Philosophy 3304 Logic
Dr. Naugle

Scientific Methods[1]

INTRODUCTION:

The scientific method is one of the most fascinating fields of the human quest for knowledge. Scientific reasoning has been the major means of acquiring knowledge since the Copernican Revolution (Nicholas Copernicus, died 1543). But most of us lack a true understanding of the so-called scientific method about which there are several misconceptions including the following:

1. Many see the scientific method as one that is singular—the scientific method—that there is only *one* way to go about discovering scientific knowledge and that the one process has been finalized (that there are no ways to change or improve upon it). Even though there are many scientific methods, one—the hypothetical/inductive method (observation, hypothesis, experimentation, observation)—tends to predominate.

2. We see it as a process that will always yield true, correct, or accurate results. Science has assumed a role of great "verily, verily" authority in our culture. But how do you know you are not being duped? Scientific mistakes and errors (even fraud) are aplenty.

3. We assume that the scientist and the scientific process are neutral and objective in which the personal outlook, biases, opinions, and worldview of the scientist plays little or no part. This is simply not the case.

The scientific method is really only one of several ways of confirming scientific knowledge. A little more background information will help.

HISTORICAL BACKGROUND:

The historical background that laid the foundation for 20th century science and theories of scientific confirmation is found in the following philosophers and philosophical movements:

1. Rationalism: In the 17th century and beginning with R. Descartes (1596-1650), rationalists began with *a priori* concepts (innate ideas, first principles, etc.) and built up the entire edifice of knowledge from those premises without recourse to experience. But is the rational the real?

[1] NB: This material is taken from several logic texts authored by N. Geisler, H. Kahane, and others. I make no claim to originality in this material.

2. Empiricism: In the 18th century and beginning with British philosopher John Locke (1632-1704), the empirical school argued that all knowledge comes from experience, *a posteriori*. In Locke's view, man is born as a blank slate (*tabula rasa*) which is subsequently marked by experiences which in turn becomes knowledge. This led to what may be called the **JUSTIFICATIONAL MODEL** of knowledge which began with observation leading to a hypothesis which culminated in a theory about reality which translated into TRUTH!

3. Idealism: In 1781 Immanuel Kant (1724-1804) published a book entitled the *Critique of Pure Reason* which criticized the rational and empirical traditions and attempted a synthesis of both. In regard to the Justificational model, he asserted that the step from observation to theory was impossible and the step from theory to truth was highly questionable. Instead, Kant suggested that the correct scientific method began with theory and in the context of the theory observations are made. That is, our presuppositions and theories color the way we view the world around us such that no one is objective in their understanding of the world and in their science.

In the light of this background we can see that it is not easy to decide what is truth, scientifically or otherwise! In what follows, I will itemize several theories of confirmation that show that there is no one single way to do science.

THEORIES OF CONFIRMATION:

1. Verificationalism: Building upon the doctrines of Bertrand Russell and L. Wittgenstein and growing out of the empiricism of Berkeley and Hume, and originally developed by a group of philosophers in Vienna called the "Vienna Circle," this approach to science, sometimes called logical positivism or verificationalism, has been forcefully and clearly articulated by A. J. Ayer in his book *Language, Truth and Logic* (1946). This position is very close to the justificational model presented above and consists of two parts: that for a proposition to be true, it must be either empirically verifiable, or it must be tautological (where the predicate defines the subject). Ayers articulated the position in these words:

"To test whether a sentence expresses a genuine empirical hypothesis, I adopt what may be called a modified verificational principle. For I require of an empirical hypothesis, not indeed that it should be completely verifiable, but that some possible sense experience should be relevant to the determination of its truth or falsehood. If a putative proposition fails to satisfy this principle, and is not a tautology, then I hold that it is metaphysical, and that, being metaphysical, it is neither true nor false but literally senseless."

Several criticisms of this principle are leveled. One, is the verificational principle empirically verifiable, or a tautology? No! Hence, on its own grounds, the principle is meaningless or senseless. Two, it rules out discussion of the non-empirical including God, morality, and even atomic particles! Three, while the verificational model purports to be inductive and objective, in fact it is highly deductive and subjective. That is, it imposes the theory or framework of verificationalism upon experience and what counts as empirical evidence to support a proposition is thereby determined in advance by the scientist's own empirical standards (hence its subjective nature). Maybe science is deductive after all. That's what the next theory suggests.

<u>Falsificationism</u>: Ever since the time of Francis Bacon's *Novum Organon* (1620), it was thought that the proper method for doing science was inductive not deductive (in Bacon's context, Aristotelian scholasticism). That is, until Karl Popper came along with his view of falsificationism in his book *The Logic of Scientific Discovery* (1934). In short, his goal was not to marshal evidence to prove a theory to be true, but rather to find evidence that would prove a theory to be false. For example, are all swans white? Assembling white swans from all over the world would seemingly prove the claim to be true, but finding one black Australian swan would immediately falsifying the thesis. Now, if no non-white swans are found, then we have increased the likelihood of the thesis being true, but it has not been proven. But if one non-white swan is found, then the claim is certainly rendered false. An more complex version of Popper's method can be found in Imre Lakatos' paper (1970) "Falsification and the Methodology of Scientific Research Programs."

For Popper, like I. Kant, what will count for a theory (verificationalism) and what will count against a theory (falsificationism) is always determined by the scientist's own theoretical, scientific, & philosophical orientation which is an unavoidable given of the human condition. Hence, the scientific method will bring us close to truth even though we will never arrive at truth, for we are always theory bound. Science always results in theory, not pure objective truth.

<u>Paradigm Model</u>: In 1962 Thomas Kuhn published a book entitled The Structure of Scientific Revolutions in which he argued that "normal science" only occurs in a paradigm or world view which embraces an understand of what the world is like, has explanatory power, attracts an enduring group of scientist advocates and is sufficiently open ended to encourage scientific investigation. As a result, normal science is a process of working within, and working out the implications of a given paradigm.

When a number of scientific anomalies occur which do not fit the reigning paradigm, a "paradigm shift" occurs (e.g., Newtonian to Einsteinian physics). The new paradigm is better at explaining problems which are currently viewed as the most important and consequently tends to gain ascendancy among other alternatives even though it is not necessarily the only one available or even the best. The new paradigm is not a logical extension of the old one as a progressive development; sometimes it is not only incompatible with the preceding one, but actually "incommensurate" with what has gone before. But once a scientist has shifted paradigms, he sees the world differently from the way he did before; there has been a change in worldviews that is analogous to a religious conversion.

Kuhn's model takes both Kant and Popper seriously in that he clearly shows how science is theory or value laden. But whereas Popper says that science proceeds in a logical order in the context of a theory, Kuhn says there is no system, only paradigms. Kuhn's paradigm model is clearly within the relativist camp regarding knowledge. He says that a scientist shifts paradigms on the basis of faith in the new model to solve future problems, and that this decision is one that is also based on subjective and aesthetic considerations. And as more and more scientists embrace a new perspective, normal science is defined in terms of that paradigm. Hence, normal science is relative.

<u>Postmodern Anarchistic Model</u>: Paul Feyerabend wrote a book in 1975 entitled *Against Methods* in which he built upon Kuhn's notion that science does not proceed rationally or progressively, but rather irrationally from one paradigm to another. Feyerabend denies that there is no such thing as normal science and that all scientists must have complete freedom to pursue nature as he so desires. There must be no restraints, but rather a complete anarchy as the history of science suggests.

<u>CONCLUSION</u>: There are numerous models of science and critical thinkers must evaluate the evidence given by science for different models produce different conclusions. Nonetheless, the scientific method explained in most informal logic classes like ours offer what we could call the hypothetical/deductive or the hypothesis and testing method of scientific discovery.

THE HYPOTHETICAL/DEDUCTIVE OR THE HYPOTHESIS AND TESTING METHOD OF SCIENTIFIC DISCOVERY

Introduction:

In the scientific quest for knowledge about the world, it is possible to distinguish between two categories: the past and the present, the historical and the empirical, origin science and operation science. The former category deals with events that occurred in the past and are not occurring in the present. The latter category deals with ongoing events in the present. The first covers the origin of the world; the second the operation of the world today. The Hypothesis and testing method is specifically designed to make discoveries about the physical and biological worlds and has the advantage of testing hypotheses against a regular pattern of events that can be observed in nature. It consists of the following steps.

I. Step One: The Situation (or Recognizing the Problem)

Step number one is to recognize a situation that is generating a problem or a question. Many of these are created by practical concerns (medical problem; manufacturing problem, etc.). Problems may be generated in the realm of the theoretical sciences as well (theory of relativity; big bang). The first step is to recognize the problem whether it be of practical or theoretical nature.

II. Step Two: Formulate the Problem

Next, the problem to be researched must be formulated. What questions need to be answered? How are the answers going to be looked for? What kind of study must be undertaken: statistical, experimental, historical, etc? The research project must be narrowed down to manageable size. This includes what kind of experiment to undertake-the rifle, rather than the shotgun approach.

III. Step Three: Observation

Sherlock Holmes once said to Watson: "You see, but you do not observe!" And Helen Keller similarly stated to a friend: "How tragic it is to have sight, but to lack vision!" Well, in the scientific process proper, it is necessary to observe with vision! Whatever relevant facts or data that can be found should be noted and recorded because the smallest clue or detail may be the key to the solution to the problem.

IV. Step Four: Reflection

Think! Think! Think! This is the next step. Reflecting on the observations made, noting patterns and regularities as clues may unlock the secret of the problem you are examining. Also, you must reflect on previous knowledge. What has other research shown? What is known about similar problems? What principles apply here? You must examine the things you observed in light of other knowledge and this leads to a tentative hypothesis.

V. Step Five: Formulate the Hypothesis

Formulating a hypothesis is the main step in the scientific method. It is a statement of what we expect to find, an intelligent "guesstimation" about the way things work, a solution to the proposed problem. It leads in a certain direction, and is a way of stating what we think is going on so that tests can be undertaken to see if it is right. This step has been called neither inductive or deductive, but adductive!—a flash of insight, an intuition worth considering and testing.

VI. Step Six: Predictions

If the hypothesis is correct, then it should behave in certain ways under certain conditions that can be predicted, a deductive maneuver. If the premises are true, then valid deductions are true. Thus, it is necessary to test the premises or the hypothesis via experimentation.

VII. Step Seven: Testing by Experimentation

The way to find out if the hypothesis is true or false is by testing and further observation of the results of the test or experiment performed. Experimentation puts the theory to the test to see if it works as expected. But how should experiments be run? Definitions of a few terms are in order. Antecedent factor is something that happens before the effect is seen. The effect is the event that we are trying to understand. The concomitant factor is a factor that happens at the same time as the cause, but does not really cause the effect. Now with these terms in mind, we can lay out the principles that help us to determine what caused something to happen

A. The method of agreement

1. Negatively, no antecedent factor is the cause in whose absence the effect occurs.

2. Positively, the single antecedent factor common to all situations where the effect occurs is probably the cause.

B. The method of difference

1. Negatively, no antecedent factor can be the cause in whose presence the effect fails to happen.

2. Positively, in otherwise identical situations, the antecedent factor unique to one situation is probably the cause.

C. The joint method

This is the method of cross-checking. It is simply a combination of the above two methods.

D. The method of concomitant variation

The antecedent factor that varies proportionately with the effect is probably the cause.

E. The method of residues

This is the simple process of elimination. The antecedent factor that remains after the other antecedent factors are found to be related to other effects is probably the cause.

F. Conclusion: These methods are the testing instruments of the scientific method. Without these, no hypothesis could be confirmed or denied. They give us positive and negative evidence of causal connections and can establish patterns to explain the effect. You can never say with positive certainty that A caused B, but probable answers using these methods are possible. This is the heart of the scientific inductive method.

VIII. Step Eight: Accept or Reject the Hypothesis

Now that a problem has been formulated, researched, developed into a hypothesis and predictions, and finally tested, the results of the test will determine if the hypothesis should be accepted or not. The results of the test should be measured against the scale of the degrees of probability:

99%±—Virtually Certain (gravity)

90%±—Highly Probable (no two snowflakes alike)

70%±—Probable (for medicines to be approved)

50%±—Possible (coin toss)

30%±—Improbable (life on other planets?)

10%±—Highly Improbable (that Jesus visited N. America)

1%±—Virtually Impossible
(Unicorns or Mermaids)

If the results of the test are greater than 70%, then the probability is good, and the hypothesis is confirmed. If it is confirmed with an even higher degree of probability, then it can be accepted as the means of working knowledge for new problems. It moves from hypothesis to theory, and if the theory is confirmed, it may even attain to the status of a scientific "law."