

LISELL

Lesson Starters

Coordinating Hypothesis, Observation and Evidence



Teacher Background

LISELL Inquiry Practice 1

Coordinating Hypothesis, Observation and Evidence

Our working definition of a *hypothesis* in the LISELL project is that it is **an expectation or prediction of what should happen in a given situation based on prior knowledge or experience**. Students develop hypotheses based on their observations and their academic and informal prior knowledge. Without considering prior knowledge relevant to a situation, students can make a guess about what might happen, but they will not be able to form a true hypothesis.

For example, most middle school students have had some experience growing plants, either at home or at school, and can tell you that plants need light, water and nutrients (usually from soil) to grow. Thus, students should be able to generate a reasonable hypothesis when asked what will happen when one plant is put in a dark closet for two weeks and a second plant is put in a sunny window. However, most middle school students have not had much experience with ozone layer depletion and the effects of UVB radiation on plants and so, while they might guess, they could not make a true hypothesis when asked about the effects of doubling UVB radiation on bean plants.

Hypotheses are important in science, but they cannot stand alone. They need to be evaluated using **observations and evidence**. In science, observations usually involve more than just what we see with our eyes. **Observations can involve all of our senses and the use of tools (e.g., microscopes, balances) that allow us to observe and measure things that we could not detect with our human senses**. Students gain experience with scientific observation through active engagement in science investigations. In the simple plant experiment described above, for example, students could measure and record plant height and observe and record plant color for the plant in the closet and the plant in the window each day for two weeks.

Not all observations will help to evaluate a hypothesis. Students need to learn how to select particular observations that can serve as evidence. **Evidence is constructed from observations for the specific purpose of evaluating a hypothesis**. That is, without a clear hypothesis, students can make observations, but they will not have any evidence. For example, the students who are collecting observational data about changes in plant height

and changes in plant color will need to decide how these data can serve as evidence to support or refute their hypotheses about the effects of darkness and sunlight on plant health.

Middle school students (and many adults too) have a hard time distinguishing among and connecting hypotheses, observations and evidence. Sometimes a student's hypothesis will fail to explain his or her observations. Perhaps a group of students hypothesize, based on their previous experience with electrical circuits, that if they complete a circuit, an attached lightbulb will light. Then they observe that when they complete an electrical circuit with a rubber band, the bulb does not light, but when they complete the circuit with a nail, the bulb does light. Thus, they conclude that their hypothesis did not match all of their observations. The complete circuit with the rubber band and the unlit bulb is evidence that refutes their hypothesis. The complete circuit with the nail and the lit bulb is evidence that supports their hypothesis. The students should conclude that their hypothesis needs to be revised, but not totally replaced. (More research will teach them that a circuit completed by an insulator will not light a bulb but a circuit completed by a conductor will light the bulb).

Revising a hypothesis can be quite difficult for people to do, especially when they have held that hypothesis for a long time. There is a good deal of research in psychology showing that people are very resistant to giving up ideas they already believe to be true, even when confronted with clear evidence to the contrary. Scientists work hard to train themselves to become better at this -- to test their hypotheses with an open mind by making careful observations and then critically examining evidence to help them refine, revise or totally replace their hypotheses.

In the LISELL project, we want students to learn that in science it's okay to be completely wrong about a hypothesis they make, as long as they learn from their observations and use their evidence to construct more accurate hypotheses. We have created a set of lesson starters that give students brief, focused opportunities to think, talk and write about how scientists develop hypotheses, observations and evidence and make connections among them.

LISELL Lesson Starter Coordinating Hypothesis, Observation and Evidence

The Invention of Rubber Tires

Have you heard of Goodyear tires? The tire company is named after Charles Goodyear (1800–1860), who invented vulcanized rubber, the type of rubber used to make tires. Goodyear was trying to find a way to take raw rubber from a rubber tree and turn it into a strong covering for the metal wheels that were common on **vehicles** in the 1800s. Goodyear knew that raw rubber would not make a good tire because it quickly wore out and fell apart.

Goodyear **hypothesized** that if he mixed the rubber with other chemicals he could make the rubber stronger. He tried different chemicals and **observed** what happened, but the rubber still wasn't strong enough. One day, Goodyear accidentally dropped some rubber onto a hot stove, and **observed** that the high temperature made the rubber stronger. The **evidence** showed that Goodyear's **hypothesis** was wrong. It was not chemicals that made rubber stronger; it was heat.



With a partner, do one of the following activities:

- 1) Write a sentence that describes in your own words Goodyear's first **hypothesis**. (Remember that a hypothesis is a prediction of what will happen based on what you already know, and is a statement, not a question.)
- 2) Write a sentence that describes the **evidence** that showed that Goodyear's first **hypothesis** was wrong.

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The Discovery of Phosphorus



Some important **discoveries** in chemistry have been made by accident. One example is the discovery of the **element** phosphorus by the German scientist Hennig Brandt in the 1700s. Brandt had a **hypothesis** that he could **create** gold from other, less valuable elements in nature. He **hypothesized** that because urine was gold colored, it would be possible to extract gold from it. First, he collected large amounts of urine in barrels. Then he stored the urine for many months until it became a dry (and very smelly) paste. When the urine dried, Brandt **observed** that it did not contain any gold, but it did have an unusual **property**: It glowed in the dark! His **evidence** led him to reject his first hypothesis, but also to form a new hypothesis, that he had discovered a new chemical element.

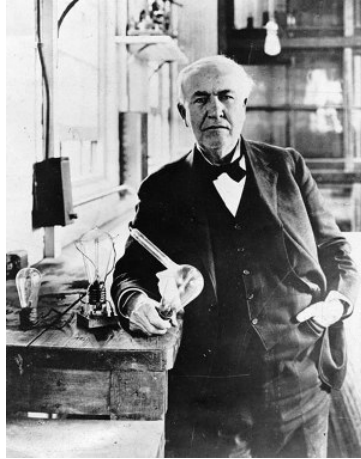
It turned out that the dry urine paste contained **concentrated** amounts of the element phosphorus. Brandt observed that the phosphorus glowed and also easily caught fire when rubbed. His use of hypothesis, observation and evidence lead to the invention of the match and of “glow in the dark” paint. The tips of matches are still made mostly of phosphorus.

With a partner, do one of the following activities:

- 1) In your own words, write down what Brandt’s first **hypothesis** was. (Remember that a hypothesis is a prediction of what will happen based on what you already know, and is a statement, not a question.)
- 2) In your own words, write down what this story teaches us about the importance of careful **observation** in science.

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Edison Invents the Light Bulb



The inventor, Thomas Edison, is remembered for having many brilliant ideas, but he also worked very hard on problems. When he wanted to solve a problem, he tried every possible **combination** until he came up with a **solution**. A good example is his invention of the light bulb. Edison had a **hypothesis** that if he burned the right material inside a vacuum **chamber** it would glow for a long time. He began to test his **hypothesis** by making **observations** using many different types of materials. He tried hundreds of materials in his lab but could not get the result he wanted.

One day, feeling frustrated, he went digging through his wife's sewing basket and found a thin strip of bamboo. When he burned the bamboo strip inside the vacuum chamber it provided a bright and long-lasting glow. This was the **evidence** that Edison was looking for to support his hypothesis that it was possible to **create** a "glowing bulb." Using hypothesis, observation and evidence, Edison invented the light bulb that **revolutionized** the way humans live and work today.

With a partner, do one of the following activities:

- 1) Write a sentence that describes in your own words the **observations** Edison made that did not support his **hypothesis**.
- 2) Choose one sentence from the paragraph and rewrite it in a simpler way so that a 3rd grader could understand it.

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Studying How Diseases Spread



John Snow was a **medical** doctor in London in the 1800's. He is known as the "father of epidemiology." Epidemiology is the study of how diseases spread. Snow was **concerned** about the cholera **epidemics** that killed many people in London during the 1840s. Cholera is a disease that causes high fever, severe diarrhea, and **eventually** death. At this time, doctors thought that the only way for diseases like cholera to spread was through the air. But John Snow had a different **hypothesis**. He thought that cholera probably spread through drinking **contaminated** water, but he had no **evidence** to prove this. The other doctors didn't believe him.

In 1854 there was another large cholera epidemic in London, and Snow developed a plan to test his **hypothesis**. He began to make **observations** by collecting data about the home address of each person who died from the disease. He got a large map of London and plotted the points of all the deaths on his map. It became clear that there was a central point around which most of the deaths had occurred. Snow saw that there was a water pump at the center of this **area** that nearly all of the victims had used. To test his hypothesis, Snow **convinced** the mayor to remove the handle from the pump to prevent people from getting the water. He **observed** that the disease stopped spreading. This was the evidence that Snow needed to convince the other doctors that his hypothesis was correct – the cholera disease was spread by drinking contaminated water.

With a partner, do one of the following activities:

- 1) Write a sentence that describes in your own words the **evidence** that Dr. Snow used to support his **hypothesis**.
- 2) Choose one sentence from the paragraph and rewrite it in a simpler way so that a 3rd grader could understand it.

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Nutrition



You have probably learned about the digestive system in science class. You have learned that your body gets the **energy** you need to **function** from the food you eat. You learned that the digestive system contains many **structures** and organs and that each has a special job. You learned that the digestive organs work together to turn food into energy, so your body can work and grow.

But does this knowledge have any value to you? Why should you care? Knowing about your digestive system can help you understand the importance of nutrition for life-long health. Did you know that over a quarter of middle school students in the United States are now **considered** to be overweight, compared to about 15% of students two **decades** ago and less than 10% of students four decades ago? What has caused this **dramatic** change?

Talk about these two questions with a partner and then write your answers:

- 1) What is your **hypothesis** about what has caused the increase in overweight middle school students? (Remember that a hypothesis is a prediction of what will happen based on what you already know, and is a statement, not a question.)
- 2) What **observations** could you make in school to begin to test your hypothesis?

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Exercise



As people get older, it gets harder to stay fit. Endurance, strength, and **flexibility** all **decrease** as we age. All of these changes are natural and, to some degree, **unavoidable**. There are many things we can do, however, to slow and **reduce** the effects of this **gradual** physical **decline**. For example, **maintaining** a healthy body mass **index** (BMI), not smoking, and being physically active can all lead to higher life-long fitness levels.

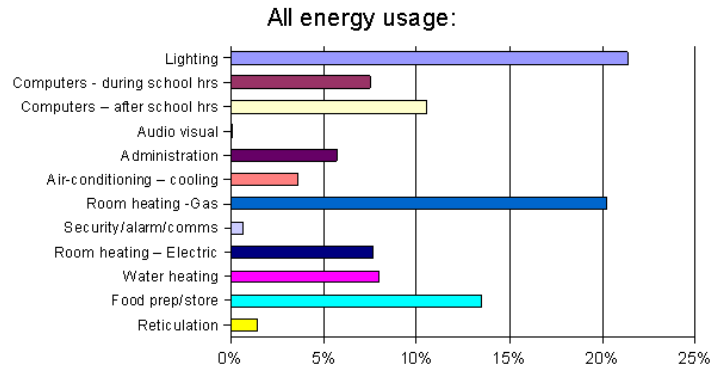
It is easier and more **effective** to develop healthy fitness **practices** when you are young. There are other **benefits** that come from physical fitness as well. A recent study of nearly 2 million students in Texas schools found that students who scored high on the state **physical** fitness test were more likely to get better grades, to have better school attendance, and to have fewer disciplinary referrals than students who scored low on the fitness test.

Talk about these two questions with a partner and then write your answers:

- 1) What is your **hypothesis** about why the students in Texas who exercised more also did better in school? (Remember that a hypothesis is a prediction of what will happen based on what you already know, and is a statement, not a question.)
- 2) What **observations** could you make to begin to test your hypothesis about the students in Texas?

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School Energy Audit



Schools are big buildings that use a lot of electricity, natural gas and other **sources** of **energy**. There are many ways that a school can save energy, and money. Schools with **effective** energy conservation programs have been shown to save as much as 25% of their **utility** budgets per year. The most effective energy conservation programs **involve** everyone in the school, including students, staff, teachers, and administrators. But someone needs to take the lead – why not your class?

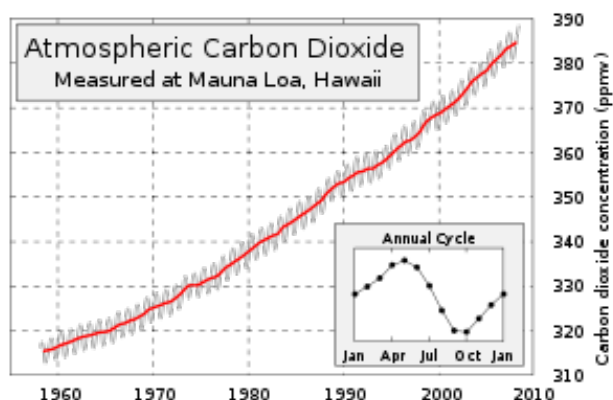
The first step is to do a school energy **audit** to look for ways that energy could be used more **efficiently**. For example, are there incandescent light bulbs that could be replaced with energy-efficient **compact** fluorescent (CFL) light bulbs? Are there rooms where lights, heat or air conditioning are being left on when there is nobody there? Could air conditioning and heat be turned down a few degrees? Are windows well insulated to keep heat and air conditioning in? Are computers and other electronics being turned off at the end of the day? There are websites that can help you plan and **conduct** an energy audit, such as the National Energy Development Program (<http://www.need.org/>).

Work with a partner, write your answer to one of these questions:

- 1) What is your **hypothesis** about one way that your school is not very efficient in its energy use? (Remember that a hypothesis is a prediction of what will happen based on what you already know, and is a statement, not a question.)
- 2) What **observations** could you use as **evidence** to support your **hypothesis**?

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Climate Change



Charles Keeling (1928—2005) was an American oceanographer. He tracked the long-term levels of carbon dioxide (CO₂) change in the atmosphere that first alerted the world to the human effects on climate change. In 1956, he set up his instruments on the top of Mauna Loa in Hawaii and collected atmospheric carbon dioxide **data** twice daily for 50 years, until he died in 2005. Over time, this continuous record, known as the Keeling Curve, began to show the first **significant evidence** of the **progressive** buildup of carbon dioxide, a greenhouse gas, in the atmosphere. The curve shows an average **annual** increase in atmospheric carbon dioxide of 0.44%.

Because of its longevity and **accuracy**, the Keeling Curve is considered to be the most important data set in climate science. Keeling's graph brought the world's attention to the effects that human activities have on the Earth's atmosphere and climate.

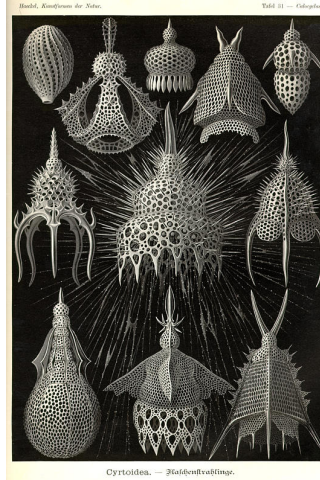
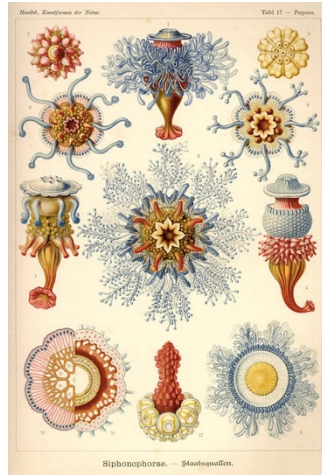
With a partner, write your answers to the following questions:

- 1) Do you think Charles Keeling had a **hypothesis** when he began his work? In your own words, write down what you think it was. (Remember that a hypothesis is a prediction of what will happen based on what you already know, and is a statement, not a question.)
- 2) In your own words, write down what this story teaches us about the importance of careful **observation** in science.

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Art and Science



Ernst Haeckel (1834–1919) was a German biologist who studied **comparative** anatomy and **evolution**. He was also an artist. He spent many years studying small **marine** invertebrates, including radiolarians and sea sponges, creatures that most scientists thought were uninteresting. Haeckel **created** a **series** of beautiful and **precise** scientific drawings of these tiny creatures for which he became well known. He discovered nearly 150 new species of radiolarians and also coined terms that are commonly used in biology today, including phylum and ecology. However, Haeckel was always most well known for his scientific drawings.

Talk with a partner about these two questions and then write what you think:

- 1) Do you think drawings are **observations**? Why or why not?
- 2) Could Haeckel's drawings be used as **evidence** to support a **hypothesis** about tiny sea creatures? How?

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Chlorofluorocarbons



Frank Sherwood Rowland (1927-) is an American chemist who discovered that chlorofluorocarbons (CFCs) cause ozone **depletion** in the atmosphere. CFCs are manmade chemicals that were very common in aerosol sprays like deodorant and hair spray, and in air conditioners in the 1960s and 1970s. Ozone (O_3) is a molecule made of three oxygen atoms that exists in the upper atmosphere and that protects the Earth from dangerous solar radiation.

Rowland **developed** a **hypothesis** in the 1960s that manmade gases could combine with solar radiation in the upper atmosphere to **create** the gas chlorine monoxide. This gas would destroy large numbers of ozone molecules. Roland **conducted** research to **observe** the effects of chlorine monoxide on ozone in his lab and in nature. He presented his **evidence** to the U.S. Congress in 1978, and Congress passed **legislation** to ban CFC-based aerosol sprays and air conditioners in the United States. Since that time efforts have been made to **eliminate** the use of CFCs worldwide.

With a partner, do one of the following activities:

- 1) Write a sentence that describes in your own words the **evidence** that Roland Sherwood presented to Congress to support his **hypothesis**.
- 2) Choose one sentence from the paragraph and rewrite it in a simpler way so that a 3rd grader could understand it.