Grade Level: 6-12

Activity Duration:
Introduction: 5-30 minutes
Activity 1: 15 minutes
Activity 2: 30-60 minutes
Wrap-up: 10 minutes

Overview:
I. Introduction to the Nature of Science
II. Sort Types of Investigative Questions
III. Observation & Investigative Question Writing

Summary: Students will explore the nature and process of science. To activate prior knowledge, students define and sort types of questions. Then, using tools such as spring scales, measuring tapes, and magnifying equipment, students begin making scientific observations of the natural world. Finally, students use their observations to develop testable investigative questions.

Topic: Scientific Observation and Question Development

Theme: The basis for scientific inquiry begins with the process of making observations and asking questions.

Objectives:
1. Students will practice the process of scientific observation.
2. Students will distinguish between three types of investigative questions.
3. Students will create detailed observations of the natural environment using numbers, words, labeled diagrams, and questions.
4. Students will use measurement tools during observation.
5. Students will develop a testable question about the natural world that can be investigated.

Lesson Adapted From:

Data Sourced for Fish Stomach Contents From:
“An Evaluation of the Importance of Mysis relicta to the Lake Superior Fish Community” (2010) A thesis submitted to the faculty of the Graduate School of the University of Minnesota by E.J. Isaac.

Tool for Understanding the Nature of Science

http://undsci.berkeley.edu/

Find guides to approaching student misconceptions and helpful teacher resources.
Suggested MN Science Standards:
*This lesson may partially or fully address the following standards.

Grade K:
0.1.1.2.1 - Use observations to develop an accurate description of a natural phenomenon and compare one’s observations and descriptions with those of others.

Grade 1:
1.1.1.2.1 - Recognize that describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.
1.1.3.2.1 - Recognize that tools are used by people, including scientists and engineers, to gather information and solve problems. For example: Magnifier, snowplow, calculator.

Grade 2:
2.1.1.2.1 - Raise questions about the natural world and seek answers by making careful observations, noting what happens when you interact with an object, and sharing the answers with others.

Grade 3:
3.1.1.2.1 - Generate questions that can be answered when scientific knowledge is combined with knowledge gained from one’s own observations or investigations.
3.1.1.2.3 - Maintain a record of observations, procedures and explanations, being careful to distinguish between actual observations and ideas about what was observed.
3.1.3.2.1 - Understand that everybody can use evidence to learn about the natural world, identify patterns in nature, and develop tools.
3.1.3.2.2 - Recognize that the practice of science and/or engineering involves many different kinds of work and engages men and women of all ages and backgrounds.
3.1.3.4.1 - Use tools, including rulers, thermometers, magnifiers and simple balance, to improve observations and keep a record of the observations made.

Grade 5:
5.1.1.1.3 - Understand that different explanations for the same observations usually lead to making more observations and trying to resolve the differences.
5.1.1.2.1 - Generate a scientific question and plan an appropriate scientific investigation, such as systematic observations, field studies, open-ended exploration or controlled experiments to answer the question.
Grade 7:
7.1.1.2.1 – Generate and refine a variety of scientific questions and match them with appropriate methods of investigation such as field studies, controlled experiments, review of existing work, and development of models.

Grades 9-12:
9.1.1.2.1 - Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations, and draw conclusions supported by evidence from the investigation.

Environmental Literacy Scope and Sequence
Benchmarks:
- Social and natural systems are made of parts. (K-2)
- In social systems that consist of many parts, the parts usually influence each one another. (3-5)
- The output from a social or natural system can become the input to other parts of social and natural systems. (6-8)
- Social and natural systems are connected to each other and to other larger and smaller systems. (6-8)
- Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs. (9-adult)

Concepts addressed: similarities and differences, cause and effect, ecosystem, patterns

For the full Environmental Literacy Scope and Sequence, see: www.seek.state.mn.us/eemn_c.cfm

Great Lakes Literacy Principles

Only the bolded Great Lakes Literacy Principles are addressed in this lesson.
- The Great Lakes, bodies of fresh water with many features, are connected to each other and the world.
- Natural forces formed the Great Lakes; the lakes continue to shape the features of their watershed.
- The Great Lakes influence local and regional weather and climate.
- Water makes the Earth habitable; fresh water sustains life on land.
- The Great Lakes support a diversity of life and ecosystems.
- The Great Lakes and humans in their watersheds are inextricably interconnected.
• **Much remains to be learned about the Great Lakes.**
• The Great Lakes are socially, economically, and environmentally significant to the region, the nation, and the planet.

For more information about the Great Lakes Literacy Principles, visit: [http://greatlakesliteracy.net/](http://greatlakesliteracy.net/)

**Materials:**

**Introduction – Essential Question:**
- **How Science Works Poster**
- White board, note paper, or giant sticky notes
- Writing utensil, colorful markers recommended
- **Video “Big Idea 1: Earth Scientists Study Our Planet”:** [http://tinyurl.com/opd8p23](http://tinyurl.com/opd8p23)

**Activity 1 - Questions to Investigate:**
- **Question Sort Cards** (1/group)
  - Cut cards, separate, and place in an envelope
- **Handout: Three Types of Investigation Questions** (1/group)
- **Answer Key: Three Types of Investigation Questions Answer Key**

**Activity 2 - Observation Investigation:**
- Hula-hoops or bike tire inner tubes or empty frames (1/group)
  OR **Lake Superior fish and stomach content images** (1 set of 3/group)
- Note pad/journal/clipboard with paper (1/student)
- Writing utensil (1/student)
- Ruler or measuring tapes (1/group)
- Spring scale (1/group)
- Weighing bag (1/group)
- Magnifying equipment and/or laser infrared thermometer (1/group)

**Wrap-up**
- **Handout: Question Reflection Sheet** (1/group)
- Concept maps from Introduction
Vocabulary:

**Comparative Question** – Questions focus on one measured variable in at least two different (manipulated variable) locations, times, organisms, or populations.

**Correlative Question** – Questions focus on two variables to be measured and tested for a relationship or pattern.

**Descriptive Question** – Questions involving descriptions of a natural system. They focus on measureable or observable variables that can be represented spatially in maps or as written descriptions, estimations, averages, medians, or ranges.

**Experiments** – Scientific tests that involve manipulating some factor or factors in a system in order to see how those changes affect the outcome or behavior of the system.

**Essential Question** – Main concept(s) in curriculum stated in the form of a question.

**Food Web** – A diagram of a complex, interacting set of food chains in an ecosystem.

**Hypothesis** – A proposed explanation for a fairly narrow set of phenomena, based on prior experience, scientific background knowledge, preliminary observations, and logic.

**Observation** – To make note, record, or attend to a result, occurrence, or phenomenon. Though we typically think of observations as having been made "with our own eyes," in science, observations may be made directly (by seeing, feeling, hearing, tasting, or smelling) or indirectly using tools.

**Scientific Process** – A dynamic, creative process built upon deeper and deeper investigations of the natural world. Observations, asking questions, testing ideas, peer evaluation, collaboration, and discoveries cycle repeatedly in an effort to gain a better understanding of the natural world.

**Testable Question** – A question that sets up what could explain an aspect of the natural world by stating what one would expect to observe and comparing that expectation to what one actually observes.
Instructor Background:
The information below is sourced from http://undsci.berkeley.edu/

The scientific process is a powerful method for understanding the natural world because it is based on observations of how the world works. Science relies on investigating ideas by gathering data to answer questions. One way the scientific process is often represented is as a simple, linear six step process (Fig. 1).

![Figure 1. A linear, six-step model is a simple way to begin thinking about the scientific process.](image)

This graphic represents the summarized version of content areas reported on in a paper, report or publication. It does not accurately capture the complexity of the actual process. The scientific process is rarely, if ever, linear.

For example, EJ Isaac, a biology masters student, was curious about what fish eat in Lake Superior. His first step was to review scientific literature to determine what is known about food preferences for Lake Superior fish. He learned that fish eat different foods at different stages in their life cycles. Sometimes fish eat plants, algae or invertebrates while other times they eat smaller fish. In fact each species has its own food preferences. Already EJ’s investigation requires asking more than one question.

After doing some additional digging, EJ learned that a particular species of zooplankton, Mysis relicta, or Mysis for short, is a particularly important link in the Lake Superior food web. He refined his very general research question to focus on a single, testable question, “Is Mysis an equally important food item to all fish in Lake Superior?” From this question he formulate a hypothesis: “Mysis is an equally important food source for all fish species”. Intuitively, he suspected this is not the case, but from here he set up experiments to collect observational data that would either support or reject this hypothesis.
Testing ideas

After an idea is refined, researchers design experiments that test their idea or hypothesis, make observations, and collect and interpret data. Data interpretation is probably the most exciting part of the scientific process because what you learn informs your next steps. Data collected may bring you back to gathering more data, or move you into a different phase of the scientific process all together.

Going back to our example with EJ, about what Lake Superior fish eat, the methods he developed for testing the hypothesis “Mysis is an equally important food source for all fish species,” required collecting 100 individual fish from five different species over three seasons. EJ learned what they have been eating by opening up their stomachs and identifying the contents. He record how many Mysis were found in each fish species, and saw that Mysis is an important food source for all fish, but not of equal importance in all species. The diet of rainbow smelt (an invasive species) and kiyi (a native species) are almost entirely made up of Mysis. However, while he conducted this work he notice something else. Some fish seem to eat more Mysis depending on the time of year. This observation leaded to an entirely different question, “Are Mysis an equally important food source throughout the entire year?” This question leads to another iteration of the scientific process.

It is natural for other questions to arise while conducting research, “muddying” the oversimplified linear approach, and there are often confounding factors, such as other environmental influences or conditions that complicate the story. The process of science involves many layers. Science is not linear; rather it is ever-changing, and cyclical as seen in the flow chart on the next page(fig 2).
Figure 2. Integral parts of the scientific process.
Looking at this fluid model of the nature of science, you can find many entry points into the process. Perhaps there is a new technology to be tested, a practical problem to solve, or a surprising observation that inspires you to learn more. Within the scientific process there is a continuous exploration and discovery phase. A researcher finds out what other scientists have learned by exploring previous research, sharing data and ideas with other researchers, asking questions, making more observations, and refining or expanding the scope of what is investigated based on what is learned. Researchers often revisit phases during a study, as there are many routes through the scientific process (fig. 3).

Figure 3. Four stages of the scientific process and two potential paths through the scientific process.

In the lesson activities that follow, we aim to build scientific literacy by strengthening a student’s observation and questioning skills. The process of developing a testable question stems from being able to make observations of the natural world. Once questions are developed, identifying which ideas are testable will be valuable to anyone starting on the journey that is scientific investigation. Using the concept map in the introduction, build on what your students already know about the nature of science, and challenge them to extend their understanding.
**Procedure:**

*Introduction – Big Question Concept Map*

1. Provide an **essential question** for students to answer.
   a. This question should be largely complex and generally does not have a single answer.
   b. This could relate to your current topic of study (i.e. *How did land forms affect nomadic populations prior to European settlement?*, *What is climate change?*, etc.), local environment (What is the carrying capacity for life in Lake Superior?), or the question could be as broad as “What is Science?” or “What is the process of Science?”
   c. For the purpose of this lesson the Essential Question is “What is the process of science?”

2. Ask students to take 5 minutes to create a concept map related to the essential question.
   
   For information about using concept maps in the classroom visit: 
   
   [http://tinyurl.com/7zlnu5k](http://tinyurl.com/7zlnu5k) - How to Use A Concept Map or [http://tinyurl.com/23alr9u](http://tinyurl.com/23alr9u) - “The Theory Underlying Concept Maps and How to Construct and Use Them”

**Helpful Student Prompts:**

   a. Use words, phrases and pictures
   b. Try to answer the big question
   c. Describe what you think you already know on the topic

3. Within student groups encourage students to share some of the concepts from their concept map.
   a. Were you able to answer the question? Why or why not?
   b. What else do you need to know? How can you find out?

4. Discuss how big questions, like the one you have been thinking about, can be very complex to answer. The process of science is dynamic and involves asking many questions based on observations and experiments. Big questions need to be broken down into simpler questions, which are observable and testable in order to build understanding.

5. This lesson’s activities will facilitate exploration of the different types of questions that can be answered in a scientific investigation (note there are many things science cannot answer - [http://tinyurl.com/kmkawhf](http://tinyurl.com/kmkawhf) - “Science Has Limits” from UC Berkeley). The
lesson will provide opportunities for students to practice developing questions based on observations.

**Activity 1: Questions to Investigate – Sort Activity**

**What types of questions can be investigated in science?**

1. Introduce students to the terms on the *Three Types of Investigative Questions Worksheet*: descriptive, comparative, and correlative. Write these categories on a board or on pieces of presentation paper for use at the end of this activity.

2. Divide your students into groups of 3 or 4.

3. Hand one set of *Investigative Questions cards* and one *Three Types of Investigation Questions worksheet* to each group.

4. For the next 10 minutes: given the categories of Descriptive, Comparative, and Correlative – sort the set of Investigative Questions Cards.

5. To help foster the discussion and understanding of the process within the small groups you can ask each group some of the following questions or post these on the board:

   a. Did everyone agree? How did you come to your final decision?
   b. Can each person in the group come up with a justification as to why these questions fall into the categories they do?
   c. Do you have an uncertainty pile? If so, why? What more do you need to know?
   d. What questions do you have about the three categories?

6. After about 10 minutes, have the class share how they grouped their questions. Using the chart created in step 1, have students from various groups place a question in the category they selected and explain why their group chose that category.

7. Explain: now that students have an understanding of how questions can be written, and may have even noticed that each question stems from an observation - they can begin to formulate their own observations and questions.

**Activity 2: Observation Investigation and Creating Questions**
1. Identify an outdoor space that is safe for students to access and make observations or use the *Lake Superior Fish Food Focus* indoor alternative lesson found on page 15.

2. Gather a variety of tools for each group to use while making observations,
   
   a. Suggested tools include: tape-measures, spring scales, magnifying equipment, thermometers, etc.
   b. Not all groups need to have the exact same tools, but each group could have multiple tools.

3. Have each student create a journal page to use for observations and emerging questions with:
   
   a. Name
   b. Date
   c. Time
   d. Location
   e. Weather (if conducting a field observation)
   f. Title of Activity (making observations, or observing ____________)
   g. Columns with the headings: I observe, I wonder.

   **Example:**
   
<table>
<thead>
<tr>
<th>I observe</th>
<th>I wonder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   4. Explain the following expectations:

   a. Students will be conducting an observation of an indoor or outdoor location (depending on the topic or focus chosen by the teacher).

   b. Students are making observations and creating at least *six questions* based on their observations while conducting this activity.

   5. Provide an overview of what good observation skills entail:

   **Tips:**
   - Small items can be placed inside weight bags and hung from spring scales to compare weight.
   - Temperatures vary even in the shade!
   - Spy-Scopes in the kit can serve as telescopes or monocles.
a. Describing using your senses: “What does it look like (size, shape, color), feel like (temperature, texture), smell like, or sound like?”
b. Including drawings that are labeled, show detail, and metric measurements.
c. Looking up, down, in the middle, far away and close-up.
d. Identifying relationships and connections that the object has with things that are around it.
e. Writing down questions that come up while making observations

6. Ask the students to organize their observations in their journal by having descriptions of the observations grouped together under “I Observe” and questions that arise grouped together under “I Wonder” in their journal.

7. Before breaking into smaller groups and handing out tools, spend 10 minutes recording observations of the whole study area and have the students start writing down questions they may have about what they are observing.

   a. Below are prompts to help students get started
      i. I am curious about…
      ii. It surprised me that…
      iii. I wonder how this part affects another part of the system…

8. After 10 minutes are up, let the students know they will now be using scientific tools to observe a smaller section of the space they were just observing.

9. Briefly cover how each science tool provided can be used.

10. Break students into groups of 3 or 4 and identify each student’s role for the group. (i.e. equipment manager, time keeper, task monitor, encourager, checker, reflector, etc.)

11. Hand out science tools to each group.

   a. Observation Boundary: hula hoop, bike tire inner-tube, or empty frame
   b. Three or more observation tools to each group

12. Ask students to place their observation boundary around an area which will become their mini-observation site

13. Give your students 15 minutes to observe their mini-observation site and formulate at least 5 or 6 questions based on their observations.

14. Remind students that they can record their observations using drawings, sentences, lists or in a metric data chart. Refer back to the recommendations in step 5.
15. Bring students back together as a large group.

16. Discuss any relationships they noticed between the large study area and the mini-observation site. What similarities and differences did you notice?

Wrap-up – Discussion Question Suggestions:

1. Hand out one Question Reflection Sheet to each group of students.
   a. Categorize the questions students created during their observations as descriptive, comparative, correlative, essential, why, or testable.
   b. Have students share their observations and questions with their group or a partner.

2. Engage in a group discussion using the following questions:
   a. Are their similarities in their observations/questions among all of the groups?
   b. Are their differences in their observations/questions among all of the groups?
   c. What made observations/questions different? Did the tools provide a different perspective (also considered a bias - were there any other bias from different groups or individuals?)

3. Out of the six categories the questions were sorted into, which category of questions are we able to conduct further scientific study to try and answer them. (Descriptive, comparative, correlative)

4. If outside, return to the classroom.

5. Have students select or rewrite one of their questions (from their observation sheet) into a testable scientific question. They can model this after the formats shown in Activity 1.

6. Have the students revisit their concept maps from the introduction, and take 3-5 minutes to add new ideas to the concept map in a new color.
Assessment:

Review student’s journal observations for a range of representational forms including numbers, words, labeled diagrams, and drawings. Descriptions might include size, shape, color, texture, or smell.

As you review student work you can look for:

- Did observations fill the notebook page?
- Were drawings detailed, with small objects enlarged to show details?
- Parts of drawings are labeled.
- Measurements are recorded in metric units.
- Student was able to correctly categorize questions from their observation.

Example Indoor Alternative Activity (for Activity 2 of the lesson plan):

If unable to go outside to conduct an observation identify an object or set of objects to observe, such as leaves, shoes, rocks, preserved organisms, etc., and collect enough specimens to conduct the observation in your classroom.

LAKE SUPERIOR FISH FOOD FOCUS:

Follow procedure for Introduction, Activity 1 and Activity 2 outlined in the main lesson plan substituting the included fish and fish stomach content images as the focus of student observation.

1. Print out enough sets of three Lake Superior fish and stomach content images so that each student will have a copy of one fish. The students will be divided into groups of three or four by matching their spring/summer/fall fish together. (These fish represent 3 of 48 species living in the lake. Groups will have different fish, some of which spend most of their time in shallow water (Kiyi), deep water (Lake Whitefish) or at the bottom of the lake (Siscowet). One side of each species includes representative stomach contents for the particular fish in the spring, summer and fall.)
2. Provide each student one fish poster from the **Lake Superior fish and stomach content images**.

3. For a sense of context, view video of live fish at:
   
   a. Lake Trout swimming in Great Lakes Aquarium exhibit  
      [http://www.youtube.com/watch?v=cvA-arTc84I](http://www.youtube.com/watch?v=cvA-arTc84I)
   
   b. Divers swimming with Lake Trout in Lake Superior at night  
      [http://www.youtube.com/watch?v=f0K6W-nyPU](http://www.youtube.com/watch?v=f0K6W-nyPU)

4. For the “whole study area” portion of the observation have the students look at the image of the fish that does not show the stomach contents and the videos. Prompt students to make and record their observations and questions about the fish in front of them (without turning it over) in their journals as described in the lesson plan.

5. Have the students turn their images to the stomach content side and match up their fish with the other students in the class. Each group should have one fish of the same species for each season. (One Kiyi spring, summer, and fall, etc.)

6. Follow the instructions for the “mini-observation site” portion of the observation using the fish that show the stomach contents.

7. Continue to the Wrap-up from lesson plan on Page 14.

**Extensions:**

1. Additional kits are available through the Great Lakes Aquarium Teacher Resource Library to support the further extension of this lesson.

   Recommended pre-lesson: MinnAqua Program: Get in the Habitat! – Lesson 2:1 – Fish Families

   Recommended post-lesson: Lake Superior: Who lives there and what do they eat?

2. Have students select 1 testable question and develop a research plan or experimental design.

3. Compose an argument for which group’s question could be answered most accurately, easily, ethically, safely, etc.
4. Show this video (an Earth Science Example) and have students add to their concept map about the nature of science:


5. Compare these two graphical descriptions of the process of science

[http://tinyurl.com/nk2o4ut](http://tinyurl.com/nk2o4ut) - Complex flow chart for the scientific process
[http://tinyurl.com/pnzsoew](http://tinyurl.com/pnzsoew) - Simple flow chart for the scientific process

6. Given a curriculum topic, have students develop a descriptive, comparative, and correlative question that relate to your current topic of study.

**K-5 Options**

1. For K-2 audiences – do a large-group introduction on how to ask a question. Conduct Activity 2 – outdoor observation or indoor alternative and have a large group discussion about questions that may arise from the observations.

2. For 3-5 audiences – The introduction and Activity 1 may need to be conducted as a large-group guided activity before embarking on Activity 2.

**References:**


Minnesota Moose Alternative Indoor Activity (for Activity 2 of the lesson Observing and Questioning):

If unable to go outside to conduct an observation or you have an interest in connecting students to the issues around moose health in Minnesota, use the following notes.

Lesson Plan
Follow procedure for Introduction, Activity 1 and Activity 2 outlined in the main lesson plan substituting the included healthy moose A and unhealthy moose images as the focus of student observation.

1. Print out enough sets of three Minnesota Moose images so that each student will have a copy of one healthy moose (Moose A) and one unhealthy moose (Moose B, C, D, or E). The students can be divided into groups by matching their unhealthy moose letter together. (These images, field notes, cause of death and management practices represent the collaborative work of Grand Portage Band of Lake Superior Chippewa and the research of Natural Resource Manager EJ Isaac from 2010 and continuing past 2017.

2. Provide each student or pairs one Moose A poster from the Minnesota Moose images.

3. For a sense of context and additional images and moose research, view Investigating Moose Populations in Northern Minnesota at: nrri.d.umn.edu/moose/

4. For the “whole study area” portion of the observation have the students look at the healthy moose, image A. Prompt students to make and record their observations and questions about the moose image in front of them in their journals as described in the lesson plan.

5. Provide each student or pair with an unhealthy moose image: image B, C, D, or E.

6. Follow the instructions for the “mini-observation site” portion of the observation using an unhealthy moose image (B, C, D, or E). Give students time to record additional observations and questions now that they have more evidence from the unhealthy moose.

7. You could choose to have each student with Moose B come together to compare their observations, each student with Moose C, etc.
8. Once students have added additional questions and observations, hand out the **Health Issues/Cause of Death** sheet for the moose they observed.

9. Students should read through the health issues, cause of death and the proposed management actions for the moose they observed. Encourage them to follow the “Next Steps:”

   a. With your group, make at least two connections between your observations and questions and the cause of death that was determined by Grand Portage research teams. *(Did they observe similar things to the scientist?)*
   
   b. What other questions will the team need to answer before, during and after the management actions are implemented? *(Consider what additional data will need to be collected and monitored.)*
   
   c. List three topics that you may need expert advice on during the management phase of this project? Who might have this expertise? Is there someone in your community that you could ask? *(This gets at the collaborative nature of science research, and asks students to think about resources in their local community.)*

10. Continue to the Wrap-up from the lesson plan on Page 14 to bring the whole class back together for a discussion of how their views, types of questions and observations changed as they collaborated with others (studying the same unhealthy moose) and across the class (with those studying other unhealthy moose).

**Additional Extensions:**

1. The healthy moose images could be introduced at the beginning of a Minnesota ecology unit. Share with students that according to researchers at UMD, “in less than 20 years moose in northwestern Minnesota declined from over 4,000 to fewer than 100. Could the northeastern moose population, with over 7,000 moose, be starting a similar decline?”

   Have students brainstorm what kinds of questions would need to be asked about the habitat and ecology of moose to answer the question on population decline. After exploring habitat needs and trophic levels above and below moose, give students the unhealthy moose images and ask them to look deeper.

2. Use the [nrri.d.umn.edu/moose](http://nrri.d.umn.edu/moose) site to have students further explore current moose research. Have students: design a method to collect data, write a professional email to a local scientist, create a map or graphic organizer to show trends from the publications, develop a PSA, compare anatomy of a moose to the human system, develop an independent research proposal, choose a management practice to research further and debate a pro or con side of the argument for implementation.