Basic Steps of the Scientific Method

The scientific method is a set of specific steps that are used to ask a question, get answers, compare answers, or solve a problem. Those steps allow others to repeat the study to try to get the same results. The scientific method uses both measurement and observation to obtain data about an event in the world and to make predictions in order to understand the event. Experiments can answer a specific question or solve a problem. The scientific method also is used to study events that cannot be manipulated, such as man-made events and naturally occurring phenomena (Anderson, 2013; Shuttleworth, 2015).

The basic steps of the scientific method are explained below. Not all scientific studies have exactly the same steps, but each will follow the sequence described below. Learning these steps and related vocabulary will help you to better understand reports of scientific studies in the news such as those for new medicines, environmental toxins, and habits that impact one's health.

1. **Identify a question, issue, or problem.** A question, issue, or problem must be testable, using the basic steps of the scientific method. For example, you could ask: *Do indoor plants grow toward light?* The scientific method does not tell *why* something happens, but it will tell when, how, or if something happens. Therefore, it cannot answer the question, *Why do indoor plants grow toward light?* But questions that can be studied with this method are, *Do indoor plants grow toward light?* or *What type of light attracts indoor plants best (sunlight or fluorescent)?*

2. **Study other published research.** Collect information related to your problem or question from trusted and reliable sources (such as journal articles), not personal opinions, newspapers, or magazines. For example, to test the question, *Do indoor plants grow toward light?* it is important to show what is already known about plant growth, especially the plant's response to light.

3. **Construct a hypothesis**. A hypothesis is an educated guess or expectation (based on what is known) about what the answer might be to the research question. A reasonable hypothesis is that *indoor plants do grow toward light*.

   The procedures to answer the question "*Do indoor plants grow toward light?"* are described below.

4. **Perform an experiment to test the hypothesis and collect data.** The data can come from experiments or from systematic observations. Either way, the data will determine whether the hypothesis is true or not.
   For both observations and experiments, the procedures used during the study and the measurable outcome(s) must be clearly defined. Procedures include the following:

   1. Identify the independent and dependent variables
   2. Determine the materials, instruments and/or equipment that will be used
   3. Decide on the procedure to collect the data

   1. Identify the independent and dependent variables.
      Variables are an important part of a scientific study. Variables define *what* is being studied. In an experiment, they can be controlled or changed. In natural phenomena or man-made events,

they can provide the basis of different groupings that exist. It is important that all variables be clearly explained in ways that are objective (not an opinion) and clearly defined (not open to interpretation).

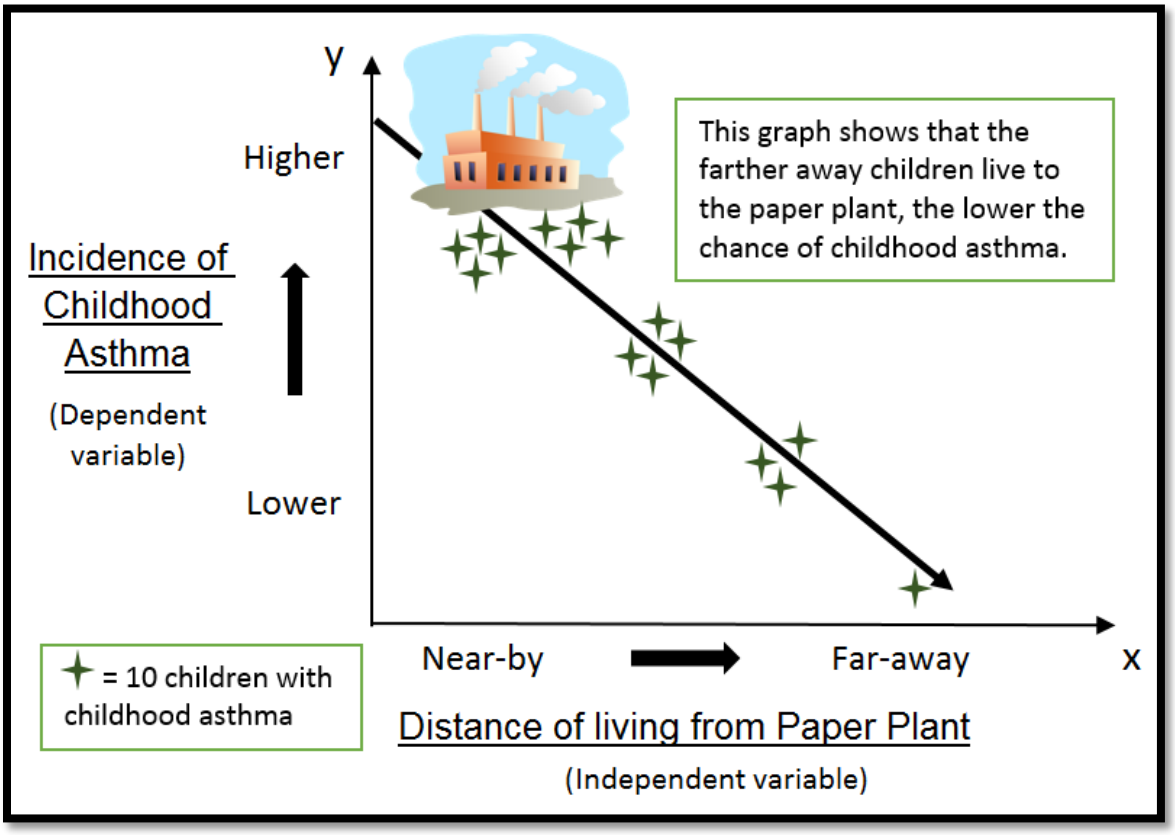
Two types of variables are part of all studies:

Independent variable.

The ***independent variable*** is what is changed or manipulated in an experiment. The independent variable causes a change in the outcome that is measured or the dependent variable. When measuring whether indoor plants grow toward light, the independent variable is where the light is placed. The independent variable in observational studies, which often compare two groups or conditions, is the naturally-occurring difference between groups since it may not be possible or ethical to manipulate the conditions. For example, to study whether living near paper manufacturing plants increases a child's risk of developing asthma, the independent variable would be *where or how far* the children lived (either near-by or far away) from a paper plant.

Dependent variable.

The ***dependent variable*** is *what is observed and measured*, such as the direction of plant growth or incidence of childhood asthma. The dependent variable is dependent on (can be changed by) the manipulations of the independent variable. The dependent variable is the *observed result* of the independent variable being manipulated or, in the case of an observational study, is the outcomes being compared (children's development of asthma or not).



The definitions of independent and dependent variables are summarized in the table below. A further explanation of these variables is at the end of this document and includes two examples of experiments.

TYPE OF VARIABLE	
Independent	**Dependent**
• *is manipulated* (in an experiment) or • *defines groups* (in an observational study)	• *is observed,* • *is measured,* • *can change,* and • is the result of the independent variable

2. <u>Determine the materials, instruments, procedures, and/or equipment that will be used</u>
   Identification of the independent and dependent variables provides clues about materials, procedures, and equipment needed for the study. If studying plant growth, first the light source placements (independent variable) for the plants need to be established. Next, the materials needed and the procedures to use for observing the direction of plant growth need to be described, such as:

   - Selecting several plants of the same type;
   - Using the same type of soil for the plants;
   - Choosing the same size and type of pots for the plants;
   - Providing the same amount of water for each plant; and
   - Defining how plant growth will be recorded.

   Plant growth could be established by measuring the height from the top of soil to the upper-most leaves. Merely observing that plants "look healthy" or "are larger" does not provide the precision and definition required by the scientific method.

   To examine the hypothesis, *Plants do grow toward light,* it is important to identify the conditions for observing several plants. Several plants need to be arranged, each with varying placement of the light source. Preferably an equal number of plants would be grown under each condition. All other variables (such as amount of water, size and type of plants, amount of soil, and size of pots) need to be exactly the same for each plant. The only difference should be the location of the light source for each group of plants. In this case, the **independent variable** is the *placement* of the light source relative to the plant, and the **dependent variable** is the *direction* of plant growth (and/or the plant height) in response to the light.

3. <u>Decide on the procedure to collect the data</u>
   All of these procedures and conditions need to be carefully recorded. Data collected for this experiment would include the detailed description of each plant at all stages of the experiment and a record of how each plant responds to different light source locations over a period of time.

5. **Analyze the data and results.**
   The data should be summarized and displayed in some kind of graphic. If possible, the experiment should be repeated to see if similar results are obtained. The data are then carefully analyzed to determine how the light source location affected plant growth.

6. **Communicate the results**.
   The last step is to share the results, often as a published report or as a board display at a conference. Those who conducted the experiment should clearly state what was observed and whether or not the results were aligned with their hypothesis. A rejection of a hypothesis is just as useful as a validation of the hypothesis. The report should clearly reflect thinking and communication skills.

The Role of the Independent and Dependent Variables in a Scientific Study

The most challenging concepts to understand in the scientific method are the roles of the independent and dependent variables. The independent and dependent variables for all studies must be *measurable* concepts. The dependent variable is what was observed when the independent variable is changed. The dependent variable depends on the outcome of the independent variable. In other words:

- Independent Variables are conditions that *are manipulated by* the experimenter.
- Dependent Variables are *measured or observed* to occur *due to* manipulation of independent variable(s).

Example 1: Consider a study of the amounts of lactose carbohydrates contained in various types of milk by measuring the amount of lactose crystals produced. The tests are done using various types of milk: low fat, powdered, and soy, as well as types of milk sources: organic and nonorganic. The independent variables are the types and sources of milk. The dependent variable is the amount (weight) of lactose crystals formed.

Example 2: Another study compared the amount of bacteria in water coolers and tap water. The comparison was between water sources: water coolers and tap. The independent variable is the source of the water – from the tap or from water coolers. The dependent variable is the size of the bacterial colony observed to grow in the petri dishes.

Summary

The scientific method is a systematic way to explore what is seen in the world (Shuttleworth, 2015). It enables researchers to provide insights based on logic, not personal opinions. What has remained the same over the years are the basic methods: observing, predicting, testing, and communicating the findings.

REFERENCES

Anderson, E. (2009). Overview of research methods in education. http://www.education.com/reference/article/research-methods-an-overview/

Shuttleworth, M. (2015). What is the scientific method? https://explorable.com/what-is-the-scientific-method