Chapter 9

Scientific Inquiry

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Introduction

This laboratory exercise has been developed with the purpose of helping students examine the concepts of inductive and deductive reasoning and how they are used to solve problems. The exercise also has the students examine their personal problem solving techniques by comparing their technique to the scientific method.

This 3-hour laboratory exercise is appropriate for both major and non-major science courses. It has been used in its present form for the last 5 years in our introductory non-major biology CORE course and for the past 2 years in our introductory field biology CORE course.

The activities in this exercise do not require students to have had previous collegiate science courses or be experts in the use of a computer.

Notes for the Instructor

Materials per 24 students

Experiment 1: Unknown in Box

1. The materials in the boxes can be of any origin or any type. I gathered most of my items from a hardware store. I used only 12 different items because it can be difficult to find 24 items that are sufficiently different to allow the students to make clear choices on identifying the unknown objects.

2. Things to remember when selecting unknowns include: (*a*) magnetic vs. non-magnetic; (*b*) weight; (*c*) volume of object, i.e., whether the box is perceived to be full or not; (*d*) sound when the box is shaken; (*e*) and whether the object rolls, slides, or does not move.

3. You need to provide open empty boxes which can be used by the students to run their own analysis and boxes which are sealed shut so the students can determine the net weight of the objects.

4. Materials include sealed boxes each containing a different object, balance, strong magnet, and an assortment of objects identical to objects in sealed boxes.

Experiment 2: Unknown Chemical Compounds

1. Students work in pairs.

2. 50 ml of a 10% acetic acid solution, 50 ml of Lugol's iodine, 50 ml of a dilute methylene blue solution, 400 ml distilled water.

3. 75 g sodium bicarbonate, 75 g powdered sugar, 75 g table sugar, 75 g table salt, 75 g starch.

4. Students dissolve approximately 5 g of each material in 50 ml of distilled water. That is enough of a concentration to give positive tests.

5. Volt ohm meter (VOM; one per lab table), pair of electrodes per meter, 12 spot plates, 6 droppers per pair of students, 5 50-ml beakers.

6. The electrodes for the VOM meter can be easily made with a few pieces of flat copper soldered to copper wire and clipped to the meter with alligator clips.

Experiment 3: Computer Simulation

1. TRIBBLES computer program, Apple II or IBM (or compatible) computer. TRIBBLES: An Introduction to the Scientific Method, written by Ruth Von Blum and Thomas M. Hursh (1976) is published by CONDUIT, P.O. Box 388, Iowa City, IA 52244. [ISBN 0-933694-11-3]

2. You can divide the class into as many teams as you want: this is usually determined by the number of computers available. You can create a contest where each team competes against the other to discover the "rules." The rules will be found in the student guide that accompanies the TRIBBLES program.

3. Let the students wander around in the program for a while to become familiar with it and then see if they are taking a reasonable approach to determining the rules. Usually the students attempt to discover all the rules at once which creates confusion. After a while you might ask the teams a few leading questions to help direct the teams to solve only one rule at a time. Also encourage the students to make sketches of the various tribble combinations they try in the program so they might begin to see a pattern.

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Student Outline

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Introduction

Scientific inquiry is an approach to solving problems which may utilize all of a person's senses and his ability to reason. Additional tools, such as microscopes, balances, chemical tests, etc., can be used to support the inquiry process.

The word *science* comes from the Latin word *scientia* which means knowledge. The word *scientific* comes from two Latin words *scientia,* knowledge, and *facere*, to make. Thus, "scientific" refers to creating knowledge. You will be testing the scientific process, i.e., process to create knowledge, by examining a series of simple projects to see if the process works and is a useful tool in today's society.

Two methods have evolved to help solve problems. One approach is *inductive reasoning* which involves reaching a conclusion based on observations, moving from the specific to the general. It is a process by which random bits of information are formulated into a generalization. For example, you may collect a set of specific data to draw broad, general conclusions.

The inductive method can be used to organize raw data into manageable categories by answering the question, What do all the facts have in common? We make an inductive leap when we go from many observed examples to all possible examples in formulating a general principle. However, without the inductive leap we could not arrive at generalizations.

The other approach is *deductive reasoning* which involves drawing specific conclusions from some larger assumptions. It is the process of using generalizations (premises) to predict new relationships. For example, you may have a set of general facts or statements which can be used to draw specific conclusions. Deductive reasoning logically leads to predictions, which may be described as "if...then" statements. The "if" part of the statement often is stated as a hypothesis.

Man has developed a process of solving scientific problems using both inductive and deductive reasoning. This process is called the Scientific Method. The Scientific Method has the following steps:

(1) observation of phenomena,
(2) construct a hypothesis to explain the observation,
(3) test your hypothesis (experimentation), and
(4) draw conclusions based on hypothesis and experimentation.

Even though the Scientific Method is stated in a rigid format it does not normally function in that fashion. Every scientist develops a personal approach which can be quite different than the above stated approach. Regardless of the approach, the outcome is the same—the support or non-support of the hypothesis based on experimental results.

The purpose of this laboratory exercise is for you to gain insight into the use of inductive and deductive reasoning and experience using them in the Scientific Method of problem solving.

Objectives

1. Given a sealed box containing an unknown object, use inductive and deductive reasoning to determine the object in the box.

2. Given a series of household compounds, use deductive reasoning to determine the name of each compound.

3. Given the computer program TRIBBLES, use inductive and deductive reasoning to determine the reproductive behavior of the tribbles.

4. Use the above objectives to further develop your approach to problem solving.

Experiment 1: Unknown in Box

Obtain a numbered sealed box from the table and record the number of the box in Table 9.1. You may gently shake, swirl, tip, weigh, or expose the box to a magnet. *Do not attempt to crush the box to feel what is inside.*

You are interested in determining what is in the box. To effectively determine what is in the box you must propose a sequence of tests to collect data. List your tests and record your data in Table 9.1.

Table 9.1. Tests and data for the unknown.

	Test	Data
1.		
2.		
3.		
4.		
5.		

Based on inductive reasoning you can now create a hypothesis about the unknown in your box. Describe your unknown as accurately as you can with words and a drawing.

Scientists work on research problems that have factors (parameters) already known about the problem. On the table is a tray containing a series of objects identical to what might be in your box. Using deductive reasoning, select one of the objects that best matches your hypothesis and test the item to see if it matches your hypothesis. Place your tests and data in Table 9.2.

Table 9.2. Tests and data to confirm your hypothesis.

	Test	Data
1.		
2.		
3.		
4.		
5.		
Name of unknown:		

Do your observations recorded in Table 9.2 support your hypothesis created from the data in Table 9.1? If not, what must you do? Do it!

Experiment 2: Unknown Chemical Compounds

On the front table you will find five household compounds labelled A through E. Place a small sample of each of the compounds into separate beakers and take the samples back to your workstation. Label each beaker according to what sample was placed in the beaker and add 50 ml of distilled water to each sample. Now you are to conduct a series of tests to determine what compound is in each beaker. The compounds include sodium bicarbonate, table salt, powdered sugar, starch, and table sugar.

Listed below are important characteristics of each compound:

Sodium bicarbonate: Soluble, ionic, will release a gas when mixed with a weak acid, salty taste, non-reactive with iodine or methylene blue.

Table salt: Soluble, ionic, no reaction when mixed with a weak acid, salty taste, non-reactive with iodine or methylene blue.

Powdered sugar: Partly soluble, non-ionic, no reaction when mixed with a weak acid, sweet taste, non-reactive with iodine or methylene blue.

Table sugar: Soluble, non-ionic, no reaction when mixed with a weak acid, sweet taste, non-reactive with methylene blue or iodine.

Starch: Partly soluble, non-ionic, no reaction when mixed with a weak acid, non-sweet taste, reactive with iodine but not methylene blue.

Tests you can conduct on the unknown compounds:

Methylene blue: Add a drop of methylene blue to the unknown solution to see if there is a distinct color change.

Iodine solution: Add a drop of iodine to the unknown solution to see if there is a distinct color change.

VOM meter: Place electrodes into the unknown solutions in the beakers to see if the meter shows a current moving through the meter. Remember to wash the electrodes with distilled water after each test.

Visual: See if the unknown goes or does not go into the solution.

Taste: See if there is a recognizable taste to the unknown solution.

(Caution: never place an unknown solution into your mouth or on your skin except when you have been informed that there is not danger!)

Smell: See if there is a distinct odor to the unknown solution.

Set up a research scheme using the scientific method and determine what is in each of the beakers. *Set up a table similar to Table 9.2 and list the tests that you decide to use and the results of each test. Then, with the information provided earlier in this exercise, name each compound and how you arrived at that decision.* What type of reasoning were you using for Experiment 2?

Experiment 3: Computer Simulation

We will now use a computer simulation as an additional technique to study inductive and deductive reasoning. This will be a team effort. Form teams so there will be one team per computer. Each team will be attempting to be the first to solve the problem.

The problem is as follows: Each of the teams have been sent to study life on the alien planet Conway. The team which first determines the life history of the only inhabitants, called tribbles, will receive the everlasting admiration of all intergalactic travellers. "Life history," in this case, is determining the rules that govern the birth and death of tribbles.

The only data you have to use are the photographs sent back by the ship's camera once each day. The camera shows that the surface is divided into a grid-like pattern and a tribble is located in the center of the square. The computer can print a pattern that simulates the photographs taken by the camera. Since tribbles are similar to earth organisms you *assume* they reproduce and need energy to survive.

Since you are limited to information supplied by the computer you are limited to the kinds of observations you can make about the critters. You are limited to studying a few aspects of the tribble population. All you know are the number and location of the tribbles on the grid. We define the addition of new tribbles as *birth*, the loss of tribbles as *death*, and tribbles that remain on the grid from day to day as *survival*. We all so have to *assume* that tribbles do not move from grid square to grid square.

To get started place the floppy disk with the TRIBBLES program on it into the computer and turn the computer on. Read the tutorial at the beginning of the program and once the team understands the mechanics of the program you are free to solve the riddle of the "tribbles." Good luck!

Once you think you have defined the laws that govern the tribble populations you are to test your hypothesized laws to see if the data supports your hypothesis. List the laws that you have identified and give a brief summary of tests that supported your hypothesis.