Reaching For Results

Teacher-to-Teacher
Video Series
for Secondary Educators

TITLE: The Blue Bottle: An Example of Teacher-Guided Inquiry

PRIMARY SUBJECT AREAS: Physical Science, Chemistry

GRADE LEVELS: 9 – 12

OVERVIEW: Using the Blue Bottle Demonstration, the teacher facilitates a guided inquiry for high school science students while introducing or emphasizing the scientific method. A flask containing a colorless solution is vigorously mixed, turns blue, then becomes colorless again. As the demonstration is conducted, students make observations, draw inferences, form hypotheses, and then engage in guided discussion as the different hypotheses are tested. A conclusion is drawn at the end of the learning experience based on the evidence gathered during the investigation.

APPROXIMATE DURATION: One 50-minute learning session

LOUISIANA CONTENT STANDARDS:
http://www/DOE/assessment/standards/SCIENCE/pdf

Science as Inquiry
Benchmarks:

SI-H-A1 identifying questions and concepts that guide scientific investigations
SI-H-A4 formulating and revising scientific explanations and models using logic and evidence
SI-H-A5 recognizing and analyzing alternative explanations and models

SI GLEs:

1. Write a testable question or hypothesis when given a topic (SI-H-A1)
2. Describe how investigations can be observation, description, literature survey, classification, or experimentation (SI-H-A2)
7. Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)

Physical Science
Benchmarks:

PS-H-D1 observing and describing changes in matter and citing evidence of chemical change

PS GLEs:

21. Classify changes in matter as *physical* or *chemical* (PS-H-D1)
22. Identify evidence of chemical changes (PS-H-D1)

EDUCATIONAL TECHNOLOGY GUIDELINES:
http://www/DOE/LCET/curric/cats.asp.

INTERDISCIPLINARY CONNECTIONS:
N/A

OBJECTIVES:
1. The student will make and record observations.
2. The student will make inferences from their observations.
3. The student will form hypotheses that explain why shaking the flask causes a colorless solution to turn blue.
4. The student will engage in the scientific method through guided inquiry.
5. The student will explain the reaction involved in causing the blue color as well as the clearing of the solution.

LESSON MATERIALS AND RESOURCES:
500 mL flask and stopper
7.5 mL 8M NaOH (sodium hydroxide)
1-2 drops methylene blue indicator
250 mL glucose solution (12 g glucose/250 mL deionized H_2O)
Student learning logs, journals, or notebooks
Area for recording student hypotheses (dry erase board, overhead transparency, flip chart, etc)
A laboratory outlet for methane gas or a small cylinder of methane gas (a small cylinder of methane gas can be obtained from a gas supply store or Flinn Scientific)

TECHNOLOGY TOOLS AND MATERIALS:
N/A

BACKGROUND INFORMATION:
For physical science students, prior knowledge would include how to correctly make observations as well as the ability to draw inferences based on observations. There should be understanding about constructing hypotheses and what hypotheses are. Because the demonstration is used to introduce and illustrate the scientific method, it is not necessary that students be able to recite the steps of the scientific method. For chemistry students, knowledge of physical and chemical properties, as well as physical and chemical change and phases of matters, will enable the student to engage in a learning experience that includes the actual reaction involved in the demonstration. Because a pH indicator is used within the demonstration system, a prior understanding of acids, bases, and indicators will allow for further understanding of the process involved.

LESSON PROCEDURES:
1. Prior to the class period, prepare the solutions needed for the Blue Bottle system (Attachment 1).
2. Prepare the Blue Bottle system by pouring 7.5 mL of 8M NaOH into a 500 mL flask. Add 250 mL glucose solution. Finally, add 1-2 drops of

methylene blue indicator solution. (The blue solution will eventually become colorless.) Stopper the flask and set aside.

3. Introduce the class to the flask system and have the students make observations and record them in their learning log, journal, or notebook. (A colorless solution inside a colorless flask should be observed.) Guide the students through a discussion of the different observations made. Ask if any inferences can be drawn as well and have the students record them before discussing them in a whole group situation. Reinforce the difference between an observation and an inference.
4. Have the students watch carefully as you give the flask a few vigorous shakes and record any further observations. (The contents of the flask should turn blue.) Set the flask aside and have the students share their observations and any inferences that might be drawn.
5. After the discussion, have the students once again observe the flask and record their observations. (The contents of the flask should have become colorless again.)
6. Repeat the vigorous shaking of the flask. Have the students record what they think might possibly be causing the solution to change from colorless to blue and back to colorless and blue again.
7. Record the student hypotheses on the board, overhead, or class chart, and design experiments to test each hypothesis. Have the students help with the experimental design. Because this learning experience is designed to introduce students to the scientific method, it is not necessary for students to complete a full experimental design using a template of any kind. This learning experience should encourage students to think scientifically, propose alternative explanations, and brainstorm ways to test hypotheses that have been stated. At the end of the experimentation, have the students focus on the parts of the scientific method they had engaged in.
8. Examples of possible test scenarios are as follows:

"Stopper Hypothesis": Something is on the stopper causing the solution to turn blue when the flask is shaken.
Response: Carefully turn the bottle upside down without shaking it. (do this slowly to prove the point) Obviously the stopper doesn't have any effect on the reaction. If the students ask you to use another stopper, guide them to the realization that replacing the stopper at this point might affect other variables and ask what those might be. Help the students realize that something might escape the system and therefore affect the test and its results—the stopper can be replaced at the end of the experiments. Swirl the contents without touching the stopper.

"Two Liquid Layer Hypothesis": There are two colorless liquids in there and they mix to cause the color change **.**
Response: Inspect the flask carefully to see if there is a boundary showing between two liquids in the flask. If there are two different liquids, the border should be visible unless they have the same index of refraction. Student observation should verify that there are not two liquids, one on top of the other, in the flask

"Heat Hypothesis": Shaking the solution adds heat and causes the color change. The contents then cool and the blue color fades. (temperature dependent equilibrium)
Response: Place the flask in a warm water bath for a short while. No change in the solution's color occurs. You can even gently heat with the flame of a Bunsen burner. No change should be noted.

"Gas Hypothesis": Air is inside the flask and the color change is due to the reaction between the liquid and gas phases on the inside of the container.
Response: Remove the stopper and flush the flask with methane gas until all the air is forced out. Although it is lighter than air, you can force it in and cap the system. Shake the flask and observe that there is no effect on the solution. Guide the students to realizing that there must be some component of air causing the change. Remove the stopper again, allow the methane to escape and be replaced by air. Once again, shake the flask and observe. The solution once again turns blue. Have the students brainstorm what gases could be involved and guide them to the discovery that is it probably either nitrogen (major component of air), oxygen, or carbon dioxide. Eventually point out to the students that oxygen is the gaseous reagent causing the color change. Further experimentation can be done to actually prove that oxygen is indeed the agent of change.

ASSESSMENT PROCEDURES:

Assessment is embedded throughout the learning experience. Observations and inferences are recorded in student learning logs or journals and can be assessed for accuracy. The student's ability to formulate testable hypotheses can be assessed as the students engage in the guided inquiry experience. Conclusions drawn, based on observations and testing, indicate student understanding of the investigation process. The ability of the student to conduct independent investigations following the learning experience will indicate an understanding of the inquiry process. Whether or not the student can explain the reaction involved with the demonstration will be assessed using the *Blue Bottle Rubric* (Attachment 3). In addition, the Blue Bottle Demonstration itself can be used as a Demonstration Assessment. Use the procedure as noted in Attachment 2.

ACCOMMODATIONS/MODIFICATIONS:

Because the learning experience is a demonstration, the student will not have actual hands-on experience with the test system. However, student success is based on the ability to be engaged in "minds-on" learning. Due to the visual impact of the experience, hearing impaired students can be fully engaged as long as the questions asked are then visibly recorded. If the student is sight impaired, the teacher's oral account of the learning experience should assist the student in visualizing the events involved.

REPRODICIBLE MATERIALS:

Solution Preparation for the Blue Bottle (Attachment 1)
Using the Blue Bottle as a Demonstration Assessment (Attachment 2)
The Blue Bottle Rubric (Attachment 3)

EXPLORATION AND EXTENSION:

Following the Blue Bottle learning experience, students should be challenged to develop an independent investigation that incorporates the scientific method. The student's ability to identify a problem, then successfully develop an appropriate investigation to test for the solution to the problem, will help the student internalize the process involved in the scientific method. More experienced students can be challenged to develop a demonstration that could be used to facilitate inquiry or assessment strategies.

LESSON DEVELOPMENT RESOURCES:

Dr. William C. Deese, Department of Chemistry, Louisiana Tech University

Summerlin & Ealy, Chemical Demonstrations—A Sourcebook for Teachers, Book 1, American Chemical Society, 1985 p. 90.

Shakhashiri, B.Z., Chemical Demonstrations: A Handbook for Teachers of Chemistry, vol 2, The University of Wisconsin Press, 1985, p. 142-146.

REFLECTIONS:

It is of utmost importance that students fully understand the scientific method and how to investigate problems in order to find solutions. Simply having students memorize the steps to the scientific method cannot and does not accomplish this goal. By introducing the students to the scientific method through guided inquiry, the teacher is able to more effectively facilitate the true understanding of this concept and therefore better equip the student for success in future investigations and explorations.

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ATTACHMENT 1

Solution Preparation for the Blue Bottle

8.0 M NaOH Solution

The heat of solution of NaOH is quite exothermic so extreme caution should be used when preparing this solution. **Always wear your safety goggles.** Add the solid in small amounts and stir until it all dissolves. Allow the solution to cool between each addition of NaOH. If your skin comes in contact with the solid NaOH or the solution, rinse with a large amount of water.

To Prepare 100 mL of 8.0 M NaOH:

1. Weigh out 32 g of solid NaOH.
2. Add about 85 mL of water to a 250 mL flask.
3. Slowly add a small amount of the solid NaOH to the flask and stir.
4. After the solution has cooled, add another small amount of the solid and stir.
5. Continue step 4 until all the 32 g of NaOH has been dissolved.
6. After the solution has cooled to room temperature, slowly add water and stir until the total volume of the solution is 100 mL. (This dilution is also exothermic so use caution.)

To Prepare 2 liters of Glucose Solution:

1. Weigh out 96 g of glucose.
2. Introduce the glucose into a plastic 2 liter bottle.
3. Add 1900 mL of distilled water. (Tap water will probably work fine for this demonstration.)

To Prepare 250 mL of Glucose Solution:

1. Weigh out 12 g glucose.
2. Add this to a 500 mL flask.
3. Add about 240 mL distilled water. (Tap water will probably work fine for this demonstration.)

ATTACHMENT 2

Using the Blue Bottle Demonstration as a Demonstration Assessment

Prepare and perform the Blue Bottle Demonstration as directed in the lesson procedure. Run through the hypotheses and tests as described, except **do not** perform any procedures that require removing the stopper from the flask.

After the class has observed the Blue Bottle system work and is familiar with the relative rates of the color changes, present the system as a demonstration assessment.

Engage in the following procedure:

1. Remove the stopper from the flask.
2. Flush the flask for several seconds with a strong stream of methane gas.
3. Replace the stopper as the hose from the methane outlet is removed (use a small cylinder of methane gas if no gas outlet is available).
4. Repeatedly shake the flask. (No color changes are observed.)
5. Remove the stopper and wait about 20 seconds.
6. Replace the stopper and give the flask one vigorous shake. (The solution will turn blue.)

Have the students record their observations in their learning log and write an explanation to accompany the observations. Apply the appropriate rubric for the Blue Bottle Demonstration Assessment. (Attachment 3)

ATTACHMENT 3

Rubric for Blue Bottle Demonstration Assessment

Deese, W. C., Louisiana Tech University

Score	Accomplishments
0	Makes no observations or inaccurate observations.
1	**Observations:** The stopper was removed, and the flask was flushed with methane gas for several seconds. The stopper was replaced, and the flask was shaken. The solution remained colorless. The stopper was removed again for about 15 seconds and replaced. The flask was shaken, and the solution immediately became blue. The blue color slowly faded until the solution was again colorless.
2	**Explanation:** The above plus: After replacing the stopper the first time, there was only methane above the liquid. The lack of the blue color upon shaking shows that the reaction does not occur with methane.
3	The above plus: Removing the stopper the second time allowed the more dense air to displace the methane. The system behaved as before. This indicated that a component of air above the liquid is necessary for the color changes to occur.