Scientific Inquiry Lecture Guide

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*Number in outline corresponds to slide number the PowerPoint presentation.

1. Scientific Inquiry and Experimental Design
2. Levels of organization:
   a. Life can be studied at different levels, from the smallest of particles known as atoms to the study of the biosphere as a single entity.
   b. Cells are the smallest unit of life that can exist as a separate living unit. At the other end of the spectrum, the Gaia Hypothesis is an idea that the planet can be considered a living entity because it has some of the characteristics of living things, such as the ability to respond to changes and maintain homeostasis (Weather patterns that help regulate atmospheric and surface temperatures of the planet, for example). It is not a widely accepted idea, but worthy of mention nonetheless.
   c. BI 101 will focus on the top third or so of these levels: The ecology portion of the term includes populations, communities, and ecosystems. The end of the term will be spent looking at biological systems at the species level where we will explore the different classifications of living organisms: Plants, animals, fungi, bacteria, and protists.

3. Ecology
   a. If you break down the word ecology into its Greek roots, you can glean the definition of the word, which is the study of house. Not only does ecology encompass the organisms that live on the planet, but it explores the environment these organisms live in and the relationship they have with each other.
   b. By the end of the term you should be able to answer questions such as:
   a. What makes a plant a plant?
   b. And what makes it different from a mushroom?
   c. And how do plants and fungi interact and depend upon each other in a given habitat?
   d. And perhaps most importantly, how have humans impacted other life that we share the planet with?

4. Why Study Biology?
   a. Some of you may be asking what is the point? Why do we want to study life? At a broad level, the study of biology is driven by humanity's natural curiosity. We ask questions, and we constantly strive to explain the things we experience and see around us. For example, how can we know what kind of an impact building a dam across a river might have if we do not understand the needs of the organisms that live in that river?

5. How do we "do" biology?
   a. The scientific method is the foundation of all scientific inquiry; it is how we "do" biology. When one thinks of science and experiments, the image that often comes to mind is that of a mad scientist with a white lab coat, and pocket protector, crazy eyebrows, maniacally pouring liquid for test tube to test tube.

6. But in reality, particularly in the realm of biology and ecology, just as much science happens outside of a laboratory setting, in the natural world.

7. How do Scientists Study Life?
   a. The scientific method is a process that allows us to find the explanations our inquisitive nature seeks to find. What you may not realize is that you already use the scientific method every single day. Any and every biology textbook that you will ever see will draw upon the quintessential example of discovering your car won't start to outline the steps of the scientific method. I will spare you the regurgitation, and let you review that example in your assigned reading, but let's go over the steps of the sci. met., as well as the fundamentals of experimental design.

8. Scientific Method in Action: Observation, Question, and Hypothesis

  a. Observations and questions are relatively self explanatory. You notice something about the world around you and you want to know more about it. Let's say you noticed that during the summer months, you have to water your house plants more often than in the winter months.

  b. Hypothesis: Once you have a question formulated, you need to develop a hypothesis. It is important to understand that a hypothesis is a simple, one sentence statement that answers your question. This will be the foundation that you build your experiment upon. If your hypothesis so too complex, it becomes too difficult to design a valid experiment to find the answer to your question.

  a. For the question posed previously

"Does increased air temperature increase the amount of water consumption in plants?"

An appropriate hypoth. could be "I think the higher the air temperature, the more water would be used by the plant." Simple, straight forward, answers the question. Nothing more, nothing less.

9. The difference between a hypothesis and a theory.

  a. Whereas a hypothesis is nothing more than an educated guess as to what the answer to a specific question is, a theory is a well tested, verified hypothesis; a generally well accepted explanation based on lots of research that has yet to be disproven.

  b. It is important to note that a theory can never be proven, or taken as fact, but it can always be disproven. There is always the possibility that there is that one little piece of information, that one discovery that has yet to happen that could overturn any theory, no matter how well established. There was once a time that it was generally accepted the earth was the center of the universe. For centuries, as a matter of fact. But the collective research and ideas of men such as Copernicus, Galileo and Sir Isaac Newton proved that theory to be entirely incorrect. But it took a very, very long time for the idea of heliocentricism (The idea that the earth revolves around the sun) to take hold. This idea was first suggested around 300 BC, but not widely accepted until the mid 1500s.

10. Scientific Method in Action: Prediction Statement

  a. The next step is the development of a prediction statement. If the hypothesis is the foundation of an experiment, then the prediction statement is the blue print. A prediction statement is ALWAYS in the form of an If… then… statement. A well written prediction statement will give you the ability to identify all the important aspects of an experiment that are necessary to answer your questions.

"<u>If</u> high temperatures increase the amount of water consumption, <u>then</u> plants exposed to higher temperatures will use more water".

It may seem a bit redundant next to the hypothesis, but once we look at the important elements of a valid experiment, you will begin to see the value in this statement.

11. Components of an Experiment: Dependent Variable

  a. The role of an experiment is to study phenomena under known conditions, controlling every aspect of an environment in order to methodically change certain aspects. Let's look at some important terms used in experimental design. Dependent variable: The depend. var. is the aspect of your experiment that you are measuring. The easiest way to identify this is by asking yourself what type of data you will be collecting.

12. Let's go back to our temperature and water usage question. Can you identify what you will be measuring from the prediction statement? (The amount of water a plant uses)

13. Components of an Experiment: Independent variable
   - **a.** Also sometimes referred to as the experimental variable, the indep. var. is the one and only thing in an experiment that changes from group to group. It is the part of the experiment that you manipulate, based on what type of information you are trying to discover.

14. Go back to our prediction statement again. Can you identify the ind. var.? (The temperature the plant is exposed to)

15. Components of an Experiment: Controlled variables.
   - **a.** This is EVERYTHING else. Controls give the experiment validity, ensuring the only differences between treatment and control group(s) is the independent variable.
   - **b.** If we are looking at the effects of temperature on water usage, the only thing we can vary between our groups is the temperature. Everything else, from soil quality, nutrients provided, air quality, type of plant tested, method of data collection, everything else beside the air temperature must remain consistent and constant.
   - **a.** If we had two plants, one exposed to 70 degree air temps and the other exposed to 40 degree air temps, but one was also given fertilizer and the other was not, how can we be sure that our results are caused by air temperature or soil quality?
   - **b.** So now that you know what types of variables we have to consider while designing an experiment, can you see why a proper prediction statement is so important?

16. Control Groups
   - **a.** Now let’s look at the two type of groups found in an experiment. Control group. This is the group that can be considered the “Norm”, the standard that you compare. If we want to look at two extremes in air temperature, an appropriate control could be the known optimum temperature at which the plant is known to grow best.
   - **b.** Spinach for example is a cool weather plant and grows best at temperatures between 60 and 70 degrees F, whereas peppers are tropical plants and grow best at temperatures closer to 70 or 80 degrees F. Which plant you choose to test your hypothesis on might influence what you will consider your control temperature.

17. Experimental group(s).
   - **a.** These groups (most often there are more than one experimental group) are the groups in which you manipulate the independent variable. Look back to our prediction statement. Can you determine the types of experimental groups you would need if we were going to use spinach as our test subject? (A series of groups exposed to an increasingly higher temperature would best fit our prediction statement)

18. Scientific Method in Action: Experiment and Results
   - **a.** A crucial step in the scientific process is the analyzing and reporting of your data. Experiments mean nothing without diligent recording of methods and observations in order to make them repeatable and verifiable. If you can’t repeat the experiments, you can’t draw any valid conclusions.
   - **b.** It is also important to note that just because you determined your hypothesis is not correct, doesn’t mean your experiment was invalid. Discovering that you are wrong is just as informative as discovering that you are right.

19. Extension of Controls.
   - **a.** To increase the robustness of an experiment, sometime you can have a use what are referred to as positive and negative controls, to help eliminate the possibility of false positives or negatives.
   - **b.** Negative control is a type of control group within your experiment that you know will give you a negative result, i.e. a definitive “No” to the question you are asking.

   - **c.** Positive control is a type of control group that are exposed to conditions that you know will result in a definitive "Yes" to the question you are asking. Sometimes, negative and positive controls are not appropriate based on the questions you are asking, so we will revisit these controls with an example problem at the end of this lecture.
   - **d.** What your positive and negative controls are is completely dependent upon how you phrase your question. You will see what I mean by this in the example problem at the end of this lecture.

20. Test Your Understanding: Let's assume you are a scientist working for large pharmaceutical company and you believe that you have invented a new drug that is more effective at controlling blood pressure in individuals that suffer from high blood pressure. The question you are tasked with answering is:

   "Does the new drug control high blood pressure better than the current industry standard?"

21. Does the new drug control ….
   - **a.** Based on this question, develop an appropriate hypothesis.
   - **b.** What is an appropriate prediction statement?
   - **c.** Based on the prediction statement you developed, can you identify your dependent variable:
   - **d.** Independent variable?
   - **e.** Now think about controls. In this example, there are a number of potential controls, both positive and negative. For the positive control, we are looking for an independent variable that, when administered to our test subjects will definitively lower blood pressure. Can you think of what that would be?
   - **f.** How about the negative control? Can you think of an independent variable that would definitely have no effect on blood pressure?

22. Controls revisited.
   - **a.** The positive control is an easy one. We already know that the current industry standard is effective at lower blood pressure, so that is our definitive "Yes". The data collected from this group will demonstrate to us what "Lower Blood Pressure" looks like.
   - **b.** If you said your negative control would be a group of individuals that do not receive any medication at all, think again. Remember what we learned about controlled variables? Do some independent research on the placebo effect, and reevaluate your negative control.

23. Hypothetical Results
   - **a.** Here is a reporting of some hypothetical data that could result from an experiment. What conclusions can be drawn?
   - **b.** Some notes on proper data reporting and graphing:
   - **a.** When graphing your results the essential components include a chart title, unit labels on each axis, and identification of all data sets. The general rule of thumb is to create a graph so that your audience doesn't have any previous knowledge on the data you are presenting. If you don't include titles and labels, how could your audience know you aren't reporting something like number of boogers picked instead of blood pressure readings?

24. Scientific Method in Action: Scientific Inquiry is a never-ending cycle
   - **a.** Just because you have shown that your new drug is not more effective, that doesn't mean the drug is a failure necessarily. You have shown that is just as effective, but what if the industry standard has a laundry list of side effects that were not reported by test subjects taking the new drug? New questions! More experimentation! Science!