Chapter 14

Scientific Inquiry: Examining the Process of Science

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Introduction

This laboratory exercise is designed to get a class of students organized into teams and examine the scientific process. The concepts of inductive and deductive reasoning will be discussed and then used in the problem solving process. The students will also examine their own problem solving process in comparison to the scientific method.

We are attempting to teach non-science students how science is done in a laboratory, and we feel working in teams is more realistic than working as individuals. We also require team lab reports. This helps develop cooperation among the students — all of whom probably work in team situations elsewhere.

This 2-3 hour laboratory exercise is appropriate for both major and non-major science courses. It has been used in the current format for several years in a non-major 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 Instructor

Creating Teams of Students for Semester

The Purpose of creating teams of students is to recognize that much of the research whether it is Biology, Psychology, Physics, Math, etc. has become a team endeavor. The amount of knowledge today almost demands that advances be made by teams rather than individuals.

1. The labs in our CORE course are all done as activities for student teams (3-4 students each). You will generally be working with a group of students who do not know each other but will need to work closely together all semester.
2. Teams can be created in a variety of ways from naturally occurring groups to random name drawing to who wants to work with whom, etc. After creating the teams have each team decide on a Team Name, which will be used throughout the lab portion of the course.
3. I have each team member introduces themselves and explain why or how they chose the Team Name. The names are written on a sheet of paper or card and placed on a bulletin board for the duration of the lab course. Anytime the team is to give a report or lead a

discussion they are called upon by Team Name. (Students are warned of this so they don't select an inappropriate or embarrasing.)

4. I then discuss why we will be working in teams and how science tends to be done by teams today.
5. I also have the labs written as team reports. (The labs I use are all inquiry based and lend themselves to be written as team reports.)
6. At the end of the lab course the students in a team evaluate each other and themselves and a percentage of the lab grade comes from the self-evaluations. (Students tend to frank about who did what and who did not carry their part of the load during the labs and evaluate accordingly.)

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 as many different items as I could find, (it is OK to use the same item twice (such as a screw so long as they have the same weight). 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) magneticvs. 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 on sealed boxes. (Don't forget to make a key of the objects in the sealed boxes.)

Experiment 2: TRIBBLES and THE GAME OF LIFE

1. TRIBBLES, An Introduction to the Scientific Method was written by Ruth Von Blum and Thomas M. Hursh (1976) computer program is MAC compatible. This is an old "gem" which is no longer being updated and used in only at a few sites. I have been in contact with Ms. Marianne Niedzlek-Feaver (writer the Student Manual) at N. Carolina State U, where the program is still in use. She granted me free use of the program to use and distribute. I can provide copies for those interested.
2. THE GAME OF LIFE is a more recent alternative to TRIBBLES. The rules are the same but it is available on the web at: < *http://serendip.brynmawr.edu/complexity/lifewithoutrules.html*>
3. Keep your teams together for this exercise. Have the students work through the instructions before beginning the exercise. Students can create a 10-grid matrix for the teams to record data from each run. Be sure to have adequate numbers of such grid sheets available. They will need them! The grid sheets emphasize the need to **record** all runs. This is a critical point to successfully determining the Rules of TRIBBLES.
4. Let the students "wonder" around in the fields for a while. They tend to create too complex patterns to solve efficiently so remind them to solve one rule at a time using simple patterns.

5. The Rules are as follows:
    a. A Tribble alone does not survive to the next day.
    b. A Tribble survives if it in contact with two but not **more** than three other Tribbles. (**Diagonals spaces count**!)
    c. A Tribble reproduces if an open box is in contact with 3 Tribbles.
    d. If a Tribble is in contact with 4 or more Tribbles it will not survive.
6. After a period of time of work by the teams, call a "Scientific Conference" and discuss what each team has found. That will allow the teams to compare data and help resolve the "rules". This also shows the value of exchanging data as is done in scientific meetings. The sharing of data is vital to good problem solving.

Student Outline

Introduction

Scientific inquiry is an approach to solving problems, which may utilize all of a person's senses, and 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 organized 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, with out the inductive leap we could not arrive at generalizations.

The other approach is *deductive reason*, 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 is often stated as a hypothesis.

Man has developed a process of solving scientific problems using both inductive and deductive reasoning. The 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 your hypothesis and your experimentation.

Even though the Scientific Method is stated as 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—support or nonsupport 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. Work with other members of your team to verify what unknown is in their boxes.
3. Given the computer program TRIBBLES or THE GAME OF LIFE, use inductive and deductive reasoning to determine the behavior of the theoretical organisms.
4. Use these objectives to further develop your approach to problem solving.

Experiment 1: Unknown in Box

Obtain a numbered sealed box from the bench and record the number of the box in Table 1. You may gently shake, swirl, tip, weigh or expose the box to a magnet. *Do not attempt to crush the box or 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 date. List your tests and record your data in Table 1.

Table 1. Tests and data for the unknown.

YOUR BOX NO._____

	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 drawings. Write or draw your hypothesis in this space.

Scientists work on research problems that have factors (parameters) already known about the problem. On the bench is a tray containing objects that may found 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 date in Table 2.

Table 2. Tests and data to confirm your hypothesis.

YOUR BOX NO._____

	TEST	DATA
1		
2		
3		
4		
5		
6		

NAME OF THE UNKNOWN OBJECT_____

- Do your observations recorded in Table 2 support your hypothesis created from the data in Table 1? **If not, what must you do? Do it!**

Now, verify the unknown objects of the other members of your team. Write a brief statement as to whether team members correctly identified their unknowns and, if not, what suggestions did you make to help your team member to make a correct identification.

Team member 1

Team member 2

Team member 3

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. The problem is as follows: Each of the teams has been sent to study life on an alien planet. The objective of the team is to determine the life history of the only inhabitants. "Life history", in this case, is determining the birth, persistence and death of the inhabitants.

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 that an inhabitant is located in the center of the square or occupying a green circle. The computer can print (on the screen) a pattern that simulates the photographs taken by the camera. Since the inhabitants 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. All you know are the number and location of the inhabitants on the grid. We define the addition of new inhabitant as *birth*, the loss of an inhabitant as *death*, and inhabitant that remain on the grid from day to day as *survival*. We also have to *assume* that the inhabitant do not move from grid square to grid square.

To get started, open the Tribbles program and 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."

For The Game of Life, go to the following web site: *<http://serendip.brynmawr.edu/complexity/lifewithoutrules.html>*. Read the information provided with the web page. Here you will observe a field of red disks. You can click on a disk to turn it green indicating it is occupied by an inhabitant. The same rules pertain to the Game of Life as to Tribbles.

Once your team thinks it has defined the laws that govern the 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.

One of the important ingredients of scientific research is that data is shared in public forums such as annual meetings of international societies, research groups, etc. Be prepared to present your data about the inhabitants in a scientific forum.

Literature Cited

Marianne Niedzlek-Feaver and Zimmweman, J. 1991. TAADs: Student Laboratory Manual. Intellimation: Library for Macintosh. Santa Barbara

Addenda

There have been several changes make in this lab exercise since it was originally presented at ABLE in 1990. I dropped the wet chemistry section because I built into the lab time the process of creating lab teams. Removing the chemistry made lab prep easier. TRIBBLES has become dated and has not been upgraded since 1991. It works on the Macintosh so long as you have Hypercard player on the machine.

I was alerted to THE GAME OF LIFE which has the same premise and rules as TRIBBLES but is current and can be found on the web so any computer with web access can use the program. The premises are the same for both so information I have supplied in the Instructor Notes works for either program.