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The Scientific Method

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There are many scientific disciplines that address topics from medicine and astrophysics to agriculture and zoology. In each discipline, modern scientists use a process called the "Scientific Method" to advance their knowledge and understanding. This publication describes the method scientists use to conduct research and describe and explain nature, ultimately trying prove or disprove theories.

Scientists all over the world conduct research using the Scientific Method. The University of Nevada Cooperative Extension exists to provide unbiased, research-based information on topics important and relevant to society. The scientific research efforts, analyses, and subsequent information disseminated by Cooperative Extension is driven by careful review and synthesis of relevant scientific research. Cooperative Extension presents useful information based on the best science available, and today that science is based on knowledge obtained by application of the Scientific Method.

The Scientific Method – What it's Not.

The Scientific Method is a process for explaining the world we see. It is:

- **Not** a formula
- **Not** Magic

The Scientific Method – What is it?

The Scientific Method is a process used to validate observations while minimizing observer bias. Its goal is for research to be conducted in a fair, unbiased and repeatable manner.

Long ago, people viewed the workings of nature and believed that the events and phenomena they observed were associated with the intrinsic nature of the beings or things being observed (Ackoff 1962, Wilson 1937). Today we view events and phenomena as having been **caused,** and science has evolved as a process to ask how and why things and events happen. Scientists seek to understand the relationships and intricacies between cause and effect in order to predict outcomes of future or similar events. To answer these questions and to help predict future happenings, scientists use the Scientific Method - a series of steps that lead to answers that accurately describe the things we observe, or at least improve our understanding of them.

The Scientific Method is not the only way, but is the best-known way to discover how and why the world works, without our knowledge being tainted by religious, political, or philosophical values. This method provides a means to formulate questions about general observations and devise theories of explanation. The approach lends itself to answering questions in fair and unbiased statements, as long as questions are posed correctly, in a hypothetical form that can be tested.

Definitions:

It is important to understand three important terms before describing the Scientific Method.

Hypothesis – This is a statement made by a researcher that is a working assumption to be tested and proven. It is something "considered true for the purpose of investigation" (Webster's Dictionary 1995). An example might be "The earth is round."

Theory – general principles drawn from facts that explain observations and can be used to predict new events. An example would be Newton's theory of gravitation or Einstein's theory of relativity. Each is based on falsifiable hypotheses of phenomenon we observe.

Falsifiable/ Null Hypothesis – to prove to be false (Webster's Dictionary 1995). The hypothesis that is generated must be able to be tested, and either accepted or rejected. Scientists make hypotheses that they want to *disprove* in order that they may prove the working assumption describing the observed phenomena. This is done by declaring the statement or hypothesis as falsifiable. So, we would state the above hypothesis as "the earth is not round," or "the earth is square" making it a working statement to be disproved.

Process

The Scientific Method is not a formula, but rather a process with a number of sequential steps designed to create an explainable outcome that increases our knowledge base. This process is as follows:

STEP 1. Make an OBSERVATION - gather and assimilate information about an event, phenomenon, process, or an exception to a previous observation, etc.

STEP 2. Define the PROBLEM – ask questions about the observation that are relevant and testable. Define the null hypothesis to provide unbiased results.

STEP 3: Form the HYPOTHESIS – create an explanation, or educated guess, for the observation that is testable and falsifiable.

STEP 4: Conduct the EXPERIMENT – devise and perform an experiment to test the hypothesis.

STEP 5: Derive a THEORY – create a statement based in the outcome of the experiment that explains the observation(s) and predicts the likelihood of future observations.

REPLICATION

Using the Scientific Method to answer questions about events or phenomena we observe can be repeated to fine-tune our theories. For example, if we conduct research using the Scientific Method and think we have answered a question, but different results occur the next time we make an observation, we may have to ask new questions and formulate new hypotheses that are tested by another experiment. Sometimes scientists must perform many experiments over many years or even decades using the Scientific Method to prove or disprove theories that are generated from one initial question. Numerous studies are often necessary to fully test the broad range of results that occur in order that scientists can formulate theories that truly account for the variation we see in our natural environment.

The Scientific Method – Is it worth all the effort?

Scientific knowledge can only advance when all scientists systematically use the same process to discover and disseminate new information. The advantage of all scientific research using the Scientific Method is that the experiments are repeatable by anyone, anywhere. When similar results occur in each experiment, these facts make the case for the theory stronger. If the same experiment is performed many times in many different locations, under a broad range of conditions, then the theory derived from these experiments is considered strong and widely applicable. If the questions are posed as testable hypotheses that rely on inductive reasoning and empiricism – that is, observations and data collection – then experiments can be devised to generate logical

theories that explain the things we see. If we understand why the observed results occur, then we can accurately apply concepts derived from the experiment to other situations.

What do we need to consider when using the Scientific Method?

The Scientific Method requires that we ask questions and perform experiments to prove or disprove questions in ways that will lead to unbiased answers. Experiments must be well designed to provide accurate and repeatable (precise) results. If we test hypotheses correctly, then we can prove the cause of a phenomenon and determine the likelihood (probability) of the events to happen again. This provides predictive power. The Scientific Method enables us to test a hypothesis and distinguish between the correlation of two or more things happening in association with each other and the actual cause of the phenomenon we observe.

Correlation of two variables cannot explain the cause and effect of their relationship. Scientists design experiments using a number of methods to ensure the results reveal the likelihood of the observation happening (probability). Controlled experiments are used to analyze these relationships and develop cause and effect relationships. Statistical analysis is used to determine whether differences between treatments can be attributed to the treatment applied, if they are artifacts of the experimental design, or of natural variation.

In summary, the Scientific Method produces answers to questions posed in the form of a working hypothesis that enables us to derive theories about what we observe in the world around us. Its power lies in its ability to be repeated, providing unbiased answers to questions to derive theories. This information is powerful and offers opportunity to predict future events and phenomena.

Bibliography

Ackoff, R. 1962. Scientific Method, Optimizing Applied Research Decisions. Wiley and Sons, New York, NY.

Wilson, F. 1937. The Logic and Methodology of Science in Early Modern Thought. University of Toronto Press. Buffalo, NY.

Committee on Science, Engineering, and Public Policy. Experimental Error. 1995. From: On Being a Scientist: Responsible Conduct in Research. Second Edition.

The Gale Group. The Scientific Method. 2001. Gale Encyclopedia of Psychology. Second Edition.