Introduction to the Scientific Method

Content Discussion and Activities

PHYS 104L

1 Goal

The goal of this week's activities is to provide an introduction to the scientific method. Students should be able to identify the purpose of the scientific method and the general process it follows. An introduction to several standard terms as well as an activity applying the scientific method are included as well.

2 Introduction

The goal of a scientist is to better understand the world around us. To do so, a scientist makes observations of how things happen and uses those observations to formulate models explaining interactions and phenomena we are able to experience. The Scientific Method is an organized process to make these observations and then draw conclusions and understandings from them. The Scientific Method is our best attempt to gather reliable empirical evidence of natural events and then draw meaningful and correct conclusions about what they tell us about the problem or process being studied. In short, the Scientific Method is a process scientists use to try and keep us from fooling ourselves into thinking we understand something when we do not.

A key benefit of applying the Scientific Method to problem solving and understanding is the intentional reduction of bias and emotion from the process. The conclusions or outcomes of any study should not be dependent on the lab or researcher completing the work. A hallmark of the body of scientific work is the concept of reproducibility. The results or outcome of an investigation should be reproducible by others following the same process and methodology of the initial researcher. Following the Scientific Method can help lead to results which will be reproducible by others thus leading to acceptance by the community at large.

3A Discussion - The Steps of the Scientific Method

The many fields of science will follow some version of the Scientific Method, however, the precise number of steps or description may vary somewhat from field to field. As a result, one will often see slightly different descriptions of the steps of the Scientific Method depending on the author's field. The broad outline of scientific inquiry generally follows up to seven steps, though this order and the steps themselves can be varied and still achieve accurate and accepted results. The steps are generally as follows:

1.) Clearly identify a relatively narrow problem, question, or topic to study.
2.) Make initial observations, or research work already reported on the topic.
3.) Formulate a hypothesis regarding the problem, question, or topic.
4.) Devise an experiment which will test the hypothesis.
5.) Collect data and analyze the results of the experiment.

6.) Draw a conclusion of whether the experiment supports the hypothesis or not.
7.) Communicate the results of the study and/or work.

In practice, the Scientific Method works best when this general process is iterated – repeated again and again with the work of each cycle serving as a starting point for the next iteration. The act of communicating results at the end of one cycle (step 7) informs the initial observations and research of the next process (step) by the same researcher or someone else. The recursive nature of scientific study and the Scientific Method itself is a key contributor to successful description and understanding of natural phenomena.

As mentioned previously, an additional important aspect of scientific study is peer review and attempts to reproduce the work of other scientists to verify the results. By communicating the results of a study, the scientist is inviting others to review that work, try to reproduce the results in their own setting, and bring up any concerns or potential flaws in the data or analysis. It is this peer review process that serves as an additional check against a scientist fooling themself into believing they understand something they really don't. This aggressive review by a broader community can more readily identify flaws or concerns and remedy them with an improved experiment or a modified hypothesis. Again, the process of the Scientific Method would be ready to start again.

Here are some common terms that come up when discussing the Scientific Method and experimental design:

Hypothesis – an educated guess, supposition, or proposed explanation made on the basis of limited evidence as a starting point for further investigation

Independent Variable – the manipulated variable or factor that is intentionally varied by a researcher in an experiment or study.

Dependent Variable – the responding variable or factor that may change as a result of changes made in the independent variable.

Control Group – the group or system in an experiment or study that does not receive treatment by the researchers and is then used as a benchmark to measure how the other tested or manipulated subjects do.

Constants – The constants in an experiment are all the factors that the experimenter attempts to keep the same. An experimenter strives to keep all factors constant except the Independent Variable which is being manipulated or varied.

Trials – replicated groups that are exposed to the same conditions in an experiment. Conducting multiple trials allows one to test the repeatability of the experimental results and identify any variation.

3B Activity – How to Untangle Students

1.) You will need to do this activity in groups of two. At your table, you should have two strings, each with loops tied at their ends. The strings should be about two feet long and the loops should be large enough for you to comfortably put your hands through but small enough that the string will not be continuously falling off. If the pre-tied loops are too big or too small for your hands, you can make a new string that is better sized.

2.) You are going to be dealing with the problem of Tangled Students. The instructor will demonstrate how each pair of students will eventually be tangled together. First, one person from the pair should place the string onto his/her wrists such that it resembles handcuffs with one hand in each loop. The other member of the pair is to place one loop of their string around one of their hands. Then, take the other end of the string and run it between their partner's body and their partner's connected hands. The second student should then put their free hand through the remaining open loop, thus tangling the two students together.

3.) The problem for your partner and you is to identify a method via which the two of you can untangle yourselves, once tangled, while adhering to the following rules:

A.) Both students must never let their loops move past their wrists. All hands must always remain through their respective string loops at all times.

B.) Both students must always keep at least one foot on the floor at all times.

C.) The strings must always remain intact and continuous. The string cannot be cut and then tied back together or broken in any way.

4.) You are not allowed to solve the problem via trial and error (entangling yourselves and then just randomly trying things until something works), rather, you are to try and intentionally devise a process for untangling in advance, then testing it to see if it works. In other words, you are to roughly follow the Scientific Method. We have now completed step 1 by identifying the problem to study. You and your partner are to now follow the Scientific Method to identify a method for untangling two students as described.

5.) You should pick up a reporting sheet for you and your partner to turn in at the end of lab with your results. The problem is identified at the top. You and your partner are to devise a step by step process via which you think you will be able to untangle yourselves, observing the above conditions, once tangled. Write out the process, in advance of actually tangling yourselves, on the report sheet under Hypothesis. Have the instructor initial your hypothesis. Now go ahead and test the hypothesis by tangling yourselves and trying your method. Once you have tested your hypothesis, remove your hands from the string loops. No trial and error allowed in the

event you were unsuccessful! You can only try out methods you have described as a hypothesis. Record your results-- either it worked or it didn't – with any accompanying notes you want to make. Explicitly state your conclusion as to whether your hypothesis was correct or not. If it was not correct, iterate the process again by devising a new hypothesis about how you might be able to untangle yourselves. Repeat until you are successful or you run out of lab time. Once done, turn in your report sheet(s) to the lab instructor.

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Activity Data Sheet

Names: _____ _____ _____ PHYS 104L

Activity 3B How to Untangle Students

Question: How can two students become untangled following the rules described in the handout?

HYPOTHESIS:

DATA/RESULTS:

CONCLUSION: Successful Unsuccessful

HYPOTHESIS:

DATA/RESULTS:

CONCLUSION: Successful Unsuccessful

HYPOTHESIS:

DATA/RESULTS:

CONCLUSION: Successful Unsuccessful