1 The Scientific Method

Introduction

Derived from the Latin word *scientia*, meaning knowledge, science is the ongoing process of learning through observation and testing.

The "scientific method" begins with the observation of a phenomenon. Based on that observation, a hypothesis is formed about the causes and/or consequences of the observed phenomenon. Scientists then devise experiments to test the hypothesis, collect and analyze data from the experiments, and reach conclusions.

Experimentation is designed to invalidate a hypothesis rather than prove it as true because an infinite number of alternate hypotheses would have to be tested to prove the absolute truth of any single hypothesis. Disproving a hypothesis decreases our confidence in its accuracy and expands our understanding of observed phenomena.

Even when testing appears to support a hypothesis, other scientists may challenge it by formulating an alternate hypothesis or testing method. In this way, science is an evolutionary learning process. While it gives us the best knowledge about the natural world that we have at a given time, our knowledge is continually expanding as new hypotheses are tested and new discoveries broaden our understanding. Amazing advances in technology continually improve our ability to observe and analyze the universe.

Just 600 years ago, conventional wisdom held that earth was at the center of the universe and that all the planets orbited around it. Only after Nicolaus Copernicus proposed otherwise did further research disprove that long-held theory. Today, we know that all planets in our solar system, including earth, revolve around the sun.

Sound science depends upon verifiable information and accurate testing methodologies. *If the theoretical assumptions underlying an experiment are inaccurate or the testing methods imprecise, the results of experimentation will be flawed*.

How does this relate to climate change? Our understanding of the natural world—including our climate—is evolving as a result of the scientific method. Although still incomplete, our scientific knowledge of climatology has increased tremendously in just the past few decades. However, hypotheses about climate change abound, and despite the popular media conception of consensus, the issues are far from settled. Due to the nature of the scientific method, no hypothesis can be proven absolutely true.

Lesson 1-A
The scientific method

Theme

This lesson explores the scientific method and will help students to understand how hypotheses are tested and how theories are developed. It provides tools to generate hypotheses about climate change and methods to test them.

Purpose

This lesson introduces the scientific method and allows students to become familiar with the process of using it.

Description

Students will apply the scientific method to a real-world observation. They will develop a hypothesis and discuss ways to test it. The purpose of the lesson is to help students understand that science evolves and that knowledge is gained through the application of the scientific method.

Procedure

1 Ask your students to think about science. What *is* science?

Science is the evolutionary process of learning through observation and testing.

2 Present *Visual 1.1: Science*. Discuss some of the scientific theories that were once believed to be true, but have since been revised or disproved.

For example, Galileo was convicted of suspicion of heresy for teaching that the sun, not earth, was at the center of our solar system (as originally formulated by Copernicus). Today, we know this to be true.

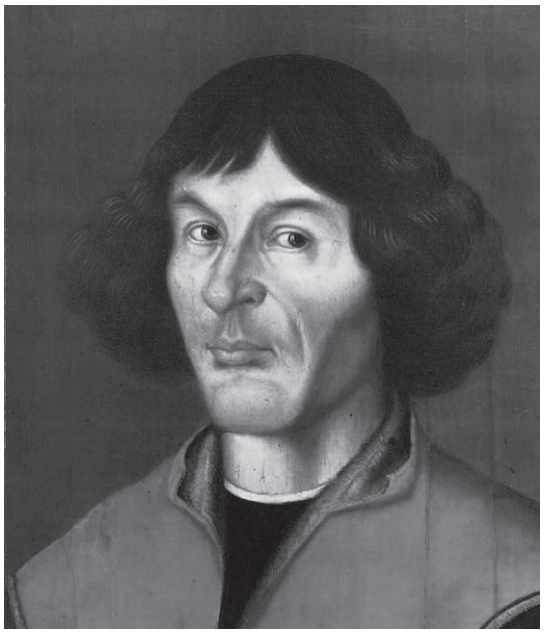
Scientific knowledge advances when scientists have the courage to question conventional ideas and to propose new theories supported by all the available evidence.

3 Present *Visual 1.2: The scientific method*. Discuss the importance of the scientific method.

It is a process of making observations, forming hypotheses, testing the hypotheses, collecting data, and reaching conclusions. No hypothesis can be proven to be absolutely true; there will always be alternate hypotheses and testing methods that challenge a hypothesis' veracity.

4 Hand out *Worksheet 1.1: The scientific method*. Have each student record a simple observation about the natural world (e.g., leaves are green; the grass is wet in the early morning). Have students follow the steps in *Visual 1.2: The scientific method* to develop a single-sentence hypothesis about why the observed phenomenon has occurred. It is not necessary for the hypothesis to be correct. Students will not be designing an experiment to test their hypothesis, but they should be able to identify at least three pieces of evidence that either support or refute their hypothesis.

Visual 1.1
Science



Nicolaus Copernicus

Is the earth the center of the universe?

Is the earth flat?

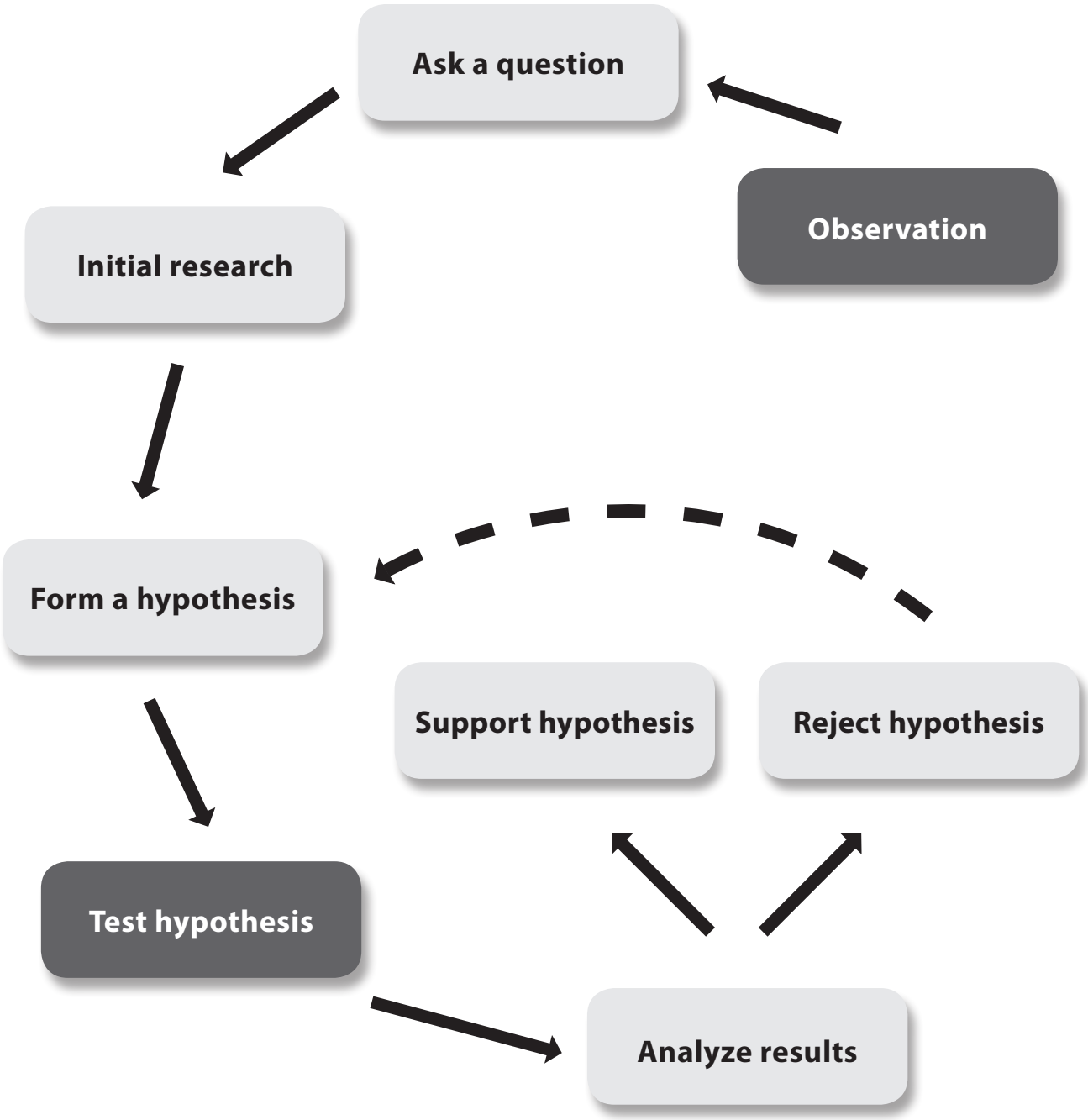
Are diseases caused by evil spirits?

Are natural disasters created by angry gods?

Does smoking pose a threat to your health?

Our history is full of examples where "common knowledge" was discarded in favor of more correct hypotheses.

Visual 1.2
The scientific method



Worksheet 1.1
The scientific method

Name:_____

Observation: Make an observation about the natural world.

Ask a question: Form a question about your observation.

Initial research: Brainstorm some potential causes that might answer your question.

Form a hypothesis: Pose a possible answer to the question in the form of a statement.

List three pieces of evidence a scientific test might yield that would either support or refute your hypothesis:

Lesson 1-B

Climate change hypothesis

Theme

Students have different ideas about climate change that they gather from various sources, not all of which have made conclusions based on proper scientific methods. Some students may believe that climate change is the result of human activity (i.e., that it is "anthropogenic"). Others may believe that climate change is a natural phenomenon. Still others may believe it to be the result of a combination of natural and anthropogenic factors.

Purpose

This lesson challenges students to think critically about climate change using the scientific method. It gives students the opportunity to explore their ideas and opinions, comparing them to alternate hypotheses.

Description

The class will organize a scientific investigation. Each student will take on the role of a scientist observing climate change and will employ the scientific method to develop and test a hypothesis about climate change.

Procedure

1 Engage your class in a discussion about their opinions about climate change and global warming, and ask them where they have obtained their information. Some questions to consider:

- What evidence suggests that our climate is changing?
- What observations have the students made?
- Are they convinced that the earth's climate is warming?
- Do they think that there are climate change skeptics within the scientific community?
- Do they believe that temperature change is the result of human activity? Are there other possible causes?
- How many students have watched movies or documentaries about climate change?
- How many students have read books or other research on the subject?
- Are there any students who have gleaned all they know about climate change from newspapers, TV, and radio?

2 Hand out *Worksheet 1.2: Climate change hypothesis*. Have students complete the worksheet individually, in the same manner as *Worksheet 1.1: The scientific method*. They may use any observation related to climate change.

3 Have each student present their hypothesis to the class. Discuss the different ideas proposed. Examples of hypotheses may include:

- Climate change is a natural, cyclical occurrence.
- Man-made emissions of carbon dioxide are responsible for climate change.
- There will be catastrophic consequences arising from climate change if we do not curtail greenhouse gas emissions.

4 Pick one of the students' hypotheses to use as a class example. Not all students need to agree with the hypothesis. Discuss how one might attempt to test it.

- What types of data and analyses would be useful to test the hypothesis?
  E.g., temperature data, weather pattern data, visual analysis of graphs, historical measures, human CO_2 emissions, etc.

- Where could such data be found?
  E.g., weather balloon temperature data from the troposphere, ice core samples, historical ground surface temperature records, etc.

- Is the testing method created by the class reliable (consistent in measurement) and valid (the best available approximation of the truth)? Would it provide useful results?

5 What conclusions can be made about the hypothesis based on the evidence or data available to the class?

Final Thought

It is important to re-evaluate prevailing ideas as more information becomes available. Critical thinking involves challenging our beliefs with alternate ideas. Science, which relies on the scientific method, is an ongoing process of forming new or alternate hypotheses, and then testing them to improve our knowledge of the natural world, including our climate.

Worksheet 1.2
Climate change hypothesis

Name:_____

Observation: Make an observation about climate change.

Ask a question: Form a question about your observation.

Initial research: Brainstorm some potential causes that might answer your question.

Form a hypothesis: Pose a possible answer to the question in the form of a statement.

List three pieces of evidence a scientific test might yield that would either support or refute your hypothesis: