Journey North

A Global Study of Wildlife Migration and Seasonal Change

Hummingbirds
Observe, Describe, Wonder


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Teacher Guide
Building Inquiry into Instruction

Inquiry Strategies
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Introduction

Build Inquiry into Instruction
Use the ideas in this guide to cultivate a classroom of young inquirers. Select those that fit with your learning goals and student readiness. Classroom procedures that support inquiry engage students in thinking and acting like scientists as they pursue meaningful questions, a core goal of the National Science Education Standards. When students explore their world as a scientist, they come to understand concepts and hone reasoning skills.

What are Inquiry Strategies?
Scientific inquiry refers to the many ways in which scientists try to understand the world and explain how things work. It includes the processes they use - observing, testing hypotheses, gathering data - and the attitudes and values - curiosity, respect for evidence, and openness to new ideas - that characterize their work.

When to Use Inquiry Strategies
Use the strategies featured here when your class is engaged in:

- observing nature and images/videos of nature
- generating questions
- forming hypotheses
- collecting, analyzing, and interpreting data
- designing and reflecting on their own and classmates' investigations

Creating a Climate for Inquiry

Overview

In an inquiry-oriented classroom, the teacher is a co-explorer and guide who cultivates curiosity and challenges students to think and act like scientists as they explore intriguing questions. It is a place where diverse ideas are valued and students feel safe taking risks to "think out loud" as they share, debate, and justify emerging ideas. Students have time and opportunities to explore, experiment, test and refine ideas as they collaboratively build understanding. But it takes time, practice, and sometimes, a shift in teaching strategies, to create a classroom where inquiry can flourish.

1. Shifting Control: Students as Decision Makers

When students are able to influence the direction of their learning and their opinions and ideas are valued, motivation, reasoning skills, and confidence flourish. Some activities in Journey North prescribe questions, procedures, and data for students to interpret; others challenge students to ask their own questions and design investigations to try to answer them. This reflects the continuum of classroom-based inquiry. Most Journey North classroom science explorations fall somewhere in between.

By gradually shifting to a more student-directed approach, you can develop comfort transferring decision making to students and they can see the inquiry process modeled and build their skills. Here are some examples of how this might work through the year in a Journey North classroom:

- Give students increasing responsibility for deciding how to approach challenge questions.

- Give students increasing responsibility for deciding how to gather, organize, and make sense make sense of migration data.

- After students follow the set protocol for the tulip study, invite small groups to design and conduct their own tulip experiments.

As students grapple with ideas and data, routinely ask yourself, Is it more productive at this point to let students struggle with this piece of the puzzle or to introduce a new piece of information (e.g., a scientist's explanation) or change the direction of the discussion?

2. Creating a Culture of Collaboration

Mirror what scientists do by nurturing a classroom of co-explorers and learners (yourself included) who, in the search for understanding, pursue questions, wrestle with data, respect diverse ideas, and exchange theories. Here are some tips for cultivating collaborators.

- When practical, have students work in small groups to gather, track, and make sense of migration data or to investigate questions and hypotheses.

- Involve cooperative groups in setting goals and expectations for their collaborative process and outcomes.

- Create opportunities for groups to routinely share, review, question, and comment on one another's data, explanations, or investigation designs. Require all group members to participate.

- Acknowledge that you don't know all the answers, When you do so, you empower students to work together to tackle challenges.

3. Modeling The Spirit of Science Inquiry

Help students grasp what makes scientists tick by modeling the spirit of curiosity, questioning, self-reflection, flexibility, openness to new ideas and theories, and respect for evidence, that characterize science inquiry. Recognize and offer praise when you notice students exhibiting these scientific values.

4. Asking Open-Ended Questions

To ignite discussions, show respect for students' thinking, and support active reasoning, try to ask questions that encourage observation and reflection and that help them explore, explain, support, and evaluate ideas. Minimize factual questions that have just one right answer or those that require yes or no response. When you accept students' responses as valid, and probe for clarification, elaboration, and evidence, you send the message that it's okay to take risks and that "rough-draft" thinking is vital to the science process. See Open-Ended Questions That Inspire Scientific Thinking.

5. Factoring in Flexibility

Like scientists, kids need time to try ideas, make mistakes, and ponder and discuss data. When practical, try to leave "wiggle room" and be willing to diverge from your plans and schedule to enable students to pursue intriguing questions when they are tracking migrations or exploring local phenomena.

Supporting Productive Discussions

Overview

Discussing ideas, data, "ahas," and possible explanations is vital to inquiry-based learning and it reflects the way scientists work. Full- and small-group discussions build community and allow students to explore ideas, clarify their thinking, consider different theories, challenge one another's views, and defend their assertions. As they do so, they begin to build coherent, shared understandings about data and concepts.

1. Open-Ended Questions That Inspire Scientific Thinking

What patterns did you notice?

Why do you think that ____?

What else might have caused _____?

Why do you suppose _____?

What did you expect to find and why?

How was it different than ____?

What do you think could be an alternative explanation?

What evidence do you have?

What were your assumptions?

How will you know if ____?

Have you considered ____?

Do you think you could ____?

How did you decide _____?

What reasons did you have _____?

2. General Strategies for Facilitating Discussions

To ignite classroom discussions and support active thinking and reasoning, use these strategies:

- Ask open-ended questions that encourage observation, reflection, evaluation, and new questions.

- Minimize factual questions that have just one right answer or those that require yes or no response.

- Pause for a minimum of 3 seconds after you ask a question or after a student responds to a question. (Research has shown that this "wait time" improves the quantity and quality of student responses and increases participation by slow learners.)

- Accept student responses and arguments at face value even if they are incorrect. Follow up by probing for elaboration, clarification, and evidence to support their statements. Have students respond to and challenge one another's ideas. If appropriate, encourage your young scientists to further observe, review data, or research to test their ideas. At times, you will want to correct students' misconceptions by sharing current scientific thinking.

- Encourage students to question one another (following your modeling) by asking probing, open-ended questions. Eventually, enable small groups to have discussions without your input. (Researchers have found that this to be an ideal situation for building understanding.)

- Keep a running class chart of "productive" questions students can reference as they participate in discussions, review classmates' investigations, or question scientists.

Asking, "How Do We Know What We Know?"

Overview

The overarching question, How do we know what we know? is vital to being a critical thinker, citizen, and scientist. It is a particularly important "lens" to use today when we are awash in information from a virtually unlimited variety of sources. Scientists rely on evidence (data from their own and others' observations and investigations) to construct explanations and answer their questions. A good scientist respects evidence and is willing to change his or her ideas, predictions, theories, and explanations if new information is inconsistent or contradictory.

1. Questions That Help Students Consider Evidence

- How do you know ___?
- What did you observe?
- What patterns or relationships did you notice in the data?
- How does it support your explanation/conclusion?
- What can you infer from the data?
- What generalizations can you make?
- What evidence led to your explanation?
- How can you justify your conclusion?
- How did the scientist use previous knowledge or experiences to support his/her conclusion?
- What evidence did the scientist use to support his/her explanation?

2. KWL Chart: How Do You Know?

If your students have created KWL charts, have them review the What We Know column. For each item, ask, the following types of questions:

- How do we know this? (They might respond that they heard it from someone else, read it in a book or on the Internet, saw it on TV, observed it, or "just knew it!")

- Which sources give you the most confidence that the information is accurate?

- How can you verify what you think you know?

- Which do you think is more accurate (reliable): information you get from _____ (a specific outside source) or information you get when you observe something firsthand, review authentic data, or conduct an experiment?

3. Identifying Sources of Evidence

As students try to develop hypotheses or explanations, or draw conclusions, ask them to categorize the different types or sources of information that help them make their judgments. Use these categories (when they apply):

- What did we observe?

- What did the data "tell" us?

- What did we already know from experience?

- What information did we find through research?

Ask the class to note and discuss the contributions that different information sources make to their emerging hypotheses (or to those of scientists).

Generating Questions: The Heart of Inquiry

Overview
1. Cultivating Keen Observers
2. Categorizing Student Questions
3. Making and Refining Predictions

Overview
Scientific investigations typically begin with observations of something intriguing or baffling, which in turn, inspire questions. When you engage your young scientists in observing the natural world first hand or via video clips and photos - or have them read about scientists' observations - curiosity and questions can flourish. With guidance, these questions can lead to fruitful thinking, discussions, and investigations.

1. Cultivating Keen Observers
When you help students hone observation skills, they'll develop a greater depth and breadth of descriptions, new questions, and more useful data. The more time you give them, the more detailed their observations will be. As students observe something firsthand or view a video clip or photo, work progressively through the following question categories to inspire "deeper" levels of observation. What new "wonderings" do the observations spark? (Students can create a What I Observe/What I Wonder chart in their journals.)

Questions About Details

- What do you notice?
- How would you describe what you see/hear?
- What more do you notice when you shift your perspective? First have students take a "macro" view of the whole scene. Then have them move closer or otherwise shift focus so they have a closeup view of a small area.
- What new information can you uncover? If practical, have students "observe" with a variety of senses or give them tools, such as hand lenses, thermometers, or a microscope to extend their senses.

Comparison Questions

- How is it the same as? Different than?
- What does it remind you of? What changes do you notice?

Counting/Measuring Questions

- How many? How long? How often?

Prediction Questions

- What do you think (predict) will happen next? Why?
- What do you think would happen if?

Reasoning Questions

- What do you think is happening and why?
- How could you explain?
- What is your hypothesis?
- How might someone else explain or interpret this same scene/phenomenon?

2. Categorizing Student Questions

Students' questions flourish when they make firsthand or video clip observations, read about scientists' research, review data, or complete KWL charts. (You might inspire younger students by asking them to write down questions they wish they could ask the animals they're tracking!) Armed with a host of questions about a particular topic or phenomena, the class or small groups should consider how they could go about finding answers to each one. Begin by reviewing the list and marking the questions as follows: (Select from or adapt this list for your grade level.)

- Put a star (*) next to questions they can answer through firsthand observations (e.g., What do robins eat?).

- Put a D next to questions they can answer by looking at measurable data (Do male eagles travel faster than female eagles?).

- Put a plus (+) next to those they can answer by conducting an experiment (Will tulips in compost come up earlier than tulips in regular soil?).

- Put a R next to those can answer by reading information from books or articles (How many times do a hummingbird's wings beat per minute?).

- Put an S next to those they think Journey North scientists could best answer (How do whooping cranes decide who leads the pack?).

- Put an X next to questions that are speculative (Why don't more people care about protecting habitat for migrating birds?). These can't be readily answered by any of the above, but students might suggest alternative means such as conducting surveys or setting up a role-play exercise.

Consider grouping students with an interest in similar questions. Challenge each group to come up with a proposal describing how they would go about answering questions and present their plans to peers for review. If time allows, have groups carry out the research.

3. Making and Refining Predictions

When will the first Monarchs arrive in Mexico? When will the ice go out of the lake? When will spring arrive in Hoboken? Will the eagles follow the same routes they did last year?

As students track migrations and ponder the arrival of spring or fall, they are routinely asked (and eager!) to make and refine predictions (suggestions about what will happen in the future.)

Predictions are more than just guesses; they are based on past knowledge and experiences and on current observations.
As students make and record predictions about events in Journey North, ask them to explain the thinking behind them. Students are, by nature, driven by wanting to "be right." Help them understand that scientific predictions are tentative and that they should be reviewed and revised as researchers gain new information (evidence).

Pose these types of questions, as appropriate:

Initial Predictions

- What do you predict will happen when ____?
- When do you predict ____?
- What reasons do you have for making that prediction?
- What do you already know or what have you observed that led to your prediction?
- What other predictions might be plausible?

During the Study

- Has your prediction changed? How? How does it compare with your original one?
- What new information or observation caused you to revise it?
- What additional information would give you more confidence in your prediction?

Reflecting on a Study

- How did the outcome compare with your original prediction?
- Did your predictions stay the same over time? Did your forecasting become more accurate? Less accurate? What do you think made the difference?
- Why do you think the outcome was the same as/different than you predicted?
- What types of information would have helped you more accurately predict?

Exploring What Scientists Do

Overview

Throughout Journey North, students think and act like scientists and they have the opportunity to "look over the shoulders" of scientists in the field. To help them better grasp the nature of science inquiry and the scientific "world view," find opportunities to explicitly focus their attention on how scientists work and think.

1. A Scientist Is . . .

Invite students to focus on the nature of science by generating a list of qualities, actions, and attitudes of scientists. Begin with the stem: A scientist . . . (e.g., is curious, carefully observes). When appropriate, ask students to describe what each item "looks like" in action. For instance, if students mention that a scientist is a good observer, ask, What does a good observer do? (e.g., notices details, carefully draws what he or she sees); include their responses under that item.
Keep the chart visible in the classroom for reference. On a regular basis, revisit and add to the list as students interact with Journey North scientists and their research. The list below highlights some of the overarching scientific values/world views to keep in mind and share with students.

2. Thinking Like Scientists

- Scientists are curious. They ask questions about the world and use their own and others' knowledge and experiences as starting points for investigations.

- Scientists are collaborative. They share their ideas, research designs, conclusions, and explanations with others, and they work together to refine them.

- Scientists systematically investigate their questions. They do this by observing over time, looking at measurable data, or setting up experiments.

- Scientists carefully and accurately communicate details of investigations in a variety of ways.

- Scientists are "healthy skeptics." They continually question their own and others' assumptions, data, investigation designs, and results.

- Scientists base their explanations on evidence (and employ a bit of imagination, too!). They value honesty in collecting, analyzing, and presenting data.

- Scientists are objective. They rely on precise observations and carefully gathered data. They cautiously avoid letting "subjective" feelings or opinions affect their conclusions.

- Scientists realize that science is dynamic and tentative. They are open to new ideas and willing to revise or discard their explanations and theories when new reliable information is revealed.

3. Tuning in to Scientists

As students read about scientists' studies, watch them in action on video clips, and interact with them online, help them think about the processes and values that characterize science inquiry.

Here's how:

- Model the kinds of questions listed below.

- Consider selecting some questions to include on an age-appropriate response sheet to go along with a reading or image.

- When students read a story or watch scientists in action, stop at certain points to ask what next steps the scientists (or the students) might take, or to explore some of the questions you selected.

4. Questions That Help Students Tune in to Scientists

- What did the scientists wonder? What are their main research questions?

- What had they observed and/or what did they know that shaped their research questions and hypotheses?

- What steps did they take to answer their questions? (Or, How would you go about answering the questions?)

- If they set up an experiment, how did they keep it "fair" (test only one variable)? What variables did they consider?

- What kinds of data did they gather? How did they decide what was useful? How did they deal with unexpected/unusual findings?

- Did they find any interesting patterns or relationships in the data? What were they? Any surprises?

- Did they have to revise or abandon their question, setup, or hypothesis at any point? Why?

- Do you think their explanation was plausible? Why or why not?
- What other factors (besides the ones they were exploring or controlling) might have affected their findings?

- Did information they gathered help answer the original research questions? Why or why not? What new questions did it raise?

- If their hypothesis wasn't supported by their research, what did they learn? What new questions/possible explanations did they pose?

- What do you think they should do differently if they were to repeat this study?

- What are the implications of their findings? Who might be interested in them?

Planning Science Investigations

Overview

1. Questions to Help Students Plan Investigations
2. Framing "Testable" Questions
3. Homing in on Hypotheses

Overview

Scientists design investigations to answer their questions and test hypotheses. These range from systematic observations to full-blown experiments, depending on the questions they're trying to answer. In Journey North, students have opportunities to learn about professional scientists' investigations and to contribute and try to make sense of data. In some cases, students set up experiments to answer their own questions.

Help students consider how they (or scientists) should investigate a question, rather than having them memorize a formula. The science process, after all, is not linear and tidy as the lockstep "scientific method" might imply. Rather, questions, hypotheses, and explanations are constantly being created and revised as new information is uncovered.

1. Questions to Help Students Plan Investigations

You can employ the following types of questions when students are setting up their own investigations (e.g., tulip experiments), describing how they or other scientists might set up a study to answer a question, or reflecting on scientists' experiments. Change the wording (see first example) to fit the situation in which you're employing these.

- What are you trying to find out? (What were the scientists trying to find out?)
- What do you already know or think you know?
- What's the best way to answer question?
- What kind of data (e.g., observations or measurements) will you collect?
- What variables/factors need to be considered? (If appropriate, How can you make it a fair test?)

- What would you look for?
- What evidence would support your hypothesis/explanation?
- How might you organize and communicate your data and results?

2. Framing "Testable Questions"

Many of the questions asked by student and professional scientists lend themselves to systematic investigations. But questions often need to be reworded so they can actually be tested. Here are some strategies for shaping questions at different grade levels:

In the early primary grades, you can help shape students' "wonderings" so they can "try out" an idea (e.g., Can we grow bulbs in water?)

As students mature, you'll need to help them refine their questions so they are clear and able to be investigated with available resources. A simple way to help students write testable questions is to use the stem, What would happen if....?

In fourth or fifth grade and beyond, you can help students refine questions so they lead to "fair tests." (investigations in which everything is kept constant except one variable). These types of questions should imply what you'll need to do to answer them or what comparisons or measurements will be made, for instance, Will tulips sprout earlier if we grow them in soil with compost or in regular soil?

A Fair Test Is . . .

To make sure an investigation is a fair test, you need to keep everything constant except the variable you're testing. Take the question, Will tulips sprout earlier if we grow them in compost or in regular soil? Students might plant one tulip in each of six pots. Three pots will contain compost and three will contain regular soil. Students must try to keep all other variables - sunlight, moisture, type of bulb, planting depth, and so on - constant. If they didn't - and planted some bulbs deeper than others, for instance - they couldn't be sure whether it was the soil type or bulb depth that made the difference.

3. Homing in on Hypotheses

Hypotheses are tentative explanations that scientists make after observing objects or events. They are based on their observations, current scientific understanding, and previous knowledge or experiences, and they typically lead to investigations. Use these approaches to help students connect to this important aspect of science inquiry.

Focus on Scientists

When students read about student or professional scientists, or view their video clips, have them ponder and respond to these types of questions:

- What is the team's hypothesis?
- What do you think they had already observed or known that led to that hypothesis?
- What other hypothesis or explanation do you think could be valid, and why?
- How could it be tested? How did the data support (or disprove) the hypothesis?
- What new questions did it raise?

Practice Posing Hypotheses

As students observe a phenomenon in schoolyard, examine migration data, or view video clips of the migratory animals they're tracking, ask them to put forth hypotheses to explain what they've seen (e.g., Hummingbirds migrate when red flowers start to open). Then ask, What have you observed or learned already that lead you to pose that explanation? How could we go about testing it?

Gathering Data

Overview
1. Setting Standards for Gathering Data
2. Representing Data: Charts and Graphs

Overview
Scientists rely on carefully gathered data to help answer their questions, test their hypotheses, and develop and justify explanations. They also critically review one another's data and collection procedures so they can assess whether the research is fair and valid or replicate the study.

Because Journey North is a data-driven project, your students will need to practice gathering accurate and useful information. When students decide how to gather and represent their own and online migration data, they will find patterns more readily revealed and conclusions and explanations easier to draw.

1. Setting Standards for Gathering Data

In scientific research, scientists set standards (protocols) for how they make observations, measurements, and otherwise collect data so there is uniformity and their investigations are "fair." If they fail to do so, they can't readily recognize patterns, make accurate comparisons or generalizations, or have confidence in their results, and other scientists can't repeat the study.

In classroom or schoolyard research, you might decide to establish measurement standards up front or let students discover the need to do so (with your guidance and questions) as they try to make sense of the data they collected.

Here are some questions you might ask as you prepare to gather data:
- What variables do we need to consider?
- How can we keep things the same each time we observe or measure?
- Will we be able to easily compare our data with that of other classrooms?
- What do we mean when we say (how do we define) _______?

2. Representing Data: Charts and Graphs

In order to make sense of data gathered during investigations and Journey North migration studies, it helps to get a visual overview of the information. Tables are used to organize amounts of numerical data (e.g., the number of different species of frogs spotted in a day.) Graphs visually show comparisons or relationships.

As students pull and organize information from Journey North maps and migration data tables, they should think about their driving question and what they'd like to depict. By exposing them to different types of graphs, helping them understand when it's most appropriate to use each one, and modeling how to create each type, you will prepare them for making appropriate choices as classroom scientists.

Here are some tips on when to use different graph types:

Circle (Pie) Graphs - Use these to depict parts of a whole, such as the fraction (percentage) of Journey North classrooms that are tracking just 1 species, 2 species, 3, species, and 4 or more species.

Bar Graphs - Use these to show comparisons of data with discreet categories, such as the number of miles traveled by each of 6 eagles.

Area Graphs - Use these to depict how something changes over time. It applies to data that may have peaks and valleys, such as the average number of monarchs spotted each week outside your classroom.

Line Graphs - Upper elementary students can use these for continuous data (e.g., height, time, temperature, volume) to show how things relate to one another. (Time is typically depicted on the X axis.) For instance, students might use a line graph to depict how the average daily temperature (or isotherm) changes over time.

Scatter Plots - These are like line graphs, but are used to represent trends; individual data points are not connected. Once students have plotted points on the graph from data tables, they can draw a "line of best fit" between or near the points that offers a visual image of the correlation between variables. From that, they should be able to write a sentence or two that summarizes the data (e.g., As the temperature warmed, the number of robins sighted increased). sense of the data they collected.

Making Sense of Data (Findings)

Overview

As scientists gather data and later try to make sense of (interpret) it, they look closely for patterns or relationships that might "tell" them something significant. They use their imaginations and think logically about this new information and relate it to what they already know and to others' findings. Then they make an overall statement or explanation. They also think about how findings connect to larger ideas. (Other people may interpret the data differently and pose alternative explanations, which can spark further research.) The data might offer little help in answering a question or supporting a hypothesis, but could suggest other questions or avenues of research.

1. Questions That Help Students Make Sense of Data

- What patterns do you notice?
- What relationships do you notice?
- What do the data "show?"
- What do you think the data mean? (What can you conclude?)
- What can you infer about ________?
- How would you explain _________?
- How does it relate to what you already know or have observed?
- What generalizations can you make based on your observations/the data?
- How does the evidence support your explanation?
- What other explanations could be plausible?
- How is it similar to/different from what you had thought would happen (hypothesized)?
- Did your hypothesis change? What information/data caused you to change your hypothesis?
- Based on these findings, what do you predict would happen if _____?
- What new questions do you have?

2. Dealing with Unusual Findings

Scientists often find that data conflicts with conventional scientific wisdom, breaks dramatically from an expected pattern, or otherwise perplexes them. In Journey North, unusual sightings are common -- a Monarch spotted in England or a hummingbird sighted “too early" in the season, for instance. When students notice data that is inconsistent with what they assume or know to be scientifically reasonable, seize the opportunity to push their thinking and problem-solving skills. The following classroom strategies reflect how a scientist might approach anomalies in data.

Question the Methods

- Have students try to verify the accuracy of the data by asking questions about the collector and collection process. (They may want to generate a list of questions and e-mail them to the observer.)

- What standards/protocols were used in collecting data?

- Who was the observer and what knowledge or experience does she or he have? (For instance, Does he know how to identify a whooping crane?)

- What other factors could have affected the findings?

3. Form Tentative Explanations

As a class or in small groups, have students use their knowledge, experience, and imaginations to come up with tentative explanations for the unusual sighting. Here are some of the questions they might ask:

- Could a change in the environment (e.g., short-term weather, long-term climate) explain the unusual sighting?

- Could a human factor be responsible (e.g., development or deforestation that affects an animal's normal habitat)?

To inspire a fruitful discussion and encourage participation, set out these guidelines.

- Explain your ideas and try to support them.
- Respectfully listen to others' tentative explanations.
- Revise your thinking, challenge others' ideas, or defend your own.

Ask the class, What new data or information would help us check and further refine our explanations? If practical, give students time to pursue further research

4. Responding to Misconceptions (and "Wrong" Answers)

Students often come to the classroom with firm theories and explanations for how things work, some of which conflict with widely accepted science ideas. These ideas, which may be reasonable in a limited context, often arise from curious imaginations, partial observations, or interpretation of language (e.g., plants "eat" since we give them plant food). To shift their thinking, students need multiple opportunities for investigative experiences in which they confront phenomena or data that are inconsistent with their "native" theories. In general, if students offer theories, explanations, or conclusions that are "incorrect," try to find alternatives to simply correcting them. Here are some strategies that show respect for students' ideas and encourage critical thinking. Employing them can offer you a glimpse of students' thought processes.

- Ask, Can you clarify or elaborate on your thinking?
- Ask, What past experiences, observations, measurement data, or other source of information inspired your ideas?
- Ask, What evidence do you have to support your idea or hypothesis?

Give students a chance to revisit data and check what they think against what they see. Facilitate a group discussion in which classmates explore, challenge, and build on one another's ideas.

Invite students to conduct hands-on research to explore and test their theories and explanations.

5. Asking "So What?" The Implications of Research

The outcomes of scientific research can help us learn about how the world "works," but the quest doesn't end there. Findings inevitably inspire new questions that lead to further research, and they may have broader impact and applications. For instance, the studies that uncovered the role of DDT in damaging the ability of eagles and other raptors to reproduce had significant ecological and policy implications.

Many research findings are communicated to new audiences to educate, raise awareness, or inspire action (growing native plants to provide food for migrating birds, for instance).

As students participate in research and learn about migrations and seasonal changes, encourage them to routinely ask these types of "so what" questions:

- What difference does this make (e.g., to homeowners, migratory species, the environment)?
- Who might be interested in the results?
- How might different types of people respond to the findings?
- What new research studies might the findings inspire?
- What do we want to communicate about this study? Who will we target and what approach will we use (e.g., presentation, newsletter, article)?
- What new questions do we have or next steps will we take?

Reviewing Science Research Critically

Overview

Legitimate skepticism and respect for evidence are vital to scientific inquiry. They are also important "habits of mind" that enable us to critically evaluate what we read, hear, and are told. Scientists continually reflect on and evaluate their research plans and progress, accuracy of data, explanations, and conclusions. They ask the following types of questions:

- Are there unintended factors that might influence, bias, or skew my results?
- Was my reasoning logical and based on the evidence?
- What might I do differently to gather better (more accurate, detailed, appropriate) data?

They also ask peers to review their investigation plans and offer feedback. Finally, they communicate their research and findings to colleagues via papers presented at meetings, conferences, and articles in scientific journals. Colleagues, in turn, ask critical questions about the research, looking for careful design and data collection, and reviewing evidence and conclusions.

The following strategies engage students in using this important scientific "lens."

1. Questions That Help Students Critically Review Research

- Was the research question clear?
- Why did you choose to investigate this question?
- What did you already know or observe that helped shape the hypothesis?
- How did you decide what to observe or test and what type of data to collect?
- What standards/protocol did you use when gathering data?

- Did you find any interesting patterns or relationships in the data? What were they? Any surprises?
- How else could the results be interpreted or explained?
- Did you have to revise your question, setup, or hypothesis at any point? Why?
- What kinds of conclusions or explanations, if any, can you draw from your data? How do they relate to your hypothesis?
- Did the information gathered help answer the question? Why or why not?
- What other factors might have influenced your results (e.g., the way data were collected)?
- How would you revise this if you were to do it again?
- Now what do you wonder about?

2. Encouraging Peer Review

Routinely create opportunities for students to evaluate and ask questions about scientific research featured in Journey North, and about peer's suggestions for investigations or actual research. Pull questions from the list below. (You can also reword these so students can reflect on their own investigation designs.)

Consider staging a classroom scientific meeting in which small groups present and discuss results of investigations (see Format of a Scientific Paper) or hold a Scientific Convention in which students prepare posters or displays to present investigations and findings. Classmates then tour the displays and write questions and comments about the research on posted sheets.