one week and compared it to how much they ate during the next week when 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.

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 was not a "dangerous" animal around. When I did not have the cat "guarding" the bird feeders, the birds ate all 2¼ cups of mixed seeds and 1¼ cups of sunflower seeds (a total of 3½ cups of seed was eaten). During the week with the stuffed cat, only ¼ cup out of the 2¼ cups of seeds was 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?



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