Exploring Knowledge and Ideas

A CASE STUDY OF SCIENTIFIC INQUIRY

BELUGA WHALES IN THE ST. LAWRENCE RIVER

Purpose

To introduce the Understandings About Scientific Inquiry from Content Standard A of the *National Science Education Standards* (NSES) through a case study of scientific research

- To develop a deeper understanding of the nature of science from a scientist's perspective
- To increase content knowledge in environmental and life sciences
- To explain science as inquiry in terms of abilities and understandings

Overview

Through a case study format, participants analyze an actual scientific inquiry that investigates the question: Why has there been no increase in the Beluga Whale population in the St. Lawrence River in the last 50 years? By reading various passages and answering questions based on those passages, participants piece together the scientists' inquiry and analyze both the process and product of the investigation. Participants come to understand that reading about and analyzing the work of scientists is one way to experience science as inquiry. Such case studies cause learners to reflect on the nature of science and develop a deeper understanding of Content Standard A, Understandings About Scientific Inquiry. (This case study is based on a May 1996 article from *Scientific American* titled "The Beluga Whales of the St. Lawrence River" by Pierre Béland.)

Estimated Time 1-1/2 to 2 hours

Materials

- transparencies of the use of case studies, Masters 3.1-3.3 (1 transparency each)
- map of North America, Master 3.4, 1 per team
- whale stickers, 2 per person
- A map of the St. Lawrence River and a picture of beluga whales (optional)
- A Case Study of Scientific Inquiry: Beluga Whales in the St. Lawrence River, divided into sections, Masters 3.5-3.7, 1 per team or per person depending on the needs of the audience

- transparencies of Understandings About Scientific Inquiry and the Abilities Necessary to Do Scientific Inquiry, Masters 3.8 and 2.2 (1 transparency each)
- strips of chart paper for “banners,” 1 per team (see Teaching Strategies)

Advance Preparation

Duplicate the Blackline Masters as indicated in the Materials List above.
Prepare transparencies of the Blackline Masters as indicated in the Materials List above.
Review the case study thoroughly as well as Content Standard A from the NSES.

Teaching Strategies

5 min Display the following transparencies and briefly discuss participants’ experience with case studies as a strategy for learning.

Master 3.1
A case is a story designed and presented to engage those using it to solve a problem, wrestle through a puzzle, discern an underlying principle, or stimulate reflection.(Source: Miller, Moon, and Elko, *Teacher Leadership in Mathematics and Science*, 2000)

Master 3.2
Why use case studies to deepen understanding of science as inquiry?

Most teachers have never experienced science as inquiry; therefore…

Case studies provide a window into the nature of science –how scientists go about their work.

Master 3.3
Many teachers do not recognize inquiry as science content; therefore…
Case studies can encourage teachers to reflect on inquiry as a body of knowledge with specific guiding principles.

Inform participants that they will continue to explore science as inquiry through a case study of a team of scientists who studied whales.

10 min Divide participants into teams of three.
Distribute the maps of North America and the whale stickers.
Ask teams to do the following:

- Talk about where they think a scientist might find whales to study;
- Place their whale stickers on the map to indicate those locations; and
- On the back of the map, list three things that a scientist might study about whales in those locations.

Briefly, ask a few of the teams to share their maps and the list of what a scientist might study.

(This brief activity is meant to engage the participants in the subject matter of the case study—whales and the nature of scientific inquiry.)

5 min — Introduce the case study by announcing that the scientists in this case study are investigating populations of beluga whales.
Ask teams to revisit their maps and place an "X" in areas where they think beluga whales might live. Invite a few teams to share where they placed their "X's" and why.

Show a map of the St. Lawrence River, if available and pictures of beluga whales (optional). Indicate that this case study took place in the St. Lawrence River where a population of beluga whales resides. (It might surprise participants that a population of whales lives in the St. Lawrence River!)

15 min — Distribute Passage One of A Case of Scientific Inquiry, Master 3.5.
Instruct participants to read the passage, to discuss their answers to the two questions, and to write a team response to the two questions.
Remind participants that they should think of themselves as scientists as they read and answer the questions.

Ask a few teams to share their responses and to explain why they chose those responses. Ask: What knowledge are they using to answer the questions? (Because this passage provides little information, participants must rely on prior knowledge of organisms and ecosystems, just as scientists would initially.)

Record teams' responses for future reference, especially from Question 1: Why do you think the number of whales has not increased?

20 min — Distribute Passage Two of the case study, Master 3.6. Again, allow teams time to read the passage and to answer the questions.

Discuss the questions as a group. Encourage discussion among participants, not just between you as the facilitator and the participants.

Concentrate on the final question, What would be the best approach to design and conduct a scientific investigation that would demonstrate a cause-and-effect relationship? Record responses.

10 min — Distribute Passage Three and the follow-up statements, Master 3.7. Allow teams time to read the passage and to compare the case study results with their previous responses.

15 min — Review the statements that follow Passage Three—How Does This Investigation Illustrate Scientific Inquiry? Assign one statement to each team. Instruct the teams to find evidence for their respective statements from the three passages they have read.

10 min — Allow time for each team to report its findings. Encourage the teams to explain what they thought their assigned statement meant in light of this scientific case study.

15 min — Ask: How has this case study helped you understand science as inquiry? Instruct teams to answer this question by creating a "banner" that defines or describes science as inquiry as they understand it from this case study. Distribute the strips of chart paper and markers; invite teams to create their banners and to display them around the room.

10 min — Display the transparency of the Understandings About Scientific Inquiry from Master 3.8. Relate participants' banners to the Understandings.

Display the transparency of the Abilities Necessary to Do Scientific Inquiry from Master 2.2. Relate participants' banners to the Abilities.

Explain that science as inquiry can take many forms. Just as scientists learn from one another through their published work, science educators can learn about the nature of science by studying the work of scientists.

Follow-up — If time allows, invite participants to suggest science content that was necessary or helpful to know to understand this case study. For example, what concepts would someone need to understand about toxicology, habitats, food chains, life cycles and reproduction, and ecosystems to understand the case study? Can one learn those concepts through such a case study? Why or why not?

How might you structure a series of learning experiences for teachers so they could use this case study as a means to understand important concepts in the life sciences?

Reflections

10 min

Allow time for participants to reflect individually on this experience. We recommend that participants take time to reflect in writing and then to share their reflections if time allows.

Use Reflection 3, Master 3.9, for this reflection or design another activity or set of questions that provides an appropriate reflection for your particular audience.

What is a case?

A case is a story designed and presented to engage those using it to solve a problem, wrestle through a puzzle, discern an underlying principle, or stimulate reflection.

(Source: Miller, Moon, and Elko, *Teacher Leadership in Mathematics and Science*, 2000)

Why use case studies to deepen understanding of science as inquiry?

Most teachers have never experienced science as inquiry; therefore…

Case studies provide a window into the nature of science –how scientists go about their work.

Many teachers do not recognize inquiry as science content; therefore…

Case studies can encourage teachers to reflect on inquiry as a body of knowledge with specific guiding principles.


North America
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ARCTIC OCEAN
Bering Sea
Beaufort Sea
Alaska (U.S.)
Greenland (Denmark)
Baffin Bay
Labrador Sea
Hudson Bay
Canada
Canadian Shield
Great Plains
Rocky Mts.
Coast Ranges
Appalachian Mts.
United States
Mexico
Gulf of Mexico
CARIBBEAN
Cuba
Haiti
Jamaica
Puerto Rico (U.S.)
Dominican Republic
Belize
Honduras
Guatemala
El Salvador
Nicaragua
Costa Rica
Panama
SOUTH AMERICA
EUROPE
ATLANTIC OCEAN
PACIFIC OCEAN
Bermuda (U.K.)
Hawaii (U.S.)
Arctic Circle
Tropic of Cancer
0° Equator
80° N
60° N
40° N
20° N
0°
20° W
40° W
120° W
140° W
160° W
180°
0 1,000 Miles
0 1,000 Kilometers

Passage One

Beluga Whales in the St. Lawrence River

The Arctic beluga whales are, at maturity, pure white and highly intelligent organisms. They have lived in the St. Lawrence Seaway for millennia. As a resource, beluga whales provided traders, fisheries, and settlers with a livelihood for centuries. But, times change. Scientists estimate that the population of belugas must have been 5,000 to 10,000 near the turn of the 20th century and about 500 in the second half of the century. As the demand for whale products decreased, the beluga were increasingly ignored and almost forgotten. One would assume that the populations would increase. However, by the 1970s the population still was estimated at 500. In 1979 the Canadian government provided the whales complete protection from hunting. Despite this twenty-year protection, the population has not increased.

- Why do you think the number of whales has not increased?

- What is the question that would best guide a scientific investigation about why the population of whales does not increase?

Adapted from "Beluga Whales in the St. Lawrence River" published in The Scientific American*, May 1996*

Passage Two

Beluga Whales in the St. Lawrence River

A team of marine biologists headed by Pierre Béland began a series of investigations with one dead beluga beached on the St. Lawrence. Laboratory work showed that the whale died from renal failure. Tissue samples revealed that the whale was heavily contaminated with mercury, lead, PCBs, DDT, MIREX, and other pesticides. Investigations of two other dead belugas revealed similar results.

Still curious about why the population remained low, the biologists continued their investigations. During a 15-year period the team recorded 179 deaths and examined 73 carcasses. The entire sample was highly contaminated with an array of chemicals. Results of the study included the following.

- 40% of the organisms bore tumors, 14 of which were cancerous.
- The whales had a high incidence of stomach ulcers, including three perforated ulcers.
- 45% of females produced smaller than normal amounts of milk due to infections or tumors in their mammary glands.
- Lesions of the thyroid and adrenal glands were common.
- Some whales had compromised immune systems.

In comparison, Arctic beluga in other locations did not display any of these conditions, nor did other species of whales or seals living in the St. Lawrence. Both of the latter groups contained the same toxic substances as the belugas, but in lesser amounts. Finally the scientists also found that the toxins were not confined to the fat in blubber. Small amounts were found in other tissues, which might have contributed more readily to the injury of vital organs. In answering the original questions the scientists proposed that the whales were victims of pollution.

When the scientists presented their evidence and explanation suggesting that pollution was the cause of the low numbers and lack of increase in the beluga population, other marine biologists maintained that toxins were not at fault. The skeptical scientists argued that although the diseases and lesions observed in belugas matched the known effects of toxic chemicals, the original investigations had not demonstrated a cause-and-effect relationship.

- ➢ Based on your understanding, were the original investigations adequate? Why or why not?
- ➢ Did the scientists use appropriate tools and techniques to gather, analyze, and interpret data? How do you know?

- What evidence did the scientists use to develop an explanation that the whales died because of pollutants?
- What would be the best approach to design and conduct a scientific investigation that would demonstrate a cause-and-effect relationship?

Adapted from "Beluga Whales in the St. Lawrence River" published in The Scientific American*, May 1996*

Passage Three

Beluga Whales in the St. Lawrence River

At first, the scientist turned their attention to the most striking disorder – cancer. The incidence of cancer in belugas is twice as high as in humans and higher than in horses and cats. Restricting the comparison to gastrointestinal organs, those most affected in whales, makes this comparison even more striking. In the latter comparison the only animals that exceed whales were sheep in Australia and New Zealand. The high disease rate in the sheep populations has been attributed to carcinogenic herbicides. The sheep graze in pastures contaminated with carcinogenic chemicals. This observation eventually provided a model that applied to whales because sediments in portions of the St. Lawrence contain an extremely potent carcinogen that collects in invertebrates. Although able to detect the carcinogen in belugas, the scientists were not certain how it entered the animals' systems until they discovered that, in addition to eating fish, belugas dig into sediments to feed on bottom-dwelling invertebrates. This seemed like a good model and likely explanation for how a specific, potent carcinogen entered the belugas.

In the end, however, the cancer data were confounding. Exposure to a certain carcinogen usually harms a specific tissue, but in the belugas a variety of organs were affected. So, the investigations moved to organohalogens, the chemicals that were most abundant in the whales. Other research has demonstrated that in many animals' organohalogens impede the activity of killer cells, the immune cells that ordinarily destroy malignant tumor cells. When given to experimental animals in embryonic, fetal, and early postnatal stages, these chemicals caused defects in the nervous, endocrine, and reproductive systems. In addition, other research indicated that organohalogens stunted the production of immune cells. This line of research led to investigations that

- Examined blood samples from contaminated whales to determine the levels of organohalogens in the plasma and the numbers and responses of immune cells, and

- Determined the minimum levels at which the ill effects of organohalogens arise.

As a result of these investigations, the biologist determined that beluga whales were in fact more contaminated than expected. The researchers found the observation puzzling because larger animals typically have lower levels of toxins. There are two reasons that larger animals have lower levels of toxins: 1) smaller whales require more food per pound of body weight than do larger whales, and 2) some larger whales consume base-level plankton while other smaller whales such as the harbor porpoise consume fish that are higher in food chain, where organohalogens accrete. Application of the model developed in this line of research provided an explanation. The belugas feed on eels, which have high levels of MIREX (a chemical produced in a plant near Lake Ontario), and adult eels migrate to the Atlantic through the beluga habitat. During the course of 15 years of eating migrating eels the beluga whales would have taken in the amounts of MIREX found in dead belugas and half the amounts of other chemicals such a PCBs and DDT. The investigations continued and the evidence was helping scientists form cause-effect explanations. But as the senior scientist indicated, "At this juncture I felt like a naïve detective who had been trying to figure out how packages move between cities by searching highway vehicles at random. I got nowhere until I chanced on a mail truck" (p.63).

In this statement the scientist was referring to an alternative explanation. The investigators noticed that organohalogen levels were often higher in very young animals, which contradicted another common explanation – toxins accumulate during the animals' lifetime. Also, they found that adult females were consistently less contaminated than the males. These observations suggested the explanation that the females passed significant amount of chemicals on to their calves. When the team examined several females that had died shortly after giving birth, they found evidence for this explanation. The milk provided the evidence. The suckling calf ingests food that is far more contaminated than its mother's food. In ecological terms, the calves feed at a higher echelon in the food chain where the toxins have been concentrated. Every new wave of calves begins life with higher levels of toxins than those of their mothers. They then take in fish that also contain higher levels of toxins each year. So, each new generation begins at a less advantageous position than prior generations.

The scientists proposed an answer to the original question – What explains the lack of increase of the beluga population? All the evidence indicates that the belugas have failed to increase in number due to the long-term exposure to a complex mixture of toxic chemicals.

How does the investigation of the beluga whales illustrate scientific inquiry?

Briefly identify portions of the passage that illustrate one of the following aspects of scientific inquiry from the National Science Education Standards (NSES).

Understandings About Scientific Inquiry

- ✓ Different kinds of questions suggest different kinds of scientific investigations.
- ✓ Current scientific knowledge and understanding guide scientific investigations.
- ✓ Mathematics is important in all aspects of scientific inquiry.
- ✓ Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- ✓ Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- ✓ Science advances through legitimate skepticism.
- ✓ Scientific investigations sometimes result in new ideas and phenomena for study.

Master 3.8a

Understandings about Scientific Inquiry

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Mathematics is important in all aspects of scientific inquiry.

- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science advances through legitimate skepticism.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies.

A Case of Scientific Inquiry

Beluga Whales in the St. Lawrence River

As a learner of science

1. What did I learn about inquiry from this experience?

2. What science content did I learn from this experience?

As a designer of professional development

1. What would I need to know or be able to do to use this inquiry experience with Points of Contact?

2. How would I adapt this inquiry experience?