EXPERIMENT

The Scientific Method

Hands-On Labs, Inc.
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Read the entire exercise before you begin. Take time to organize the materials you will need and set aside a safe work space in which to complete the exercise.

Experiment Summary:

In this experiment, you will identify the importance of science and how it is a part of our daily lives. You will list and describe the steps of the scientific method, and define control groups, independent and dependent variables, and quantitative and qualitative data. You will also conduct research on topics associated with global climate change, develop hypotheses, and conduct experiments to test those hypotheses. Finally, you will use all of the knowledge gained throughout the lab to design your own experiment that demonstrates the importance of sea ice in regards to global temperatures.

Learning Objectives

Upon completion of this laboratory, you will be able to:

- Relate science to your daily life.
- List and describe the steps of the scientific method.
- Describe controlled experiments and define conditions, independent and dependent variables, and controls.
- Differentiate between qualitative and quantitative data.
- Demonstrate the weight difference between dry air and carbon dioxide (CO_2).
- Model the effects on temperature of normal and excess levels of greenhouse gases.
- Design your own experiment to model the effects of sea ice on water temperatures.

Time Allocation: 5 hours

Materials

Student Supplied Materials

Quantity	Item Description
1	Baking soda
1	Bottle of vinegar
1	Box of matches or lighter
1	Candle
1	Clear plastic wrap
1	Coffee cup
2	Containers of equal size; Suggestions: - Plastic containers - Milk cartons - Cardboard boxes - Glass dishes
1	Digital camera or smartphone
1	Dish soap
2	Large jars or glasses (with no bottleneck)
1	Measuring cup, 1 cup
1	Metal kitchen spoon
1	Pair of scissors
1	Pen or pencil
1	Reflective surface; Suggestions: - Aluminum Foil - Mirror - Slab of metal
1	Roll of paper towels
1	Rubber band
1	Set of measuring spoons, 1 tablespoon and 1 teaspoon
2	Sheets of white paper
1	Source of heat; Suggestions: - Direct sunlight - Heat lamp - Incandescent light (non-LED/energy saving light bulb)
1	Source of tap water
1	Stopwatch or timer
1	Tape, clear

2	Thermometers, analog mercury filled*
1	White paper product: - Construction paper - Card stock - Foam board - Poster board

*The recommended thermometers for performing this experiment are standard oral or anal analog thermometers that can be found at pet stores or drug stores. If you do not have access to two analog thermometers, one digital thermometer may replace one of the analog thermometers for Exercise 2. If you choose to do this, be certain to include this information in your Lab Report Assistant to account for variability in using two different materials. For Exercise 3, digital thermometers may be used if necessary.

To fully and accurately complete all lab exercises, you will need access to:

1. A computer to upload digital camera or smartphone images.
2. Basic photo editing software such as Microsoft® Word or PowerPoint®, to add labels, leader lines, or text to digital photos.
3. Subject-specific textbook or appropriate reference resources from lecture content or other suggested resources.

Background

What Has Science Done for You Lately?

The modern world would not be so advanced if it were not for technology, courtesy of science. Science is responsible for most modern conveniences such as electricity, raw material production, communication resources, and agricultural practices that supply food worldwide. Health care would not be what it is today without science. We would not have X-ray or MRI machines, prosthetics, medications or vaccinations, or knowledge that hand-washing reduces the spread of disease-causing microbes. Science is the foundation for most innovations. Science promoted the invention of cars in the 1800's, and science continues to contribute to current transportation innovations such as improved gas mileage, reduced carbon emissions, and new discoveries regarding alternative fuels. Science also promotes the conservation of our planet through the preservation of millions of living species. See Figure 1.

Figure 1. A few developments made possible by science. ©Robert Adrian, Noyan Yimaz, jaroslavaV, Goran Bogicevic, Ekaterina Minaeva, Everett Historical, STUDIOMAX, Spotmatik Ltd, Andre w Mayovskyy, pixinoo, Harvepino, aastock, Triff

Because of the role science plays in our everyday life, it shapes not only our personal decisions, but also policies and regulatory decisions made by the government. The creation of nutrition and warning labels, and the illegal dumping of hazardous waste are just a few protections developed because of science.

The Scientific Method

Science is important in our daily lives, but how is science conducted? Scientists investigate and learn about the world either by an open-ended discovery process or by application of the scientific method.

The **scientific method** is a process used by scientists to acquire new knowledge or correct previous knowledge, solve a problem, or develop theories or explanations of natural phenomena. Scientists use the scientific method to collect and report information that is free of bias or opinion. The general process and the typical order of the steps are shown in Figure 2.

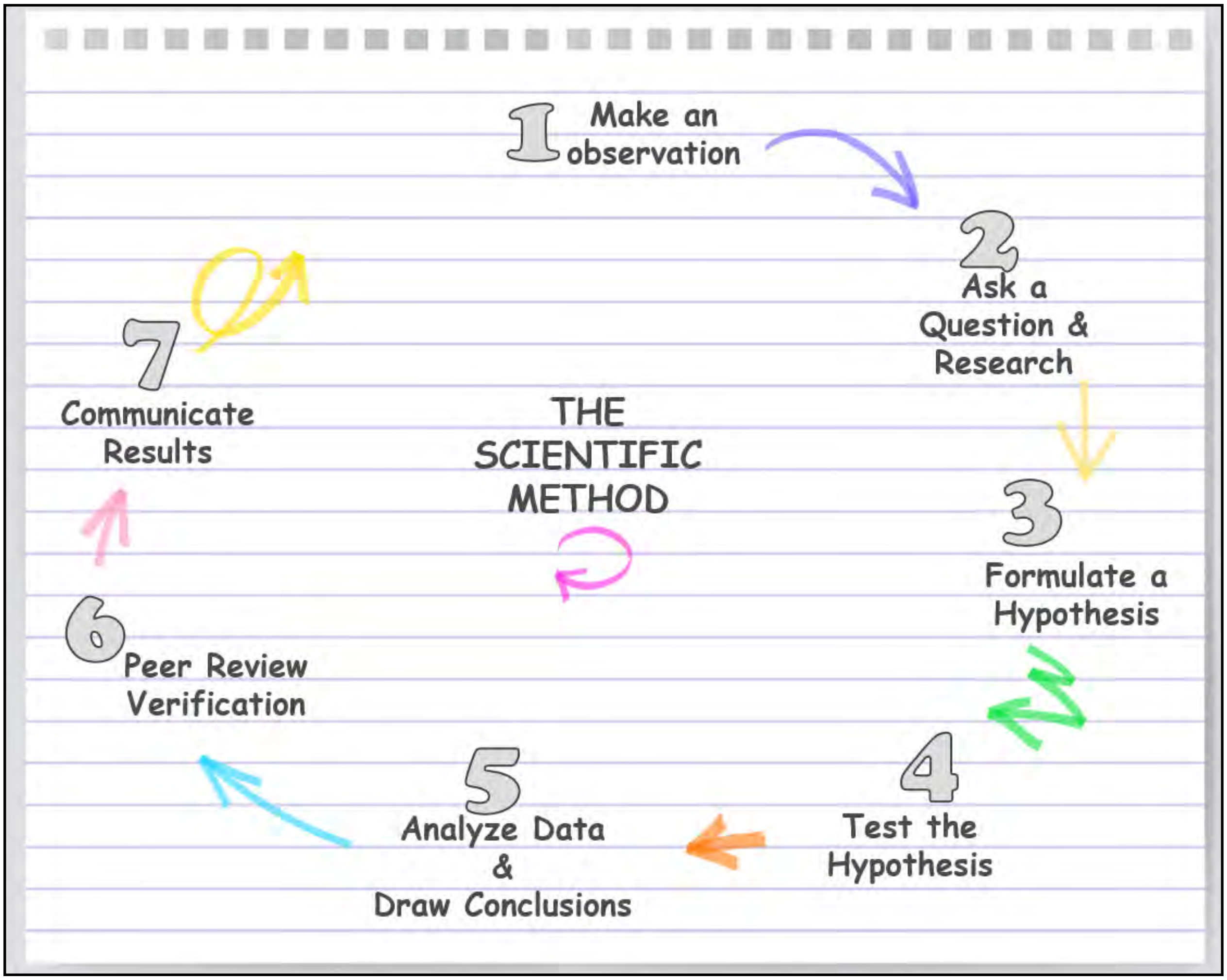

Figure 2. The scientific method. ©schab and janoon028

The scientific method has seven steps:

1. Make an observation.
2. Ask a question and conduct background research on what is already known.
3. Formulate a hypothesis.
4. Test the hypothesis through experimentation.
5. Analyze data and draw conclusions.
6. Verify the conclusions through peer review.
7. Communicate the results.

The steps may vary, based on the scientist's needs. For example, background information may be researched before conducting observations and asking questions. The steps of the scientific method are continuous and often lead to greater advancements in science through new observations and questions, all of which result in continued investigation. Often the results of discovery-based science are then used as the observations for a hypothesis-driven investigation.

Observations, Questions, and Research

Many research projects begin with simple observations. Observations should be objective and verifiable by other scientists. Clear observations lead to research questions. For example, an ecologist who observes a unique stand of trees in one area of the forest might ask, "Why is this unique tree species growing in this area?" The ecologist would then conduct research and collect background information about the tree species' needs, such as how much nitrogen must be in the soil or how much water is needed for the tree to grow in an area. The ecologist might also look into how the tree reproduces and disperses seeds. Once information is collected, the scientist could begin to theorize about why the unique tree is growing in that particular location.

Formulating and Testing a Hypothesis

A **hypothesis** is a proposed explanation for a phenomenon and is a starting point for further investigation. A good hypothesis has the following characteristics:

- Is best stated as "if, then" to imply cause and effect
- Holds across space and time
- Is a tentative idea
- Agrees with available observations
- Is simple
- Most importantly, a good hypothesis is testable and potentially falsifiable. In fact, some of the most important scientific discoveries resulted from experiments in which the original hypothesis was NOT supported.

Hypotheses can begin broad and after research is conducted new hypotheses can be formulated for a more detailed explanation or discovery. For example, a scientist might hypothesize that “if nitrogen is the primary nutrient for plants, then they will grow more rapidly with nitrogen fertilization than with phosphorus or potassium fertilization.” Once a hypothesis is formulated, the scientist designs a study to test the hypothesis.

Controlled experiments are commonly used to test hypotheses. A controlled experiment is a scientific investigation in which both the control group and experimental groups are kept under similar conditions apart from the variable being tested so that the effect or influence of the variable can be identified. A **variable** is one or more condition that is subject to change. There are two types of variables, independent and dependent. **Independent variables** are the variable being studied and manipulated during the experiment. As the scientist changes the independent variable, he/she makes observations. **Dependent variables** are the outcomes that are observed from the effect of the variable(s) on the study. The value of the dependent variable depends on how the independent variable is manipulated. A **control group** is not exposed to the variable(s) being tested. For many experiments, a control group is necessary to compare the results of the experiment.

Figure 3 shows an example of a controlled experiment regarding plant growth in relation to specific nutrients typically found in fertilizers. The independent variable, the factor being manipulated, is the type of nutrient (nitrogen, phosphorous, or potassium) in the fertilizer. The dependent variable, the outcome being observed, is the amount of plant growth, which could be the measurement of height in millimeters or centimeters. The plant that is not given any fertilizer is considered the control because it is not being exposed to any added nutrients. Conditions not differing between experimental and control groups include sunlight exposure, soil type, and water availability.

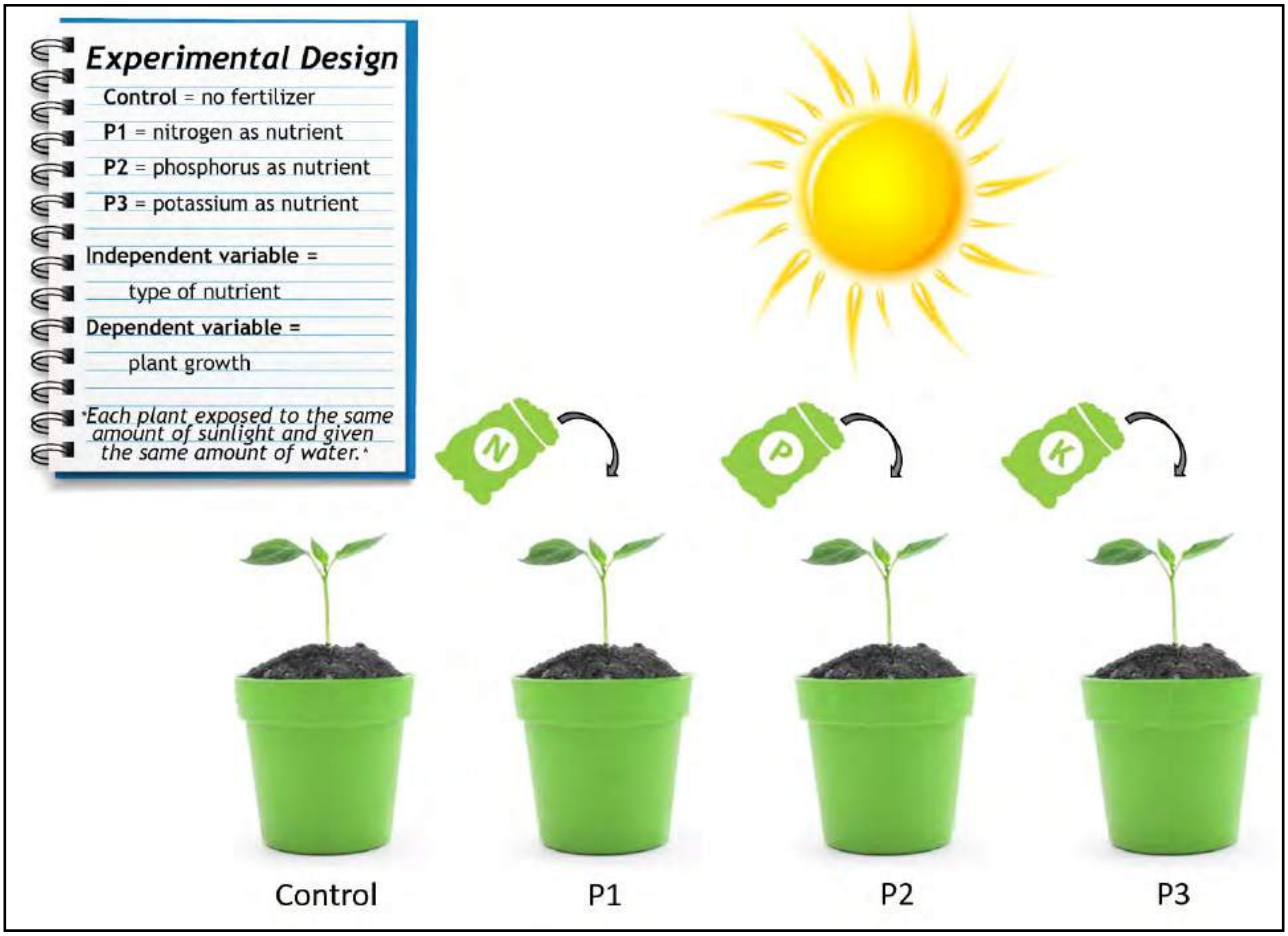

Figure 3. Controlled experiment of plant growth versus the type of nutrient given to the plant.
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Experimental Design Example

Consider another example of an experiment; a scientist wants to determine if Drug X is effective for reducing blurred vision in patients with multiple sclerosis. The experimental design follows:

- **Observation:** The chemistry of Drug X is designed to target and improve vision in patients with multiple sclerosis.
- **Question:** What percent of patients that use Drug X experience reduced blurred vision?
- **Hypothesis:** If Drug X is effective, then it will reduce blurred vision in at least 30% of patients with multiple sclerosis.
- **Independent variable:** Drug dosage: amount (mg) of the drug consumed by each patient each day.
- **Dependent variable:** Percentage of patients with reduced blurred vision.
- **Control group:** Given a placebo (a sugar pill that does not contain the drug) in place of Drug X.

Let's assume that the drug is effective at reducing blurred vision in 30% of patients. In this case, it would be said that, "The hypothesis is supported." One key aspect of all hypotheses is that they *cannot* be proven true. In this example, not all patients on earth with multiple sclerosis were included in the experiment. Therefore, science cannot prove that the drug is effective for all patients.

However, a hypothesis can be rejected or refuted based on the results. Let's assume that the drug was only effective at reducing blurred vision in 20% of patients or that the control group also experienced a 30% reduction in blurred vision. In this case, it would be said that, "The hypothesis is rejected." The scientist would ask new questions and refine the experimental design. Regardless if a hypothesis is supported or rejected the purpose of the experiment is fulfilled, in that we learn something new.

Analyzing the Data

Data collected from the experimental process must be analyzed before conclusions are made regarding the hypothesis. There are two types of data: **quantitative** data are numerical, and **qualitative** data are non-numerical. Recall the example with Drug X. An example of quantitative data would be the numeric scores that patients receive during formal vision tests. An example of qualitative data would be the patient's opinion of whether their vision has improved. Analyzed data is typically illustrated as graphs, tables, and charts.

Independent variables are usually plotted on the horizontal axis (x-axis) and the dependent variable is plotted on the vertical axis (y-axis). Figure 4 shows a bar graph that describes data associated with Drug X from the earlier example. Notice that dosage amount (the independent, manipulated variable) is on the x-axis, and the percentage of reduced blurred vision (the dependent, outcome variable) is on the y-axis. Scientists would use this graph to show that vision test scores increased for more than 30% of patients at a 20 mg dose of Drug X.

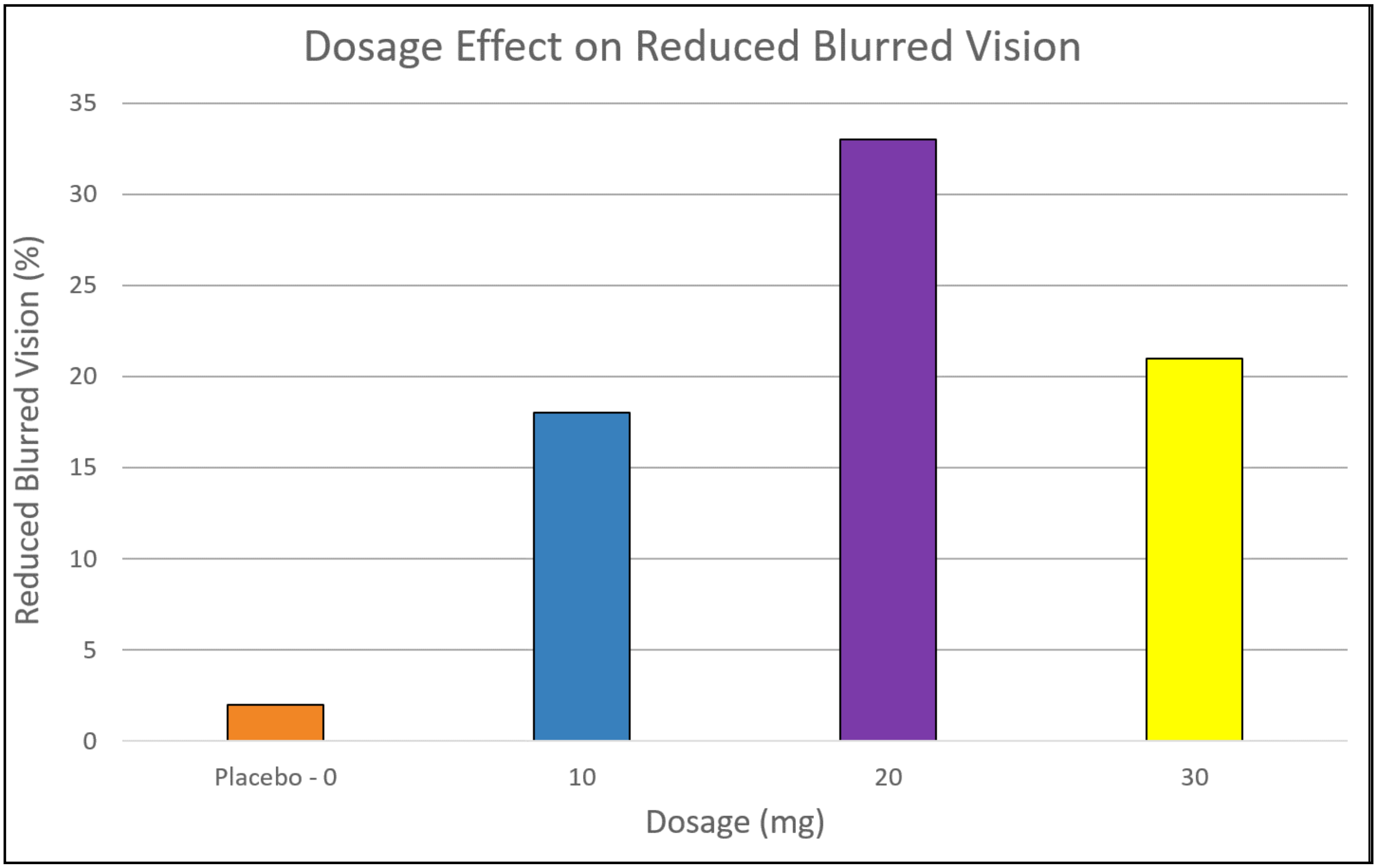

Figure 4. Example of a scientific figure for the effects that dosage of Drug X has on the percentage of patients with reduced blurred vision.

Statistical analysis is used to evaluate scientific data to determine if there is a significant difference between the control group and the experimental group. For example, if analysis of Drug X shows that 30% or more patients had a reduction in their blurred vision compared to patients in the control group that were given the placebo, then the hypothesis can be supported. For the purposes of this experimentation, you will not be asked to carry out a statistical analysis for the data you collect.

After a scientist analyzes the data they begin to draw conclusions based on the data and write a report on the findings of the experiment. This report includes the background research that was conducted, the experimental design, data results, and conclusions. The conclusions typically include an explanation about why the hypothesis was supported or refuted, a comparison of the investigation to other similar research, and ideas for future experimentation.

Peer Reviewed Verification

For research to be reliable, it must be validated by a group of qualified peers. Most scientists send their findings to respected peer-reviewed journals for validation and publication, such as *Nature*, the journal pictured in Figure 5. The validation process is stringent and the report is reviewed by multiple topic area experts that provide recommendations for revisions. Then, the report may be accepted for publication in the journal. In addition to published papers, research findings are also shared via posters and live presentations. Presenting findings allows other scientists to verify results, develop new tests for existing hypotheses, and develop entirely new hypotheses of their own. Sharing the knowledge gained leads to solving other problems and facilitates the cycle of the scientific method.

Figure 5. A cover of "Nature - The International Weekly Journal of Science." ©www.nature.com

Large-Scale Investigations

The scientific method is used for many types of investigations beyond controlled experiments. Scientists often conduct large scale analyses, or **meta analyses**, that include data from multiple published investigations. Meta analyses can answer questions on a broader scale using validated data from other scientific experiments. Scientists regularly use complex computer models and extensive datasets to describe large-scale phenomena that cannot be captured with simple experimental designs. One example of using the scientific method for a large-scale analysis is monitoring climate change. Climatologists, ecologists, geologists, chemists, biologists, and other scientists are working together to compile data and protocols that can be used by other experts to continue cutting-edge research.

Climate change studies are difficult to reproduce since independent variables, such as the weather, cannot be controlled. For example, a scientist studying methane concentrations at a natural gas site in Colorado would have different results than a scientist conducting the same study at a site in Italy. However, the aggregation of data from multiple sites provides insight into climate change on an expansive, global scale rather than a smaller, regional scale. Climatologists have aggregated temperature data since the late 1800's because climate must be measured over the course of decades and not yearly like the weather. See Figure 6.

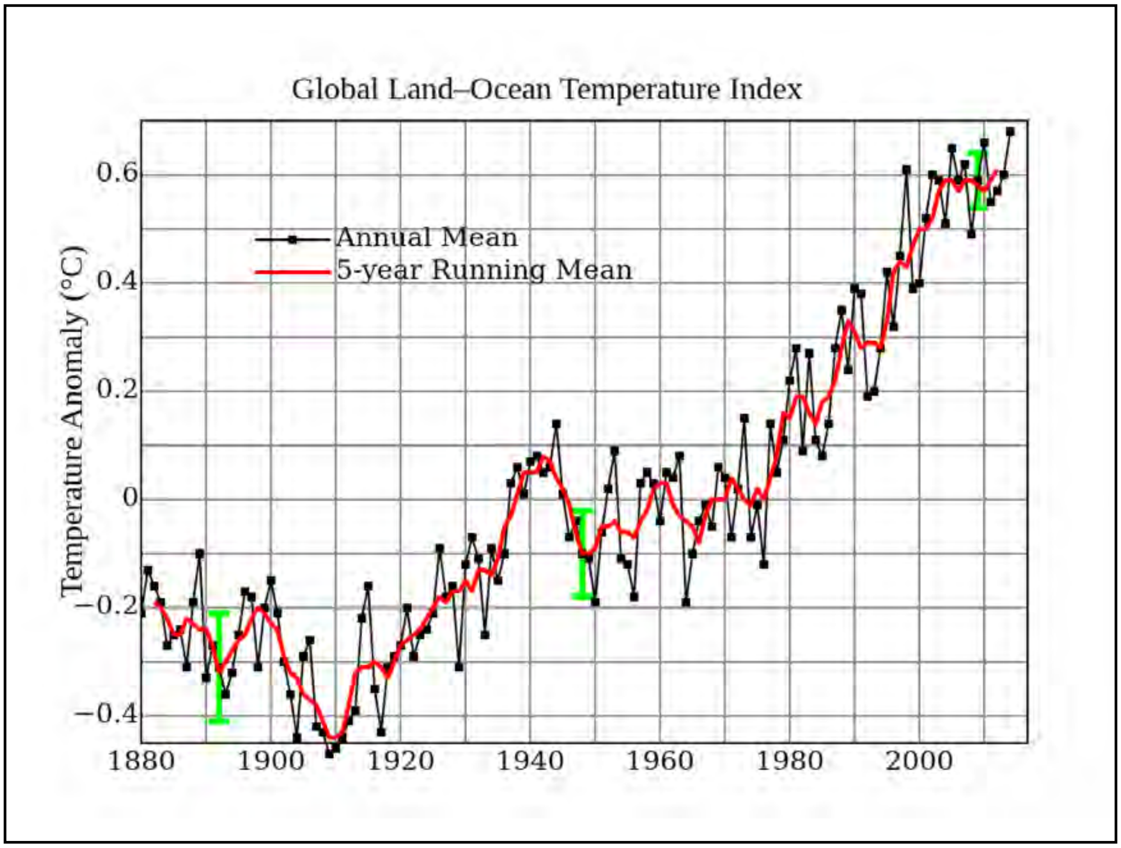

Figure 6. Global temperature data (1880 to current) showing an increasing trend in the annual mean. ©Data and graph courtesy of NASA

The Scientific Method Is Used Whenever There Is a Question!

The scientific method is used across all science disciplines. For our example of Drug X, a chemist may look at the molecular structure of the drug and determine how those molecules are affected by acidity in the stomach. A biochemist may conduct experiments to determine the ideal dosage for Drug X. A microbiologist may examine interactions between Drug X and naturally occurring bacteria present in the intestines. A biologist may investigate how the drug affects the environment when expelled from the human body as waste.

Is Science Reliable and Valid?

So why should we believe that science is reliable or valid? The definition of **reliable** is "yielding the same or compatible results in different clinical experiments or statistical trials." The scientific method allows for replication and consistency of results when performing the same experiment under similar conditions. **Validity** is a description of the strength of the final results and whether those results can be regarded as accurate in describing the real world. Science is valid based on the strength of experimental design following the principles of cause and effect.

We have confidence in using the scientific method because it provides the most accurate answer to a question, as well as an estimate of how much confidence we can put into the accuracy of that answer. Science is always changing as research continues on new and historical questions with the use of advanced technology and variability in circumstances at the time of the research.

Using the scientific method has resulted in many of the greatest achievements, such as predicting eclipses, sending astronauts and space crafts into space, developing vaccinations to eradicate diseases, and developing medical treatments for illnesses and injuries. The scientific method has also been the basis for much of technology.

For thousands of years people believed that the Earth was flat. It is thought that the first scientific evidence of a round Earth was found around 200 BC by a Greek thinker, Ptolemy, who demonstrated that ships approaching the horizon appeared to be rising from under the water indicating a curve to the land. Over many centuries, numerous astronomers and others recording the movement of the stars also theorized that the Earth was round. It wasn't until 1519 (35 centuries later), when Magellan, the famous Portuguese explorer, found direct proof of the theory of a spherical planet when he sailed with five other ships that circled the world without "falling off the edge." Over time, more scientific evidence supported that the Earth was round. New studies and inventions, such as the telescope invented by Galileo, which provided evidence that the moon and other planets were also spherical.

Exercise 1: Investigating the Weight of Carbon Dioxide

In this exercise, you will apply the scientific method and conduct a simple experiment that tests the mass of air and carbon dioxide (CO_2) gas.

Note: Read all instructions for this procedure before you begin.

Procedure

Step 1: Make an Observation

1. Prepare your work area. Make sure you have a stable, flat work surface that is out of reach of pets and children. Gather all of the materials and equipment listed in the materials list before beginning. Perform the experiments near a source of running water and have paper towels on hand in case of spills.

2. Making observations is central to science. Observe the baking soda and vinegar, and record the appearance of each in **Data Table 1** of your **Lab Report Assistant**. Be specific in describing the color and state of matter.

3. In the next step, you will mix baking soda and vinegar together. This is similar to the classic "volcano" experiment performed in grade school. Gather a coffee cup or drinking glass and the measuring spoons.

4. Closely observe what happens and record observations:

    a. Add 1 teaspoon of baking soda to the cup.

    b. Pour 1 tablespoon of vinegar into the cup.

    c. Observe and record observations in Data Table 1. Rinse the cup with tap water and repeat the test as needed.

Note: Foaming is an indication that a chemical reaction has taken place and a gas has been created. The gas produced in the chemical reaction of vinegar and baking soda is carbon dioxide (CO_2).

Step 2: Ask a Question and Conduct Background Research

5. Mixing vinegar and baking soda produces carbon dioxide gas. But where does the gas go? Does it remain in the cup or does it rise into the air? If carbon dioxide gas is heavier than air, then the carbon dioxide will remain in the bottom of the cup. If carbon dioxide gas is lighter than air, then it will rise into the air.

6. Create a question about the mass of carbon dioxide gas compared to the mass of air. Record the question in **Data Table 1**.

7. We have conducted background research for you using the Periodic Table of Elements and reliable online resources. For simplicity, let's assume the following:

    a. A particle of carbon (C) has a mass of 12.01 amu (amu = atomic mass unit).

    b. A particle of nitrogen gas (N_2) has a mass of 28.02 amu; but a single particle of nitrogen (N) weighs roughly 14.00 amu.

    c. A particle of oxygen gas (O_2) has a mass of 31.99 amu; but a single particle of oxygen (O) weighs 15.99 amu.

    d. Dry air is composed of predominantly nitrogen gas and oxygen gas.

Note: *Dry air is made of 78.09% nitrogen gas, 20.95% oxygen gas, and the remaining 1% is made of argon, carbon dioxide, and other trace gases.*

8. The mass of CO_2 is recorded in **Data Table 1**. For the equation used to determine the mass of CO_2 see below:

Note: *An **element** is a substance that cannot be broken down into simpler substances (i.e. carbon (C) or nitrogen (N)). A **compound** is a substance composed of two or more separate elements (i.e. water is a compound consisting of two hydrogen atoms and one oxygen atom per molecule).*

Mass of a Compound: CO_2

Molecular Weights
C = 12.01 amu
O = 15.999 amu

Multiply mass by number of each element in the formula:
C = 12.01 x 1 = 12.01 amu
O = 15.999 x 2 = 31.98 amu

Add final calculated masses together to determine mass of the compound:
12.01 + 31.99 = 43.99 amu

9. Since the chemical formula changes for dry air at different altitudes, the percent composition of gases in dry air will need to be used to calculate the mass. For simplicity, we calculated the mass of a particle of dry air that is composed of 80% nitrogen gas (N_2=28.02 amu) and 20% oxygen gas (O_2=31.98 amu) and recorded it in **Data Table 1**. For the calculation used to determine the mass of a particle of dry air based on percent composition see the equation below:

Mass of a Compound: Dry air is made of roughly 80% nitrogen gas and 20% oxygen gas.

Molecular Weights

$N_2 = 28.02$ amu

$O_2 = 31.98$ amu

Multiply the mass of each gas by the percentage found in the gas mixture:

$N_2 = 28.02 \times \underline{0.8} = 22.42$ amu

$O_2 = 31.98 \times \underline{0.2} = 6.39$ amu

Add final calculated weights together to determine mass of the gas mixture:

$22.42 + 6.39 = 28.82$ amu

10. Based on the background research, consider which gas (CO_2 or air) weighs more and add your thoughts in the row titled "Notes about Gases" in **Data Table 1**.

11. Gases have unique behaviors in the presence of fire. For example, hydrogen gas causes an explosion. CO_2 will extinguish a flame, whereas oxygen in the air will promote the burning of a flame. In fact, many fire extinguishers contain pressurized CO_2. Add any pertinent information regarding the effects of gases on fire to the "Notes about Gases" row of **Data Table 1**.

Step 3: Formulate a Hypothesis

12. We have designed an experiment to test whether CO_2 or air weighs more. First, you will create CO_2 gas by mixing baking soda and vinegar in a drinking glass. Then, you will transfer the gas from the glass onto a burning flame. Read through Step 23 to visualize how this experiment will be carried out. Take a moment to predict what will happen. Refer to your notes in **Data Table 1** as needed.

13. Formulate a hypothesis of what will happen to the flame based on the weight of CO_2 versus air. Record the hypothesis in **Data Table 1**. For example: If CO_2 weighs _____ than air, then the _____ will _____ and the flame will _____.

Note: *Remember, it does NOT matter if your hypothesis is supported or rejected. The point is to learn about the relative weights of air and carbon dioxide by carrying out an experiment.*

Step 4: Test the Hypothesis

14. Gather 2 glasses, 2 measuring spoons (teaspoon and tablespoon), baking soda, vinegar, candle, and matches or a lighter. See Figure 7.

Figure 7. Materials for investigating the relative weight of carbon dioxide gas.

15. Use the teaspoon to measure 1 tsp. of baking soda. Add the baking soda to the first glass. See Figure 8A.

Figure 8. A. Adding 1 tsp. of baking soda to a glass. **B.** Adding 1 tbsp. of vinegar to the glass containing the baking soda.

16. Use the tablespoon to measure 1 tbsp. of vinegar. Add the vinegar to the glass. See Figure 8B.

17. Allow the reaction to take place. Once most of the foaming has occurred, proceed to the next step.

18. Use the matches or lighter to light the candle. Place the candle next to the second glass.

19. Pick up the glass containing the reaction from the baking soda and vinegar and carefully tilt this glass over the empty second glass "pouring" the gaseous contents into the glass. DO NOT transfer any of the solution into the empty glass. See Figure 9A.

Note: *To "pour" the gas, you will tip the glass slowly into the other glass as if you were going to pour the liquid, except you will stop "pouring" before the liquid nears the edge of the glass so as to not transfer any of the liquid into the other glass.*

Figure 9. A. Pouring the reaction into an empty glass. **B.** Pouring the reaction onto the flame of a candle.

20. Observe the second glass. Both air and CO_2 are invisible gases.

21. Pick up the second glass and carefully pour the gaseous contents onto the candle. See Figure 9B.

22. Record detailed observations regarding the entire experimental procedure in **Data Table 1**. Include observations of the chemical reaction, the transfer of gas from each glass, and the transfer of gas to the candle.

23. If you wish to repeat the experiment, thoroughly wash and dry the glasses and begin at step 16. Before moving on to the next section, ensure that the candle is extinguished and is located in a safe area where it can cool completely.

Step 5: Analyze the Data and Draw Conclusions

24. Analyze the data: The “Experimental Observations” recorded in **Data Table 1** are the data to be analyzed in this experiment. Consider the following:

    a. What gas is formed from the reaction between baking soda and vinegar?

    b. According to the background research, does dry air or carbon dioxide weigh more?

    c. Which gas, dry air or carbon dioxide, would sink to the bottom of the second glass due to its heavier weight?

    d. What happens to a flame in the presence of air versus carbon dioxide?

    e. When “pouring” the gas from the second glass onto the candle, did the flame continue to burn or was it doused?

25. Draw conclusions: Determine whether the hypothesis was supported or rejected and explain why in **Data Table 1**.

Step 6: Peer Review Verification

26. Typically the analyzed data and results would be written into a scientific report including the following sections:

    a. **Abstract** – a short synopsis of the experiment: the purpose, hypothesis, and general procedural approach, the data that was collected and analyzed, and the outcome.

    b. **Introduction** – background information citing similar experiments conducted by others.

    c. **Materials and Methods** – the materials used to conduct the experiment and the methodology followed.

    d. **Results** – the outcome of the experiment including the calculations and analyzed data represented in descriptive paragraphs, tables, graphs, and figures.

    e. **Conclusions** – the determination if the hypothesis was supported or rejected, a description of what the results indicate, a comparison of the results to similar experiments, and possible questions and experimentation that can be conducted to further evaluate the topic of interest.

27. Once the scientific report is written, a scientist sends the report to recognized and respectable journals for validation. Since this experiment has already been validated by peers, it was conducted solely to guide you through the steps of the scientific method. There is no need to write a formal report, unless your instructor directs you to do so.

Step 7: Communicate Results

28. After the report is accepted by the journal, it is published for other scientists and the public to read. Oral presentations may be given at conferences or outreach events. You may wish to communicate your results by sharing this experiment with your peers or your instructor may provide a means of communicating your results, such as through discussion forums.

Cleanup:

29. Clean the glasses and measuring spoons with soap and water, and allow them to dry.
30. Make sure the candle flame is completely extinguished and that the wax has cooled and hardened before storing the candle.

Questions

A. Why is a hypothesis supported or rejected, rather than being proven true or false?

B. Is an experiment considered to be a failure if the hypothesis is not supported? Explain your answer.

C. What gas did you find to be in the glass after mixing the baking soda and vinegar? Explain how you are certain.

D. Did you collect quantitative or qualitative data during this experiment? Explain your answer.

E. Describe your conclusions, including the observations that led to your conclusions.

Exercise 2: The Effect of Greenhouse Gases on Global Warming

In this exercise, you will research the effects of excess greenhouse gases in the atmosphere. You will apply the scientific method and model how greenhouse gases warm the planet by covering a jar with plastic wrap. You will then relate the findings of your experiment to global warming.

Procedure

Part 1: Greenhouse Gases and Global Warming

1. In Exercise 1, we observed that gases have different properties. In this section, we will further investigate gases and ask the question, "How are greenhouse gases related to global warming?"

2. Conduct background research on global warming from reliable Internet sources such as NASA, USGS, IPCC, and major universities with current research on the topic such as U.C. Berkley, Yale, Stanford, etc.

Note: *The most acceptable websites to use for Internet sources end in ".gov" or ".edu." Websites ending in ".com" or ".org" should be avoided since recognizing biased information may be difficult. Political, blogs, and news websites often have information that is biased and not based solely on scientific support. For this reason, these sites should also be avoided in investigating scientific topics.*

3. Write a short synopsis of your findings in **Data Table 2** of your **Lab Report Assistant**. Use full sentences and proper grammar and spelling. Write the synopsis in your own words – DO NOT copy text directly from websites. The synopsis should be 1 to 2 pages in length, unless otherwise indicated by your instructor. Include a paragraph for each of the following:

    a. Define greenhouse gas, global warming, and climate change.

    b. Explain the difference between global warming and climate change.

    c. Describe the relationship between greenhouse gases and global warming (i.e. normal versus excess amounts of greenhouse gases).

    d. List 3-4 types of evidence that support human influenced climate change.

    e. Describe 2-3 negative ecological and/or economical outcomes of global warming.

4. Record each website source you used to conduct your research in **Data Table 2**.

Part 2: Modeling the Relationship between Temperature and Greenhouse Gases

5. In the next steps, you will model temperature changes in the Earth's atmosphere by creating two models from large jars or glasses, each containing a thermometer. One jar will remain uncovered while the other jar will be covered with plastic wrap. Consider the following as you create each model:

    a. Plastic wrap is used in this experiment to model greenhouse gases in Earth's atmosphere; however, it should be noted that greenhouse gases not only trap heat but also reflect heat into space, whereas the plastic wrap only traps heat.

    b. The two models will be placed in the same environment and exposed to direct sunlight. Since the models will be placed in the same environment, factors such as air pressure, ambient temperature, and light exposure will be consistent for the two models.

6. Gather 2 thermometers, a clock or timer, measuring cup, spoon, clear plastic wrap, dish soap, 1 rubber band, and a sheet of white paper. Gather 2 large glasses (or jars) of the same size. The glasses should be large enough to fit the thermometers inside.

Note: *Jars or glasses with bottlenecks are NOT recommended for this experiment.*

7. Prepare a diluted dish soap solution as an anti-fog agent. When moisture is trapped in a container, by a lid or other covering, condensation can form on the inside of the container walls. If condensation forms on the inside of the jars or glasses used in this experiment, then it will be difficult to see the markings on the thermometer placed inside.

    a. Fill the measuring cup to the 1-cup mark with lukewarm tap water.

    b. Add 1 drop of dish soap to the water and gently stir with a spoon.

Note: *The solution should not form bubbles when stirred. If it does, then too much dish soap has been added and the solution needs to be re-made following step 7.*

8. Dip a paper towel into the solution and wipe the inside of the glasses (or jars). The glass should have a thin layer of solution, and there should be no pooling or beading of moisture.

9. If the thermometers do not have a solid back, create backs from thick, white paper products, such as foam board, poster board, cardboard, or card stock. The backing will block direct sunlight, and prevent exaggerated temperature readings.

    a. Use scissors to cut a strip of paper for each thermometer. The strips should be slightly longer and wider than the thermometers.

    b. Attach each strip to the back of the thermometers with clear tape. Ensure that the numbers of the thermometer are still visible.

Note: *Do not use dark paper or brown cardboard as those materials absorb heat and will influence the temperature readings.*

10. Place a thermometer inside the first glass. See Figure 10. Tape the thermometer to the front of the glass ensuring that the markings are legible. This is Model #1, which represents the Earth if it had no greenhouse gases in the atmosphere.

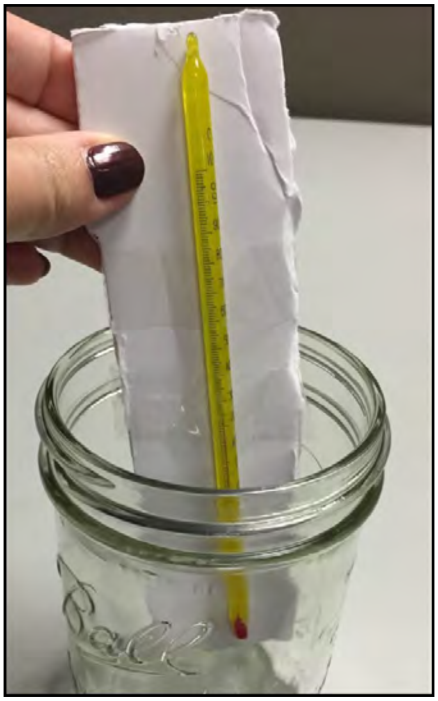

Figure 10. Placing the thermometer with a white foam backing into Model #1.

11. Place the other thermometer inside the second glass, and tape the thermometer to the front of the glass.
12. Use scissors to cut a square piece of plastic wrap that is large enough to cover the opening of the glass. Fit the plastic wrap over the opening of the second glass and secure it with a rubber band. This is Model #2, which represents the Earth plus its greenhouse gases.
13. Set the two models on a sheet of white paper. This is how the experiment will be conducted when you are ready to begin.
14. Remove the plastic wrap and rubber band from Model #2, and set them next to the glass. Model #2 will not be covered until the experiment begins.
15. Consider what each model represents. Define the term "independent variable" and record the independent variable for this experiment in **Data Table 3** of your **Lab Report Assistant**.
16. Define the term "dependent variable" and record the dependent variable for this experiment in **Data Table 3**.
17. Define the term "control group" and record which model acts as the control in **Data Table 3**.
18. Formulate a hypothesis and record it in **Data Table 3**.

Note: *When formulating your hypothesis, think about how temperature will be affected in the two models (one covered and one uncovered). There is no "correct" answer for the hypothesis; however, it should be well-thought-out.*

19. Once the hypothesis has been recorded, the experiment may begin.

    a. You will record temperature data in **Data Table 4** of your **Lab Report Assistant** every 5 minutes during the experiment. Print or draw a copy of **Data Table 4** if necessary.

    b. Transport the experimental setup to a sunny location, leaving Model #2 uncovered.

    c. Working quickly, place the two models on the sheet of white paper in direct sunlight. Turn the glasses so that the thermometers face the same direction, away from the sunlight.

Note: *Be sure to turn the jars so that the faces of the thermometers are not facing the sun.*

20. Place the plastic wrap and rubber band over the opening of Model #2, and immediately record the temperature of each model in **Data Table 4**. See Figure 11.

Figure 11. Model #1 with no covering and Model #2 covered with clear plastic wrap secured by a rubber band.

21. Continue to record the temperature every 5 minutes for an hour in **Data Table 4**.

22. Record notes and observations as the experiment progresses. Describe in detail any changes inside of the models. Make note of changes in cloud coverage and light exposure in the comments section of **Data Table 4** next to the time of the observation.

23. Calculate the change in temperature for each model by subtracting the final temperature from the initial temperature. Record the change in temperature in **Data Table 4**.

Note: *If the thermometers measure in Fahrenheit, be sure to convert each reading to Celsius after the experiment is complete using the following equation:*

$$°C = \frac{(°F - 32) \times 5}{9}$$

24. Create a line graph of temperature versus time, similar to Figure 12. Place time on the horizontal axis (x-axis) and temperature on the vertical axis (y-axis). The graph should have two lines total, representing Model #1 and Model #2.

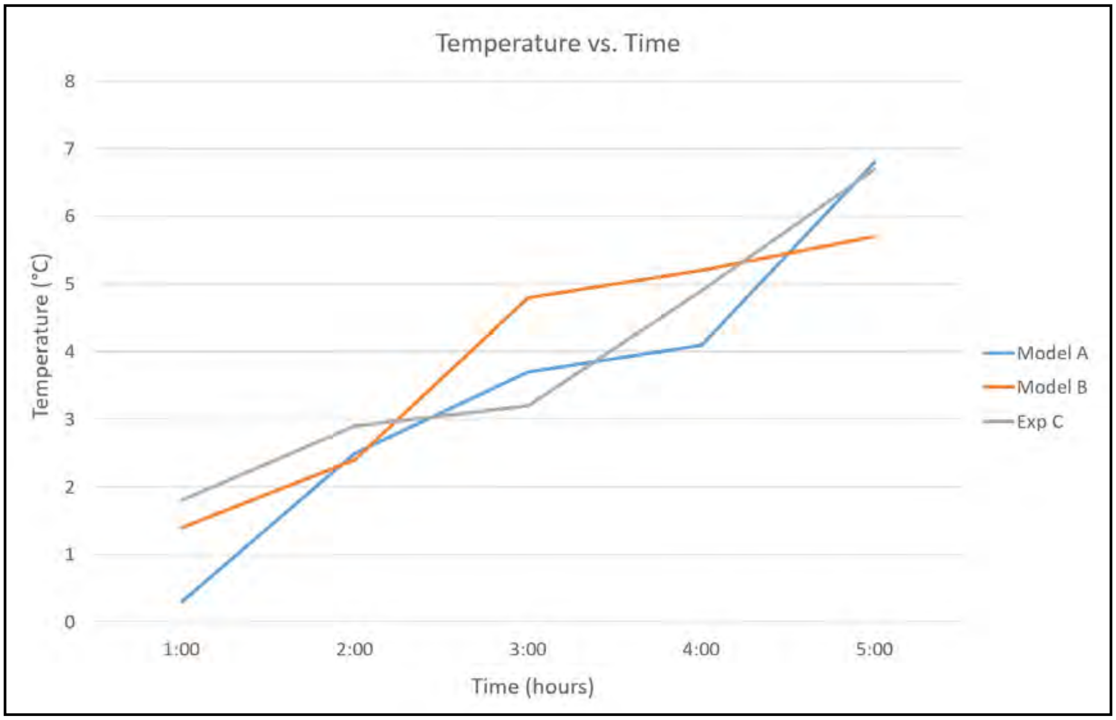

Figure 12. Example line graph of temperature versus time for three different models.

25. Resize and insert an image of the graph into **Data Table 5** of your **Lab Report Assistant**. Refer to the appendix entitled, “Resizing an Image” for guidance.

26. Describe the trends in the graph. Indicate which model held more heat and which model had the greatest increase in temperature. Relate patterns in the graph to the observations recorded in **Data Table 5**.

27. Indicate whether or not the hypothesis was supported or rejected, and explain why in **Data Table 5.**

Cleanup:

28. Remove the thermometers from the glasses.

29. Dispose of the plastic wrap.

30. Clean and dry the glasses.

Questions

A. Compare temperature measurements between the two models. Which model showed the greatest increase in temperature? Which model showed the least increase? Answer these questions by writing a short, descriptive paragraph comparing the models.

B. Describe the role of the plastic wrap in the experiment including both the similarities and dissimilarities to greenhouse gases.

C. If a third model (Model #3) was created by adding greenhouse gases, such as water vapor or carbon dioxide, and covered with plastic wrap and put into direct sunlight with Model #2, how would the temperatures vary? Explain your answer.

D. Relate the findings of this experiment to global warming. Include the benefits of greenhouse gases, but also describe the impact that excessive amounts of greenhouse gases have on global temperatures.

E. List each step of the scientific method. Describe how the experimental procedures applied to each step. ***Note:*** *Since you are not expected to perform a peer review verification or communicate results to the science community, the description for those steps can be indicated as "Not applicable."*

Exercise 3: Design and Perform your own Experiment

In this exercise, you will use the scientific method to research and design an experiment that models ocean temperatures and sea ice. You will then conduct the experiment and relate your findings to the impact that rising ocean temperatures have on global climate change.

Procedure

1. Use the scientific method to investigate the effects of melting sea ice on ocean temperatures. Using the **Scientific Method Template** in your **Lab Report Assistant**, you will record background information, describe the experiment in detail, and analyze your results.

2. Conduct background research on melting sea ice, specifically the effects it has on ocean temperatures. Be sure to cite your sources. Here are a few points to get you started:

    a. Where does sea ice occur on Earth?

    b. How does sea ice influence global climate?

    c. How are areas covered by sea ice different from areas without sea ice in terms of solar energy absorption and reflection?

    d. What impacts will melting sea ice have specifically on climate change?

    e. List 2-3 negative ecological and/or economical impacts of melting sea ice.

3. Consider your research and think about a potential question and an experimental design to test the question. A common experimental setup for modeling ocean ice is shown in Figure 13: water-filled containers represent the ocean and aluminum foil represents ice. If you choose a similar experiment, consider what conditions you will apply in the experimental design. Here are some questions to ask yourself:

    a. What types of containers should be used (juice or milk cartons, glass containers, or plastic bins)? Should the containers be equal sizes? How much water will be added?

    b. What material will model ice? (Aluminum foil, a mirror, or a different piece of metal?)

    c. What will represent the Sun? (Actual sunlight, a heat lamp, or an incandescent bulb?)

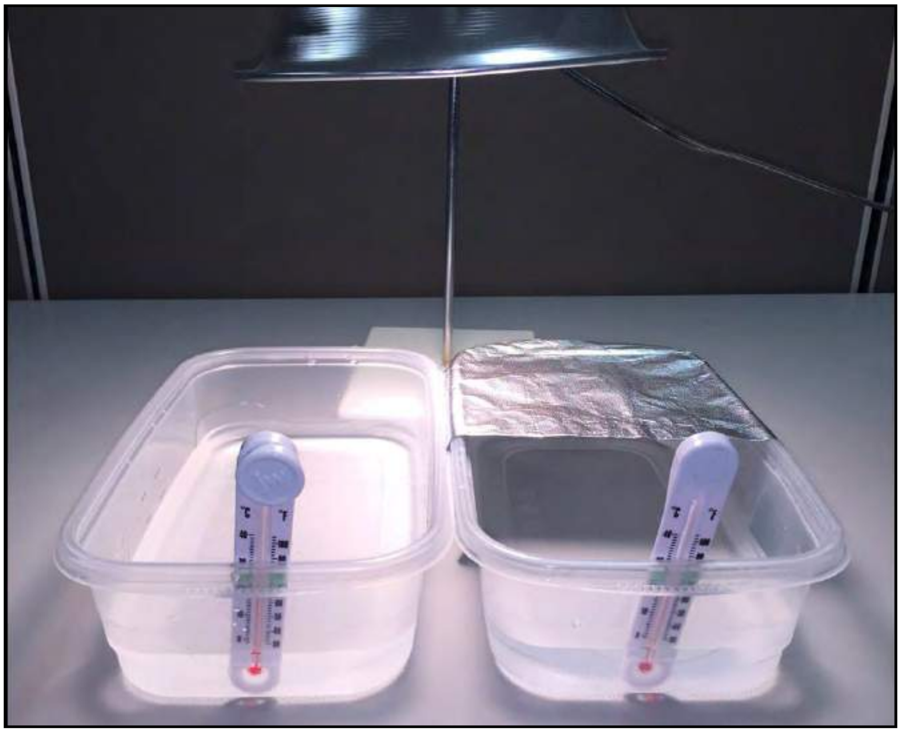

Figure 13. Example of an experimental setup for determining the relationship between water temperature and sea ice.

4. The "Experimental Design" should include:
    a. A list of materials.
    b. A description of the experiment or a list of procedural steps. (This should be specific enough that another scientist could replicate the experiment.)
    c. A list of the independent variable(s), dependent variable(s), and control group.
    d. A photo of the experimental setup, like the one shown in Figure 13.
    e. A well-articulated hypothesis.
5. The "Results and Observations" should include:
    a. All pertinent observations and experimental notes.
    b. At least one data table.
    c. At least one visual representation of data, such as a bar or line graph.
6. The "Conclusions" should include a summary of your results and indicate whether or not the hypothesis was supported and why. The conclusions should also relate the experiment you designed to the broader phenomenon of sea ice and global temperature.

7. When you are finished uploading photos and data into your **Lab Report Assistant**, save and zip your file to send to your instructor. Refer to the appendix entitled “Saving Correctly,” and the appendix entitled “Zipping Files,” for guidance with saving the **Lab Report Assistant** in the correct format.

Questions

A. List the possible flaws with your experimental design, and describe how they could be corrected.

B. Use the findings from your research to develop a new question for future research that could be conducted to add to your experiment.

C. Relate the findings of your experiment to the impact rising ocean temperatures has on global climate change.