Precipitating Bubbles
Introduction to the Scientific Method

Florida Sunshine State Standards Benchmark: SC.H.1.3.4 - The student knows that accurate record keeping, openness, and replication are essential to maintaining an investigator's credibility with other scientists and society.

Background Information:

Scientists aim to gain knowledge and reach an understanding of the world around them. To achieve this goal, scientists must be curious, make observations, ask questions, and try to solve problems. Early scientists tended to draw conclusions from observations that were largely speculative (e.g., that the Earth was flat or that the sun circled the Earth). By the mid-sixteenth century, some scientists began to realize that using a systematic approach to obtaining information and solving problems could obtain far more knowledge. This resulted in a process which we call the Scientific Method.

Steps of the Scientific Method
- Identify the problem.
- Collect information about the problem.
- Propose a hypothesis.
- Test the hypothesis by conducting experiments, making comparative observations, and collecting data.
- Evaluate the data collected through investigation.
- Draw conclusions based on data and determine whether to accept or reject the hypothesis.
- Communicate results and ask new questions.

The problem is a statement of the question to be investigated. Observations and curiosity help to define exactly what problem should be investigated and what question(s) answered. Once a problem is defined, a scientist should collect as much information as possible about it by searching journals, books, and electronic information sources. This information will provide a basis for forming the hypothesis.
A hypothesis is often considered to be an “educated guess.” The word “guess” is inappropriate, however, because a hypothesis should be based on information gathered. A hypothesis can be defined more accurately as a “proposed” answer to the problem, based upon background information either gathered through research or through experience. The hypothesis is then tested through experimentation and observation. The results of experimentation provide evidence that may or may not support the hypothesis.

To be effective, experiments must be properly planned. The plan is called the procedure, which describes the things that actually will be done to perform the investigation. This is where decisions are made about which variables will be tested and which will be kept constant, what to use as a control, how many samples to use, how large the sample sizes should be, safety precautions needed, and how many times to run the experiment.

Many scientists investigate questions that cannot be answered directly through controlled experiments in laboratories. For example, scientists studying global warming, the AIDS epidemic, and losses of biodiversity must use comparative methods to examine differences that occur in the natural world.

When developing the procedure for an experiment, consider the following:

1. Test only one variable at a time.
A scientist wanting to find out “why trees shed their leaves in the fall” would have to consider the factors that affect trees, such as the type of tree, the amount of water they receive, the temperature, the length of daylight to which they are exposed, and the type of soil in which they are growing. These are the variables which can cause changes to occur in an experiment.

To obtain reliable results, only one variable should be tested at a time. All others should be kept constant, whenever possible. If the scientist’s hypothesis states that shorter daylight hours cause trees to shed their leaves in the fall, trees of the same age should be tested. They should be placed in the same size pots with the same type of soil, given the same amount of water, and kept at the same temperature. The only thing changed should be the number of hours of light to which different groups of trees are exposed. Any variable that the experimenter chooses to change, such as the hours exposed to light, is referred to as the independent variable. The change in the experiment that happens as a result of
the independent variable, such as the length of time that it takes for the leaves to fall, is referred to as the dependent variable.

2. **Use controls.**
The control is used for comparing the changes that occur when the variables are tested. If a number of young oak trees are placed in a greenhouse and exposed to 10 hours of light to simulate fall conditions, how will the scientist know if a loss of leaves is due to the amount of light? It could be due to the temperature that he/she chose or the amount of carbon dioxide in the air. To avoid such uncertainty, two identical experiments must be set up: one in which the trees are exposed to 10 hours of light and the other, the control, in which they are exposed to light for a longer period of time to simulate summer conditions. All factors for the control are exactly the same as for the test except for the variable being tested—the amount of light given to each tree.

3. **Use several samples.**
Using a number of samples prevents errors due to differences among individuals being tested. Some trees are heartier than others. If only a few trees are tested, some may lose leaves for reasons that are not related to the amount of light. This will produce misleading results. Larger numbers of samples will provide more accurate results.

4. **Always use appropriate safety measures.**
Safety measures to be followed vary according to the type of experiment being performed. For example, laboratory-based experiments frequently require that participants wear protective clothing and safety goggles and that dangerous volatile chemicals be used only under a vented fume hood.

5. **Repeat the experiment several times.**
To make valid conclusions, the scientist must have reproducible results. Ideally, comparable results should be obtained every time the experiment is run.

After the plan or procedure is complete, the experiment is run. It is essential that careful and accurate records be kept of all observations during an experiment. The recorded observations and the measurement comprise the data. It is always useful to present data in the form
of charts, tables, or graphs, as these provide a visual way to analyze and interpret the results. When drawing graphs, the independent variable is conventionally plotted on the horizontal axis, and the dependent variable is plotted on the vertical axis. Analysis of data from the experiment allows the scientist to reach a conclusion. The scientist determines whether or not the data support the hypothesis and decides whether to accept or reject the hypothesis.

The conclusion should provide an answer to the question asked in the problem. Even if the hypothesis is rejected, much information has been gained by performing the experiment. This information can be used to help develop a new hypothesis if the results repeatedly show that the original hypothesis is inappropriate. After performing many investigations on a particular problem over a period of time, a scientist may come up with an explanation for the problem, based on all the observations and conclusions made. This is called a theory.

A Scientific Theory is an explanation, supported by data, of how or why some event took place in nature.

Students should be encouraged to understand that the Scientific Method can be applied to solving everyday problems, such as “Under what conditions do I study best?” or “What type of lunch box will keep my lunch coldest?” See The Science Room for an excellent example of using the scientific method to obtain a dating companion (http://www.howe.k12.ok.us/~jimaskew/hsimeth.htm). This site is a fantastic resource period. The author of the website believes that the Internet is a medium for the free exchange of ideas and information. No copyright is claimed on the website material. It is published for Howe High School student and faculty use and evaluation by the Internet Community. Feel free to use any of the ideas in your own educational setting, as long as you adhere to the idea of “free exchange.” Many of the graphics on these pages have been copied from the Internet "for educational purposes only." Copying images from this website does not relieve you of any copyright held by the original file owner.

**MAJOR CONCEPTS**

- Our exhaled breath contains carbon dioxide gas.
- The carbon dioxide we exhale reacts with calcium hydroxide in solution to form insoluble calcium carbonate and water.*
- Formation of calcium carbonate precipitate can be used as a test for the presence of carbon dioxide.
• If carbon dioxide continues to be bubbled into limewater (calcium hydroxide solution) after a period of time, the white precipitate disappears. The excess carbon dioxide forms carbonic acid in the water and the calcium carbonate reacts with the carbonic acid to form calcium ions and bicarbonate ions, which are soluble in water. **

\[
\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \\
\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \\
\text{CaCO}_3 + \text{H}_2\text{CO}_3 \rightarrow \text{Ca}^{++} 2\text{HCO}_3^+ 
\]

This activity allows students to test for the presence of carbon dioxide in exhaled air. In Activity 1, each student will blow through a straw into a solution of calcium hydroxide. The carbon dioxide in the air will combine with the calcium hydroxide to produce a white precipitate of calcium carbonate. Students will compare their solutions to those of the teacher whose solution will not contain a visible precipitate. They will not immediately be able to observe that if they continue to blow into the calcium hydroxide solution, the white precipitate will disappear. Students will then generate hypotheses to explain the divergent results.

The second part of this activity involves designing an experiment to test the hypotheses determined in the class discussion. It may be handled in different ways depending on the age of the students.

**Time Frame**
30 minute teacher preparation
60 minutes / student activity

**MATERIALS**
10 grams calcium hydroxide powder
One liter of water
Filter paper
Filter funnel
Large bottle (2 liters)
Flasks or small bottles
Straws
25 or 50 mL graduated cylinder
125 Erlenmeyer flasks
Test-tube rack
Aluminum foil
Stop watch
Hot Plate
Goggles

Procedure:
Part 1: Lab Prep
The preparation of one liter of limewater
(should be prepared a day ahead of time):
1. Add 10 grams calcium hydroxide $\text{Ca(OH)}_2$ powder to one liter of water.
2. Cover and shake well. Calcium hydroxide is only slightly soluble in water and 10 grams will provide more solid than will dissolve.
3. Allow the suspension formed to settle for a few minutes.
4. To separate the limewater from the suspension, use the filter paper and filter-funnel apparatus to filter the suspension.
5. If the limewater filtrate is still slightly cloudy, filter for a second time, using a new filter paper.
6. Keep the limewater tightly closed when not in use, as it will react with carbon dioxide from the air and become cloudy.
7. The calcium hydroxide and water suspension can be stored in a large bottle, and the limewater filtered off when needed.
8. The filtered limewater can be stored in smaller bottles or flasks, 500 milliliters in volume, for use in class. One (1) liter will be sufficient for one class of 24 students for Activities One and Two.

Procedure Part 2:
1. Organize into groups of 4–5 according to your teacher's instructions. Assign each member a role (see Group Roles in the Appendix).
2. Read the following background information
BACKGROUND
Carbon dioxide comprises only 0.033 percent of Earth’s atmosphere, yet it is the principle inorganic source of carbon for living organisms. Carbon dioxide and water are the raw materials required by plants for the synthesis of sugars through photosynthesis. Organisms release carbon dioxide back into the atmosphere as a waste product of respiration and other cellular processes.

3. It is important for scientists to make careful observations, and you will practice doing the same in this activity. Keep a record of all of your observations.

4. Put on safety goggles.

5. Each student is to fill a 125 mL Erlenmeyer flask with 15 mL of the calcium hydroxide solution. Record your observations in your notebook.

6. Use a straw to bubble your breath into the liquid slowly for no more than 2 minutes. DO NOT blow vigorously as you do not want to spill the solution!

7. Observe the solution after blowing through the straws for approximately 1 - 2 minutes.

8. Record your observations in your notebook. These observations will make up your data.

9.

Data Analysis: Teacher Directed Part 1
1. Have group members discuss the following questions and place their answers on sticky notes.

2. Have one member of the group place their answers on the poster paper (one question/poster paper) provided by the teacher. Have another member read the group answers when called upon.

3. Questions for groups to answer:
   • What gases are present in exhaled air?
     Carbon dioxide gas (nitrogen, water vapor, and small amounts of oxygen are also present.)
   • What is the clear liquid?
     Limewater (calcium hydroxide)
   • Why did a precipitate form? Why did the solution turn cloudy?
     There must have been a chemical reaction
   • If a chemical reaction took place, what two ingredients do you think reacted?
     The limewater and the carbon dioxide
• How can we test for the presence of carbon dioxide?
  Bubble the gas into the clear limewater.
• What is a positive test for carbon dioxide?
  Limewater is a solution of calcium hydroxide. It chemically reacts with carbon dioxide to form solid calcium carbonate (chalk).
4. The responses from all groups will be discussed in class to ensure that all students understand the experiment.

Data Analysis: Teacher Directed Part 2
1. When the teacher is convinced that class knows exactly what happened, he/she will bring out the "teacher's results" and say to the class, "Your teacher did the exact same experiment but got very different results!" His/her test tube has no white precipitate—it is clear.
2. The class now has a problem to solve:
   How can there be no white precipitate when the teacher performed the same experiment?
3. Your group will discuss what factors might affect the production of the precipitate (cloudy solution which will settle into a white solid and clear liquid in time).
4. Your teacher will not tell you how his/her results were obtained.
5. Have your group propose a factor that might have affected the results.
6. Possible answers might be:
   • Time—how long exhaled air was bubbled into the solution.
   • Adults vs teenagers
   • Rate of bubbling
   • Light vs dark
   • Temperature of the liquid—either hotter or colder
   • Amount of limewater
7. The factors identified are known as variables.
8. Each group will be assigned at least one of the variables to test.
9. Use the following questions to guide the groups in the development of their group hypotheses and experimental design:
   • Does the hypothesis offer an answer to the problem?
Yes it does. The problem was, "Why was there no white precipitate when the teacher performed the experiment?" The hypothesis states that the teacher may have (choose a variable).

- **Does the experiment have a control?**
  Yes. The control is the average length of time that the students exhaled into the solution of limewater (possibly about one minute).

- **Which materials are needed? Are the materials readily available?**

- **What conditions are being kept constant?**
The conditions kept constant are the temperature of the liquid, the size of the straws, the rate of bubbling into the liquid and the amount of limewater used for each test.

- **What is the independent variable being tested?**
  This is the variable that the experimenter chooses to change.

- **What is the dependent variable being measured?**
The dependent variable is the amount of precipitate present after exhaling into the tube of limewater.

- **How will each group present its data?**
The data may be presented in the form of a chart (see below).
  *This can be indicated by using + to represent the amount of the precipitate.*

10. Each group must submit to the teacher prior to any experimentation
- a proposed hypothesis.
- a draft procedure (which may be modified as students work through the experiment).
- a draft data table

**Procedure: Part 3**

1. Groups will be provided with the needed materials to perform their experiments, collect data, and draw conclusions.
2. Each group must turn in a completed Laboratory Report.
3. A post-experiment class discussion may be conducted to review the conclusions made by each group.
4. Compare the experiments performed by each group of students. For each experiment designed, discuss the variable tested, the control, the factors kept constant, and the results obtained. Note that the amount of limewater used and the size of the straws and flasks should be the same for each experiment. A chart, such as the one below, can be developed on an overhead projector.
5. Add any other variables tested to the chart as necessary.

6. From the class observations, it can be concluded that only the length of time affects the amount of precipitate formed. However, results have also varied based upon how vigorous the blowing was, i.e. amount of carbon dioxide introduced.

7. At this point, explain that excess carbon dioxide bubbled into limewater forms carbonic acid, which dissolves the precipitate of calcium carbonate. If appropriate, place balanced chemical equation on the board.

8. The use of the Scientific Method to systematically test different hypotheses will enable the students to determine which hypothesis is correct in answering a problem.

**Assessment:**

1. You will be evaluated according to the amount of effort expanded, your specific job performance, your participation within the team, and on the final product—the laboratory write-up.

2. Your group’s experiment should be evaluated based on the appropriateness of the design you initiated to test the group’s hypothesis (not whether the group actually found the “correct” solution.)
3. You will be asked to test the hypothesis that “the length of time that air was blown into the solution” caused the teacher’s results to be different. Each student in a group of four will use the same size tube and the same amount of lime water, run the experiment at the same temperature, use the same size straws, and attempt to bubble at the same rate. Students should estimate how long they exhaled into their liquid the first day. This could be the control time. One student in each group will blow into his/her tube for the control time. Each of the remaining students in the group should increase the control time by two to four minutes.

4. For scoring use rubrics which may be found at http://school.discovery.com/schrockguide/assess.html#rubrics

**Home Learning:**
1. Work on designing and writing-up an experimental design for completion of Part 2.
2. Work on the completion of the laboratory write-up which may include data analysis, graphing, and drawing conclusions after completion of Part 3.

**Extensions:**
1. Have each group perform four more different experiments, to test several variables.
2. Do not share the final chemical equation with students. Additionally, challenge them to find the correct reaction mechanism.