How the Scientific Method Works

We hear about the scientific method every day. Middle and high school students learn about it in science class and use it in research competitions. Advertisers use it to support claims about products ranging from vacuum cleaners to vitamins. And Hollywood portrays it by showing scientists with clipboards and lab coats standing behind microscopes and flasks filled with bubbling liquids.

flashfilm/Getty Images

You don't have to wear a white coat and goggles to use the scientific method.

So why does the scientific method remain such a mystery to so many people? One reason has to do with the name itself. The word "method" implies that there is some sacred formula locked in a vault -- a formula available to highly trained scientists and no one else. This is absolutely untrue. The scientific method is something all of us use all of the time. In fact, engaging in the basic activities that make up the scientific method -- being curious, asking questions, seeking answers -- is a natural part of being human.

In this article, we'll demystify the scientific method by breaking it down to its basic parts.

We'll explore how the scientific method can be used to solve everyday problems, but we'll also explain why it is so fundamentally critical to the physical and natural sciences. We'll also examine a few examples of how the method has been applied to make landmark discoveries and support groundbreaking theories. But let's start with a basic definition.

Ask a group of people to define "science," and you'll get a lot of different answers. Some will tell you it's a really difficult class wedged between social studies and math. Others will tell you it's a dusty book filled with Latin terms that no one can pronounce. And still others will say it's a useless collection of facts, figures and formulas. Unfortunately, most dictionaries don't shed any significant light on the subject. Here's a typical definition:

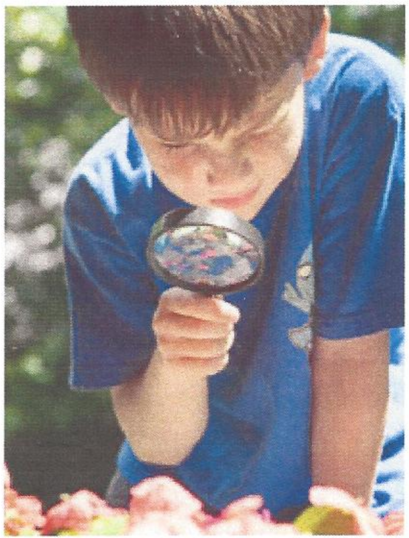
Science is the intellectual and practical activity encompassing the structure and behavior of the physical and natural world through observation and experimentation [source: Oxford American Dictionary].

Sounds difficult, right? Not if we break this long-winded definition into its most important parts. By doing so, we'll achieve two things: First, we'll support the argument that science isn't mysterious or unattainable. Second, we'll demonstrate that the method of science is really no different than science itself.

Scientific Method Definition

Let's break down the definition of science.

Part 1
Science is **practical**. Although science sometimes involves learning from textbooks or professors in lecture halls, its primary activity is discovery. Discovery is an active, hands-on process, not something done by scholars isolated from the world in ivory towers. It is both a search for information and a quest to explain how information fits together in meaningful ways. And it almost always seeks answers to very practical questions: How does human activity affect global warming? Why are honeybee populations suddenly declining in North America? What enables birds to migrate such long distances? How do black holes form?


Ron Levine/Photographers Choice/
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Scientists of all ages use all of their senses to observe the world around them.

Part 2
Science is based on **observation**. Scientists use all of their senses to gather information about the world around them. Sometimes they gather this information directly, with no intervening tool or apparatus. Other times they use a piece of equipment, such as a telescope or microscope, to gather information indirectly. Either way, scientists will write down what they see, hear and feel. These recorded observations are called **data**.

Part 3
Data can reveal the **structure** of something. This is **quantitative data**, which describes an object numerically. The following are examples of quantitative data:

- The body temperature of a ruby-throated hummingbird is 40.5°C (105°F).
- The speed of light is 299,792,458 meters per second (670,635,729 mph).
- The diameter of Jupiter is 142,984 kilometers (88,846 miles).
- The length of a blue whale is 30.5 meters (100 feet).

Notice that quantitative data consist of a number followed by a unit. The unit is a standardized way to measure a certain dimension or quantity. For example, the foot is a unit of length. So is the meter. In science, the International System (SI) of units, the modern form of the metric system, is the global standard.

Part 4
Data can also reveal **behavior**. This is **qualitative data**, which are written descriptions about an object or organism. John James Audubon, the 19th-century naturalist, ornithologist and painter, is famous for the qualitative observations he made about bird behavior, such as this one:

Generally, scientists collect both quantitative and qualitative data, which contribute equally to the body of knowledge associated with a certain topic. In other words, quantitative data is not more important or more valuable because it is based on precise measurements [source: Audubon].

Next we'll learn about science as a systematic, intellectual pursuit.

Scientific Method Parts

Part 5
Science is an **intellectual** pursuit. Making observations and collecting data are not the ultimate goals. Data must be analyzed and used to understand the world around us. This requires **inductive reasoning**, or the ability to derive generalizations based on specific observations. There are many classic examples of inductive reasoning throughout the history of science, but let's look at one to understand how this intellectual exercise works.


Margaret Bourke-White/Time & Life Pictures/Getty Images

Astronomer Edwin Hubble looks though the eyepiece of the 100-inch telescope at the Mt. Wilson Observatory in 1937.

In 1919, when **Edwin Hubble** (of Hubble Space Telescope fame) arrived on California's Mount Wilson to use the 100-inch Hooker Telescope, then the world's largest, astronomers generally believed that the entire universe consisted of a single galaxy -- the Milky Way. But as Hubble began making observations with the Hooker Telescope, he noticed that objects known as "nebulae," thought to be components of the Milky Way, were located far beyond its boundaries. At the same time, he observed that these "nebulae" were moving rapidly away from the Milky Way. Hubble used these observations to make a groundbreaking generalization in 1925: The universe wasn't made up of one galaxy, but millions of them. Not only that, Hubble argued, but all galaxies were moving away from each other due to a uniform expansion of the universe.

Part 6
Science makes predictions and tests those predictions using **experiments**. Generalizations are powerful tools because they enable scientists to make predictions. For example, once Hubble asserted that the universe extended far beyond the Milky Way, it followed that astronomers should be able to observe other galaxies. And as telescopes improved, they did discover galaxies

-- thousands and thousands of them, in all different shapes and sizes. Today, astronomers believe that there are about 125 billion galaxies in the universe. They've also been able to conduct numerous experiments over the years to support Hubble's notion that the universe is expanding.

One classic experiment is based on the **Doppler effect**. Most people know the Doppler effect as a phenomenon that occurs with sound. For example, as an ambulance passes us on the street, the sound of its siren seems to change pitch. As the ambulance approaches, the pitch increases; as it passes, the pitch decreases. This happens because the ambulance is either moving closer to the sound waves it is creating (which decreases the distance between wave crests and increases pitch) or moving away from them (which increases the distance between wave crests and decreases pitch).

Astronomers hypothesized that light waves created by celestial objects would behave the same way. They made the following educated guesses: If a distant galaxy is rushing toward our galaxy, it will move closer to the light waves it is producing (which decreases the distance between wave crests and shifts its color to the blue end of the spectrum). If a distant galaxy is rushing away from our galaxy, it will move away from the light waves it is creating (which increases the distance between wave crests and shifts its color to the red end of the spectrum).

To test the hypothesis, astronomers used an instrument known as a spectrograph to view the **spectra**, or bands of colored light, produced by various celestial objects. They recorded the wavelengths of the spectral lines, and their intensities, collecting data that eventually proved the hypothesis to be correct.

Part 7

Science is **systematic**. It is rigorous and methodical, requiring that tests be repeated so results can be verified. The hypothetical redshift described above has been proven in repeated experiments. In fact, it's so well documented that it has become an integral part of the Big Bang, a theory that describes how the universe expanded from an extremely dense and hot state.

So, science can be thought of as a way of thinking, but also as a way of working -- a process requiring scientists to ask questions, make hypotheses and test their hypotheses through experimentation. This process is known today as the scientific method, and its basic principles are used by researchers in every discipline, in every part of the world.

And yet it was not always so -- the move to scientific inquiry evolved slowly over time. In the next section, we'll look more closely at the history of the scientific method to better understand how it developed.

Close Read: How the Scientific Method Works?

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LAFS.68.WHST.3.9
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** Answer the following questions in complete sentences.

**Cite the paragraph number at the end of each answer.

Example -- (P.4)

1. According to paragraph 3, this article is meant to "demystify" the scientific method. Demystify essentially means to reveal the truth about something. State 4 truths this article revealed to you about the scientific method.
2. How can observations be made in scientific inquiry through the scientific method?
3. At paragraph 17, the article begins to discuss the studies conducted by Edwin Hubble. What was the hypothesis proposed by Hubble for his study?
4. How was the experiment conducted to prove Hubble's hypothesis?
5. Empirical evidence can be broken down into qualitative and quantitative data. Describe the difference between qualitative and quantitative data. Provide examples from the text for each.
6. Why are scientific studies not singular, or conducted only one time? What evidence is provided by the text to show that scientific inquiry is not a singular experience?

Culminating Activity: Extended Response

7. Referring to the study conducted by Edwin Hubble for the expansion of the universe, explain the use of the scientific method as a systematic approach to analyzing natural occurrences.