The Scientific Method

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The motivation for this discussion came from an article in the California Institute of Technology magazine "Engineering and Science", October 1980. This is an article by Judith and Davis Goodstein titled "The Scientific Method."

This prompted me to consider having a discussion on the scientific method and whether scientists really use it. Science fairs put emphasis on the scientific method and require that participants follow the steps of the method, so as to suggest that if these steps are followed accurately truth results. However, the usual results found at science fairs, and results found in elementary physics labs, taken by themselves, would refute much of classical science, and call into question the scientific path to truth. Science fairs are no doubt a good educational experience, but conceivably could lead to the participants questioning the validity of science. I suggest that everyone read the Wikipedia article "Scientific Method" to prepare for the discussion.

Various versions of the simple steps of the Scientific Method presented to students are:

Version i

1. Ask a Question
2. Do Background Research
3. Construct a Hypothesis
4. Test Your Hypothesis by Doing an Experiment

5. Analyze Your Data and Draw a Conclusion
6. Communicate Your Results

Version ii

1. Ask and define the question.
2. Gather information and resources through observation.
3. Form a hypothesis.
4. Perform one or more experiments and collect and sort data.
5. Analyze the data.
6. Interpret the data and make conclusions that point to a hypothesis.
7. Formulate a "final" or "finished" hypothesis.

Version iii

1. identify the question
2. make a hypothesis
3. create an experiment
4. preform an experiment
5. analyze data
6. go over the experiment
7. make a conclusion

Version iv

1. Make observations.
2. Form a hypothesis.
3. Make a prediction.

4. Perform an experiment.
5. Analyze the results of the experiment.
6. Draw a conclusion.
7. Report your results.

Version v (Data Fitting Version)

1. Collect Data.
2. Find a equation that fits the data.

Version vi (Statistical Version, often used in the social sciences and medicine)

1. Collect Data.
2. Run the data through a statistical program such as SAS.
3. Publish relationships between variables that are statistically significant.

The media often reports on this last type of science, for example: *A new study has shown that pimples can be caused by a teenager staring at the rear end of a bus.*

Contributors to Theories of the Scientific Method.

1. Aristotle (384 BC , 322 BC)
2. Francis Bacon (22 January 1561 , 9 April 1626)
3. David Hume (7 May 1711, 25 August 1776)
4. Charles Sanders Peirce (10 September 1839 , 19 April 1914)
5. Michael Polanyi (1891, 1976)
6. Karl Popper, (28 July 1902 , 17 September 1994)
7. Thomas Kuhn (18 July 1922 , 17 June 1996)
8. Imre Lakatos (9 November 1922 , 2 February 1974)

9. Paul Feyerabend (13 January 1924 , 11 February 1994)

Aristotle Everything has a cause. So the task of the scientist (i.e. philosopher) is to find the cause. The idea of the empirical science did not exit at this time. Motion for example, requires a constant cause. This is contrary to Newton's first law of motion of course.
Francis Bacon Scientist, Lawyer, Politician, Taker of bribes. According to Bacon the scientist starts by making observations. These observations lead to generalizations. One must start with a clean slate. There is need for experimentalists and a much smaller number of interpreters. The test of the generalization is that it lead to new discoveries.
David Hume Scotish Philosopher. Rebutted Aristotle's idea that everything has a cause. David Hume is said to have refuted Aristotle's idea of Cause and Effect.
Charles Sanders Peirce American Mathematician and Philosopher. Peirce in *How to Make Our Ideas Clear* (1878) outlined an objectively verifiable method to test the truth of knowledge in a way that goes beyond mere foundational alternatives, focusing upon both deduction and induction.

`(http://www.cspeirce.com/menu/library/bycsp/ideas/id-frame.htm)`

Michael Polanyi Chemist and Philosopher. His book *Personal Knowledge*, 1958 criticized the common view that the scientific method is purely objective. He characterized this view as a misunderstanding of the scientific method. He argued that scientists follow personal passions in determining which scientific questions to investigate. Polanyi claimed that a structure of liberty is essential for the advancement of science - that the freedom to pursue science for its own sake is a prerequisite for the production of knowledge through peer review and the scientific method.
Karl Popper was an Austrian and British philosopher of science and a professor at the London School of Economics. His main idea was that the important aspect of the scientific method is the falsification by experiment, rather than the Baconian creation of generalities. His basic ideas on falsification are given in his book, *The Logic of Scientific Discovery*, 1934. He was involved also in political philosophy and aligned with the Milton Friedman school of conservative economics. His ideas in this area are outlined in his work *The Open Society and Its Enemies*.

Thomas Kuhn Kuhn's influential book *The Structure of Scientific Revolutions* argued that scientists work in a series of paradigms, and that falsificationist methodologies would make science impossible. A paradigm is literally a pattern, and was initially a term applied to grammar. After Kuhn it came to mean a model or structure of thought that is acceptable to the scientific community at a given time. Thus for scientific progress the current paradigm must be overthrown.

Imre Lakatos Lakatos was a philosopher of mathematics and science. He is known for his thesis of the fallibility of mathematics and its 'methodology of proofs and refutations' in its pre-axiomatic stages of development. Lakatos was a student of Popper. He attempted to reconcile Kuhns work with falsificationism by arguing that science progresses by the falsification of research programs rather than the more specific universal statements of naive falsificationism.

Paul Karl Feyerabend Feyerabend was an Austrian philosopher of science. He was a professor of philosophy at the University of California, from 1958 to 1989. He was another of Poppers students. He argued that the only universal method characterizing scientific progress was anything goes. His major works include *Against Method* (published in 1975), *Science in a Free Society* (published in 1978) and *Farewell to Reason* 1987). Feyerabend became famous for his anarchistic view of science and his rejection of the existence of universal rules, and a universal scientific method.

A couple of other relevant references for this discussion are Eugene Wigner's paper, *The Unreasonable Effectiveness of Mathematics in the Natural Sciences,* and C. P. Snow's famous small book *The Two Cultures.*

The Least Squares fitting of data is often considered a common part of the scientific method. Some people seem to have the naive belief that after collecting data, that there is a unique method to find an equation that fits the data. However, many models can fit the same data.

What is the meaning of the terms: belief, theory, law, conjecture, and hypothesis? We have the Law of Gravity, the Theory of Relativity, the Riemann Hypothesis, the Poincaré Conjecture, and the Belief in Predestination.