Experimental Method

Purpose: Experiments are designed to pinpoint the effects of one specific component of a system on another part of the system.

> **Example:** In our aquaponic system, we can use the experimental method to pinpoint and measure the effect of growing plants in full sun vs. partial shade.
>
> > By varying the amount of light (sun vs. shade) that a plant gets, we can observe the effect on how well the plants grow.

Below is the basic outline of how to design an experiment.

Step 1: Identify a question or a problem about how the system works. Pose the question as a "What If" question.

> Example: What if we change the amount of light plants get, what will be the effect on how well the plants grow.

Step 2: Form a hypothesis

The hypothesis poses an answer to the question you came up with in Step 1.

The hypothesis is in the form of a statement (a declarative sentence), not a question.

> If we do _____, then we will observe _____.
>
> If light is increased, then plants will grow faster.

Step 3: Specify (clearly identify) the Independent Variable (also known as the Treatment Variable).

> An Independent Variable is the variation in the system that the scientist manipulates.
>
> In our example, the amount of Sunlight the plants are exposed to is the Independent Variable.

Step 4: Specify (clearly identify) the Dependent Variable.

> A Dependent Variable is the thing that your hypothesis predicts will change or VARY, DEPENDING on how it is treated (the Independent Variable).
>
> In our example, the speed of plant growth is expected to vary depending on the amount of sunlight. So we would measure plant growth to see IF the Independent Variable has the expected effect on the Dependent Variable.

Step 5: Create or gather a fairly large number of experimental subjects.

In psychology, scientists might gather a large number of undergraduates from their lectures to serve as experimental subjects.

In medicine, scientists might work with hospitals to use their patients as experimental subjects for a drug experiment to test the effectiveness of drugs.

In our example, we will plant a number of seeds in individual pots. Each seed in a pot will be one experimental subject.

Step 6: Use a method of random assignment to put half of the experimental subjects in one group and half in another group.

One group is called the Experimental Group. The experimental group receives the experimental treatment.

The other group is called the Control Group. The control group does not receive the experimental treatment.

In our example, we will be planting Marigolds, a variety of plant that prefers to grow in sunlight. Therefore, planting marigolds in sunlight is the normal way marigolds are treated. So the group of marigold seeds that we grow in the sun will be the Control Group. The group of marigold seeds that we grow in the shadier areas of the aquaponic system will be the Experimental Group.

Experiments are often referred to as "controlled experiments." A controlled experiment means that all of the other components of the system are CONTROLLED or held CONSTANT, so that the only difference between the way the Experimental Group is treated and the way the Control Group is treated depends on the Independent Variable. Everything else about how they are grown should be exactly the same.

Step 7: Establish the directions for how all of the plants, whether in the Experimental Group of the Control Group will be treated, except for the difference of the amount of light they receive.

This is often called the Experimental Protocol.

The directions should include information about how the subjects are cared for, how often they are observed or measured, and how they are measured.

Ideally, the person taking care of the plants would not know whether the plants are in the Experimental Group or the Control Group. That way, the experimenter cannot accidentally treat the groups differently by unconsciously favoring one group over the other.

In our example, varying the sunlight, that will not be possible—though we could take elaborate precautions to ensure that when we measure the plants, the experimenter doing the measuring does not know whether the plants are in the Experimental Group (shade grown) or in the Control Group (sun grown).

Step 8: Carry out the Experimental Protocol and maintain detailed notes of actions taken in relation to the care of the plants, when measurements were taken, and how the measurements were made.

Every scientist maintains a lab notebook that includes notations about all of the above matters.

Step 9: Write up a lab report that describes the experiment, the observed results, and draws a conclusion of findings related to the hypothesis.

Are the findings consistent with the hypothesis or inconsistent with the hypothesis.

Step 10: Consider alternative explanations.

If the experiment does not give the expected results, think about what things might have happened that explain why you did not find the expected results.

One of these explanations will always be that the hypothesis was wrong.

But other explanations may suggest that the experiment had design flaws.

For example, in our example, if we measure the plants at two weeks after planting and find no difference, the reason may be that our hypothesis is wrong. That is, we were wrong that marigolds will grow more slowly in the shade.

Alternatively, we may wonder whether the effect of light is not observable until the plants have gotten more mature. Perhaps we need to observe the plants longer to see if growth rates change.

These alternative explanations become the new questions to spawn a new experiment, or several new experiments.

In our example, we may be able to simply continue the experiment and see if differences in growth occur at a later stage—after 4 weeks of growth, for example.

Sample Experiment

Title: The Effect of Light Levels (Sun vs. Shade) on Growth of Marigolds

> **[English Literature Note:** A famous play is entitled "The Effect of Gamma Rays on Man in the Moon Marigolds", written in 1964 by Paul Zindel. It is about a high school student with a troubled home life who immerses herself in a science experiment to escape from the stresses at home.]

Question: What would happen if we grew a sun-loving plant, like marigolds, in the shade?

Hypothesis: If marigolds are grown in the shade, they will grow less than those grown in sun.

Independent Variable: Amount of light

Control Group: Full sun

Plants grown on the top level of the aquaponic system.

Experimental Group: Partial shade

Plants grown on the middle or bottom level.

Dependent Variable: Plant growth

Measures of plant growth:

Height of plants in inches

Experimental Protocol (Detailed description of Procedures)

1. Prepare 50 or more planting pots (ten per student).

   Place one inch of coconut coir at the bottom of a plastic pot, approximately 2 inches in diameter. Place garden soil on top to within ¼ inch of the top edge of the pot.

2. Plant 50 or more marigold seeds with one seed per pot.

   Place one marigold seed on the surface and cover with soil.

3. Each student places pots in a random pattern on a table with other students' pots.

> Lightly water all of the pots as evenly as possible before selecting pots for the Experimental and Control groups.

4. Moving from left to right, select every other pot to be part of the Control Group.

> Place the Control Group pots in the top tier of the aquaponic system.

5. Move the remaining pots to shady sections of the middle and bottom tier, without moving the watercress. Most pots will receive some sun at some times of the day. But none will receive full sun all day like those in the top tier.

> NOTE: A *well* controlled experiment would have all of the experimental pots receive exactly the same amount of sun. We may be able to approximate that, but the system was not built specifically to serve as an experimental apparatus for this example experiment. Don't sweat it!

6. Once a week, look for growth. As growth emerges, measure each plant and record the height of the plant. Plants that have no marigold growing should be measured as "0" (zero) inches high. Record all measurements on a data sheet that is kept with your lab notebook.

7. Each week, calculate the average height of the Control Group and the Experimental Group. Record this number in your lab notebook. Record other relevant information in your lab notebook. For example, if we have four days of cloudy weather, that would be relevant to the experiment because the Control Group would also have been lacking sunshine during that period.

8. After four weeks, graph the average height for the Control Group and Experimental Group, by week.

9. Determine whether you have observed a difference between the two groups.

10. If you observe no difference, continue the experiment for another two weeks.

11. After the two weeks, if you observe no difference, write down in your lab notebook as many explanations for why the hypothesis was not confirmed as you can think of.

Design your own experiment

Each of you should design your own experiment relating to different components of plant growth.

As a group, we may also design at least one experiment relating to the fish.

Question:

> Think about the different aspects of plant growth that you might manipulate and vary between one group of plants and another. For example, you could repeat the marigold experiment with different varieties of plants. Or you could try different planting media (soil combinations). Or you could elevate some plants so that they are not in as much water as the Control Group.

Hypothesis:

Variables:

> **Independent Variable:**
>
> **Dependent Variable:**

[Remember to provide detail about how you will treat the Experimental Group differently from the Control Group and how you will measure the Dependent Variable.]

Experimental Protocol (Procedures)

Provide step-by-step instructions that have enough detail that another experimenter could read your instructions and carry out the experiment as you intended or as you carried it out.

Evaluation Rubric

Part 1: The Experimental Protocol

Title: The title clearly identifies both the independent and dependent variables. The title uses the words "the effect of" and "on".

Hypothesis: The hypothesis clearly states how you think the Independent Variable will affect the Dependent Variable. The hypothesis includes words like IF, is INCREASED [or DECREASED], THEN, and will INCREASE [or DECREASE], or similar observations.

Independent Variable: The independent variable is clearly identified and expected to be the cause of differences observed, if any, between the Experimental and Control Groups.

Dependent Variable: The dependent variable is clearly defined, including how you will measure the result on the dependent variable.

Procedures: The protocol spells out clear, step-by-step instructions with enough detail that another experimenter could faithfully reproduce the experiment and obtain the same results.

Part 2: Lab Notebook and Lab Report

Lab Notebook:

The lab notebook clearly shows the measurements of each experimental subject as called for in the protocol, including the date and units of measurement (for example, inches, ounces, etc.) and clearly divided between experimental subjects and control subjects.

The lab notebook shows the average of all experimental subjects in each group.

The lab notebook records other observations that could be relevant to the outcome of the experiment, including unexpected (or uncontrolled) variation or treatment of one or both groups.

Lab Report:

At the end of the experiment (or before symposium, whichever comes first), the student turns in to Shane a lab typewritten report that includes:

- the Experimental Protocol,
- the results,
- the conclusion (whether the hypothesis was confirmed or not),
- any relevant uncontrolled variation between the treatment of the two groups as recorded in the lab notebook, and
- possible alternative explanations if the hypothesis was not confirmed