Chapter 1

The Nature and Utility of Scientific Theory

All humans spend time puzzling about the world around them and wondering why and how things happen. In fact, this curiosity and thought really defines what we call human consciousness. We wonder about the way that things work and we speculate about the causes of interesting events. One way or another, we come up with a reason or an explanation about the nature of reality, or at least the part of reality which interests us. In many cases, our observations of events have provided the evidence that forms the basis of our explanations.

Naive Science and Theory

When we act in this way, we are behaving like scientists. Our goals as inquisitive human beings are identical to those of the scientist: we are interested in understanding how things work, in finding explanations and in predicting outcomes. Since we are not acting with awareness of the rules of science, we'll call our activities naive science. The major difference between ordinary thought and scientific investigation is in the more stringent requirements for scientific study. But this is a very important difference, as we'll see later.

As naive scientists, we try to understand some interesting situation in a way that will predict or explain its operation. This understanding is a kind of theory. The word *theory* is sometimes used to mean a wild speculation ("It's only a theory, but could ancient spacemen have landed in mid-town Manhattan?"). That's not what we refer to when we speak of theory. We'll use the term to mean a simplified explanation of reality.

Kerlinger, in the classic textbook *Foundations of Behavioral Research* (1986), gave this definition of theory:

> *A theory is a set of interrelated constructs (concepts), definitions, and propositions that present a systematic view of phenomena by specifying relations among variables, with the purpose of explaining and predicting the phenomena.*

On the face of it, this looks like a rather formidable (and properly scientific) definition. But let's take it apart and look at what it says.

First of all, the purpose of theory is to explain and predict events. If we can predict an event, we may be able to avoid the danger it poses, or to profit from its occurrence. And if we can understand something well enough to explain it, we have the additional possibility of controlling it to our benefit or even changing it. Early naive scientists developed a theory of fire which predicted the consequences of sticking one's hand in the bright flames; later scientists developed a theory of oxidation which allowed them to make the fire hotter or cooler by regulating the flow of oxygen to the flames.

A theory achieves prediction and explanation by stating relationships between *concepts* which are defined as *variables*. So what are variables? Things which *vary*, that is, take on different intensities, values, or states. We're only interested in predicting or explaining things which change. While we can describe something which never changes, predicting its behavior is trivial: it'll be the same tomorrow as it is today, and the same for all days after that, and nothing will produce any change in it. And there's no need to explain its relationship to other variables, as they cannot affect it. Therefore we have no need for a theory about nonvariables. In developing a theory of fire, our naive fire scientist probably observed that a fire could be very small (a smoldering ember), bigger (a camp fire) or huge (a forest fire). "Size of Fire" is thus a variable, and it can be theoretically related to other variables like "Time it Takes to Cook a Mastodon".

So what are concepts or constructs? They are the mental image of the thing which varies. In the example above, "Fire" is the concept, while "Size of Fire" is the variable based on the concept. Concepts are described in language through definitions. Had he thought to do so, primitive man might have passed on to a neighbor a definition of his concept of a fire: "occurs on wood, gives off flickering light, is hot… ." A later scientist might have defined his concept of the same situation somewhat differently ("electromagnetic radiation in the infrared through visible light region given off by the exothermic combination of oxygen with another element or compound"). In both cases, however, these people have described the concept of fire using words they understand.

Humans, as naive scientists, just naturally try to explain and predict ordinary events in their world. We are uncomfortable with unexplained phenomena, and we have a very basic drive to explain things. Although we'll be talking about theory in the context of human communication for the remainder of this book, let's take another look at a very ordinary example of naive science in the physical world to illustrate the process of building a theory.

Francine Brown decides to take her vacation at a popular ocean resort. The first day at the beach, the water is warm and wonderful for swimming. The second day, the water is very cold. The next day, the water is again very warm. Now this *phenomenon* (variability of the water temperature) interests her, because she likes to swim, and she doesn't like cold water.

What could be causing this day-to-day variation? The sun has been out every day, so that can't be the cause of different water temperatures. Since the sun itself is not variable, she doesn't need to include it in her theory. She begins to observe the water very carefully each day, and she notices that the water is clearer on the days that it is cold, and murkier on the days that are better for swimming.

Francine now can predict whether swimming will be good or not by observing the clarity of the water. She can therefore avoid the shock of diving into frigid water. But this still does not explain *why* the water temperature should shift. In other words, she can *predict* the phenomenon, but she can't yet *explain* it.

After several more days of observation, she notices a relationship between variations in the direction of prevailing winds on the previous day and the water temperature the next day. Days in which the winds are out of the Northeast are followed by days with cold water. Days in which the wind is from another direction are followed by warm water. Now Francine has another way of predicting the water temperature: If the winds are out of the Northeast today, the water will be too cold to swim tomorrow.

Why should the wind direction affect water temperature, she wonders? After looking at a map, she improves her theory by adding some *process* or *mechanism* to explain why things should be working this way. To the Northeast lies open ocean, while the bay in which she is swimming is protected on all other sides by land. Thus Northeast winds may blow colder deep ocean waters (which are clearer, as less algae grow in cold temperatures) into the bay.

What Francine has done is to identify variables (bay water temperature, bay water clarity and wind direction) and to specify relationships among them. In fact, she will probably call one of these variables (wind direction) the *cause*, and the other two variables the *effects.*

Northeast winds will cause bay water to become colder and clearer. Causality will be discussed in more detail later in this book, but Francine has an intuitive idea of what constitutes a *causal relationship*: it's a specific condition of a variable (Northeast wind) which occurs earlier in time than a corresponding condition of another variable (such as cold water), combined with some reasonable explanation for the relationship between these two variables (the nature of the geography of the region).

However, the utility of Francine's theory is limited by the extent to which she is confident that it reflects reality. Do things always work this way? Maybe it was just a coincidence that the wind happened to be from the Northeast before cold swimming days. Francine's theory is no good for making decisions about swimming if there is no real relationship between wind direction and water temperature.

Her next logical step is to collect more evidence. Being a really committed naive scientist, Francine extends her vacation two weeks, and observes the wind direction and water temperature each day. Her logic here is very straightforward. If the phenomenon operates the way she thinks it should, then the direction of the wind today is always going to determine the water temperature tomorrow. Each additional day that this prediction proves correct provides Francine with more evidence that her explanation is the correct one and that her theory can be used to make decisions about swimming the following day. Francine realizes that more evidence can improve the *probability* that her theory is true. But with each additional confirming observation, she is more certain that the relationship between the variables is not just a coincidence.

Francine has carried out all the major steps of a scientific study: she has sought out relevant constructs which vary, observed their values (e.g. water is cold or warm; wind is from the Northeast or South), created a theory which contains a testable prediction, and collected evidence to see if her predictions are probably correct. She has done this actually without really being conscious of it, because that's the way humans learn about their world.

But humans are also often somewhat sloppy in their reasoning, and sometimes create incorrect naive theories. The process of developing explanations for phenomena and for testing whether the explanations are probably true or false has many opportunities for error. To overcome this, the *scientific method* has evolved as a highly formalized, systematic and controlled version of the innate human activity of collecting and summarizing information into naive theories.

Naive Inquiry Versus Scientific Method

The main thing which differentiates between science and naive inquiry is the awareness that our observations and reasoning are error-prone, and that we must employ strategies that help us guard against committing error. Kerlinger (1986) emphasizes five points on which science and naive inquiry differ. These points, which are summarized below, offer striking illustrations of the differences between formalized, systematic, and controlled inquiry ("science") and naive inquiry.

The Development of Theories

A theory presents us with an explanation of a phenomenon: it consists minimally of a concept considered to be a cause, a concept considered to be an effect, and a statement about how and why the two should be related. More formally, a theory is a set of two or more concepts interrelated by one or more hypothetical or theoretical propositions. A theory represents a statement about what *might* logically be happening.

Science and naive inquiry differ greatly in the way in which the concepts of inquiry are selected for study. The scientist will systematically select all the concepts which can be reasonably thought to be possible causes of a phenomenon. The scientist will also eliminate from the theory all other concepts considered to be irrelevant.

This process of selection and elimination continues until the total set of available concepts has been reduced to those that are determined by the scientist to be relevant to the problem. This process is accomplished in part via a thorough review of the published research literature, which tells the scientist which concepts have or have not been found to be linked to the phenomenon to be investigated. The scientist relies on the previous work of others to justify using the concepts, and to explain the cause-effect sequence in their relationships.

But the scientist also realizes that the concepts previously used by other researchers may not exhaust all possible causes or effects. Previous researchers may have overlooked the "real" cause simply because they were not aware of its existence. For example, for all the time that physicians were not aware of the existence of bacteria, they could not consider them as causes of disease. Consequently, by logic, insight or observation, the scientist may add new concepts to the theory. The scientist is always considering alternative concepts and processes, and seeing if they might explain the phenomenon being studied more clearly.

The naive scientist, on the other hand, does not go through this process of systematically reviewing the work of others, and of considering alternative concepts. Rather, guided by his biases or convictions, he may select a concept as a cause simply because he finds it to be appealing. Similarly, a naive scientist may latch onto a concept as being a possible cause simply because she would *like* it to be the cause, not necessarily because there is a logical reason for it to be so. In this way, moral decay has been held up as the "cause" of natural disasters; the color of a person's skin has been believed to predict his willingness to work; and God's wrath has been seen as the cause of disease.

In other cases, however, naive scientists like Francine Brown base their explanation of phenomena on their own observation of reality. In this way they are like true scientists who also may use personal observation to help develop theories. The difference is this: the naive scientist will probably consider her personal observations to be sufficient to construct her completed theory. For the true scientist, however, personal observations are only a preliminary step in the process of scientific investigation.

The naive scientist selects concepts based on their *appeal* rather than their *relevance*. This constitutes a decidedly non-systematic method of constructing theories, and the resulting theories are often wrong. Naive scientists do not critically examine alternative explanations for phenomena, and thus may include irrelevant concepts, fail to include important concepts, and miss the true relationships among concepts.

The Testing of Theories

Naive science and science differ dramatically in their demand for evidence which supports the truth of a theory. The naive scientist will frequently be satisfied that his theory is correct because its truth is obvious, and conclude that no further support is needed. The theory is thought to be correct because it is "self-evident", "common sense", "is what any reasonable person would conclude". If evidence is obtained at all, the naive scientist's own, informal, personal observations are usually considered sufficient.

Often, if more "objective" evidence is sought, it is frequently done in such a way as to provide information which is consistent with the theory and to ignore conflicting information.

For instance, some media critics believe television crime programs cause viewers to commit similar crimes. As evidence, they cite the example of the broadcast of a program which depicts a distinctive crime, which is then followed by the commission of several similar crimes the next day. However, they ignore the millions of people who watch the same program and do not commit the crime, and those persons who did not watch the program but yet committed the same kind of crime.

This is not necessarily conscious behavior; all of us tend to select certain evidence because it is consistent with our preconceptions, and to ignore other evidence because it is not. This is basic human psychology, but it is also bad science, and we must guard against it.

Unlike the naive scientist, the true scientist is not satisfied by the mere fact that a theory conforms to common sense or personal observation. He insists on obtaining objective evidence before making judgments about the probable truth or falsehood of the theory. *Objective* means that the evidence can be collected by any other person (the evidence is reproducible), and that it is not biased toward proving the theory either true or false. Furthermore, the true scientist is aware of the human tendency toward the selective use of evidence and will try mightily to guard against preconceptions or biases affecting his or her research. The scientist does this by giving alternative explanations of the phenomenon, many of which may be quite different from her own theory, an equal chance to be proven true. The true scientist also publishes her research procedures, so that unconscious bias can be detected by others. There is also the additional benefit of enabling other researchers to reproduce the observations.

There are many other procedures to ensure against unbiased testing of theories, such as using randomly selected subjects, using persons who do not know the purpose of the research study to administer tests, etc. Some of these will be covered later, but there are three key ideas to be remembered: (1) theories must be tested objectively, rather than just assumed to be true or false; (2) all information must be considered on an equal basis, rather than selected just to support the theory; (3) testing of theories must be done under conditions which will minimize the possibility of conscious or unconscious subjective biases of the researcher.

Control of Alternative Explanations

This point is very closely related to the development of theories. Recall that the scientist systematically eliminates those concepts which are irrelevant to the phenomenon to be explained, and includes all relevant concepts. This process will, in all likelihood, leave the scientist with a number of possible competing "causes" for any phenomenon ("effect"). If several concepts produce the same effect, how are we to distinguish among them?

The answer lies in the *control* of competing causes. In order to measure the effect of any single causal variable on the effect variable, the scientist will have to control for all other potential causal variables. By doing this, the scientist will be able to guard against confusing one causal relationship with another. In other words, the scientist will be able to design a study in such a way that it can be unequivocally stated that this particular variable causes this particular effect, *independent* of all other causal variables.

The naive scientist is neither systematic nor thorough in investigations. Consequently, control over other confounding causal variables is not possible, because other relevant concepts may not have been identified. A particular cause and an effect may appear to be linked together, but we can not say that this particular "cause" truly brought about this "effect", because we do not know whether other causes may have been operating simultaneously.

The key idea here is that the scientist will control the research situation so that he can state with confidence that whatever effect is observed is in fact due to a particular cause, *and not to competing causes*. He can make this statement because other known causes have been eliminated or controlled in some way. The particular methods used for control will be described in detail later in this book.

The Nature of Relationships

There are three possible relationships between two concepts. First, the relationship might be *null*. This means that there is no relationship at all—the concepts operate independently of each other. We may observe that children who watch more televised violence are no more or less aggressive than other children. In other words, there is no relationship between viewing violence and acting aggressively.

A second type of relationship is *covariance*, where the concepts vary together, but one is not the cause and the other the effect. The price of rum and the size of professors' salaries vary together quite consistently (as one goes up, so does the other), but we could not reasonably state that one causes the other. A covariance relationship can be *positive* or *negative*. If we see more of one variable (price of rum) associated with *more* of the other (professors' salaries), the relationship is positive. If more of the first variable (say, consumption of rum) is associated with *less* of an associated variable (accuracy in doing math problems), the relationship is negative.

Finally, the concepts might have a *causal* relationship. In this case the concepts covary (are related) and changes in one concept precede changes in the other concept, and the causal relationship between the two can be justified logically. We can say that changes in the inflation rate cause changes in the price of rum. The inflation rate changes first, and then, by the process of devaluation of currency, the price of rum increases. Causal relationships can be positive or negative, just like covariance relationships.

It is absolutely essential that theories distinguish among these kinds of relationships. If null relationships are confused with covariance or causal relationships, we fail to explain reality correctly with our theory. If covariance relationships are confused with causal relationships, we may make serious errors in applying our theory. For example, if we state that changes in the price of rum cause changes in professors' salaries, we might conclude that the way to improve compensation to academics is by enacting a large tax on rum!

The scientist applies the rules of mathematics and statistics to distinguish between null and non-null relationships. She subsequently applies the conditions of causality to non-null relationships to distinguish between covariance and causal relationships. The techniques of research design are used to establish covariation and causal relationships. Again, these techniques will be discussed later in this book.

In contrast, the naive scientist is likely to capitalize on the joint occurrence of two phenomena and to assume them to be linked in a cause-and-effect fashion, particularly if this fits his or her preconceptions or beliefs. A naive scientist whose nephew is arrested for drug possession may conclude that his antisocial behavior is caused by his habit of listening to rock music. After all, many drug users also listen to lots of rock, and some lyrics can be interpreted as advocating drug use. A true scientist will apply more stringent tests of evidence and causality before reaching such a conclusion.

Testing Theories with Observable Evidence

Science requires objective evidence before making decisions about the truth or falsehood of a theory. Answering scientific questions demands unbiased observation and testing. This requires that the search for relevant concepts be limited to those concepts which are *observable* by any person. The scientist cannot be concerned with that which is not observable, or that which is observed in one fashion by one person, and in another way by someone else. This requirement limits the areas which can be scientifically investigated. For example, there can be no real scientific investigation of morality, as this concept cannot be objectively observed. What is perceived as moral behavior for a Shiite Muslim may be quite immoral for a Methodist, and vice versa. Morality is thus a concept which is not objectively observable, and cannot be included in a scientific theory. Similarly, science will never be able to determine the number of angels that can dance on the head of a pin, as most persons cannot observe angels.

But the naive scientist is often not concerned with such rules of evidence. If she accepts a naive theory as true because its truth is obvious to any reasonable person, then observable evidence is not required. Likewise, if the naive scientist assumes that everyone observes concepts just as he or she does, then the resulting theory will apply only to similar-thinking people.

There are many areas of human concern which are worthy of thought and debate, but which are off-limits to scientific investigation. A naive scientist is less likely to distinguish between these areas and those which may be properly investigated with the scientific method. There are different methods of acquiring knowledge about what's real and what's not. Science is only one of them.

Methods of Knowing

As the previous discussion has shown, a distinguishing characteristic of science is the method by which we *know* something to be true. This can be highlighted by contrasting science to other methods of knowing reality. Charles Peirce (in Kerlinger, 1986), classified methods of knowing, or as he called them, methods of "fixing belief" into four categories: the *method of tenacity, the method of authority, the "a priori" method* and finally, *the method of science*. These four categories will be presented in a hierarchy, because each level can be seen as having introduced additional safeguards to assure truth.

Probably the least sophisticated method for fixing belief is the *method of tenacity*. This method determines truth, or establishes explanations, by asserting that something is true simply because it is commonly known to be true. Period. This sometimes-fanatical adherence to a set of beliefs is exemplified in racial or ethnic stereotypes. In the method of tenacity, the process of formulating beliefs occurs entirely within a given individual and is entirely subject to that person's beliefs, values and idiosyncrasies. Although it is the most primitive, this method of forming beliefs about what is true and what is false is very commonly used. Remarkably, people often sustain belief even in the face of contrary evidence. For instance, a person who tenaciously holds to the view that the portrayal of sexual themes in motion pictures causes sex crimes would probably never be convinced by any number of research studies which indicate no evidence for such a relationship.

The second method is the *method of authority*. In this method, truth is established when someone or something for which I have high regard states the truth. I may accept my physician's diagnosis of my illness as truth because my physician has been correct in the past, or because I have been taught that physicians are expert in what they do. Or I may regard a religious text or a political tract as the distillation of truth, because they are sources of authoritative statements.

This method has an advantage over the method of tenacity because it often relies on the testimony of experts. If the source is indeed expert, adopting the expert's advice may be beneficial. In the case of medical problems, for instance, it would be better if a patient followed a doctor's expert advice rather than clinging to the personal belief that his condition was the consequence of the wrath of a vengeful god and not subject to cure.

The method of authority is quite widespread and has both its uses and abuses. The number of people who make a living as consultants, or purveyors of expertise, testifies to its popularity. The method is also used in advertising, as products are ringingly endorsed by people who "ought to know", such as a champion tennis player endorsing a racquet. But this method is dangerous when the purported expert is really not knowledgeable (such as a medical "quack"), or when persons with expertise in one area give advice in an unrelated area (a movie star endorses a political candidate).

The third method of knowing is *the a priori method* or *the method of reasonable men*. This method rests on the idea that the propositions submitted are self-evident, that is, they agree with reason. The criterion for fixing belief thus lies in the reasonableness of the argument, which is to be furthered by the unfettered exchange of information among people. The idea of a "marketplace of ideas" applies here, as the truth would ostensibly emerge after each proposition was examined for its logical consistency and reasonableness. There are again some advantages over the previously discussed method of authority. Whatever emerges as truth will at least have been able to withstand scrutiny by a number of people who evaluate its logical consistency, quality of reasoning, etc. In this respect, whatever is held to be true will be the product of a social process involving many authorities, rather than the statement of a single authority.

The problem with this method lies in the definition of *reasonable*, or, more properly, who gets to define what is reasonable. The same facts presented to a number of reasonable people could lead to vastly different conclusions. For example, a set of regulations on communication technology may be evaluated by one government official as a prescription for economic development, while being dismissed by another official as stifling the free flow of information. Furthermore, the test for truth is that statements *agree with reason*, but *not necessarily that they agree with observable fact or experience*. By starting with a faulty premise, one can deduce a whole array of logical, but incorrect conclusions.

The final method for fixing belief is *the method of science*. This method constitutes a critical shift in perspective. The previous three methods are focused inward: with the method of tenacity, what we believe is determined by what we have believed all along and it may be completely idiosyncratic; with the method of authority, what we believe is determined by our evaluation of the credibility of the source of the knowledge; with the "a priori" method, truth is determined by whatever criteria we personally wish to establish for reasonableness. *Science shifts the locus of truth from single individuals to groups, by establishing a set of mutually agreed upon rules for establishing truth.* This establishes, in Peirce's words, an "external permanency" which transcends the belief systems of any single individual.

Scientific truth still demands logical consistency, like the "a priori" method. But the logical deductions must also be tested against an external reality which can be perceived by any person, and is not just the property of a single individual or group.

Contrasting the Methods Of Knowing

It is interesting to consider the relationship between beliefs which are accepted as truth by each of the above three methods and TRUTH, the objective reality that exists "out there". Of course, it can be argued that there is no such thing as objective reality. But if one accepts such an argument, one cannot use the method of science, which requires at least some common experience of reality which can be shared among individuals.

The method of tenacity is a complete roll of the dice. Tenaciously held beliefs may well agree with objective reality or may be far removed from it, but there is no way of knowing which is the case. The method of authority eliminates some of the more outrageous propositions that otherwise might arise. However, there is no guarantee that what is considered an outrageous proposition today might not in fact prove to be true tomorrow. The "a priori" method might eliminate idiosyncratic beliefs held by a single individual by submitting them to the scrutiny of the marketplace of ideas. Beliefs subjected to this method may be logically consistent, reasonable and popular, but may still be incorrect.

Science states that there is an objective reality and that our ideas about it (our theories) do not alter that reality. The next step is then plainly obvious: in order to establish our theories as true, we must see how closely our vision of the way the world works corresponds to the way the world *actually* works. Unlike any of the other methods of knowing, science demands that we support our internal beliefs with external evidence.

Herein lies the strong suit of science. By imposing on the scientist the requirement that theories be tested against some observable reality, science has one attribute that the other ways of knowing do not: it is self-correcting. We may take a tenaciously held belief, elevate it by finding an authority who will vouch for it, and further justify it to reasonable men by showing its logic. But if the theory will not predict commonly observed reality, we must reject it and replace it with a corrected theory.

Because science requires that we determine the extent to which our theories about the real world agree with the way in which the real world operates, we need a method for testing the theoretical predictions against the observed reality. The supreme requirement imposed by this method is that all persons subscribing to it will agree about the truth or falsity of a theory when they are presented with the same information.

The Scientific Method

In the remainder of this chapter we will outline the basic requirements of the scientific method. We need to meet these requirements if our efforts are to achieve the advantages that make science superior to other methods of fixing belief, as outlined above, and which give it the rigor that differentiates true science from naive science. These rules will be briefly introduced here, and they will be extensively discussed in the chapters to come.

The Use and Selection of Concepts

We begin by conceptualizing the cause and effect phenomena, that is, by developing a verbal description or name for the events. By using the scientific method we seek to explain phenomena by linking a concept called a cause to another concept called an effect. Whereas naive science may select as the cause some concept which has some innate appeal, science will consider as causes only those concepts which can be reasonably argued to be related to the effect. Scientists arrive at causally related concepts through a thorough review of previous research, by using logical deduction, and by insight and personal observation.

Linking Concepts by Propositions

If we are interested in explaining a phenomenon, we need to specify the functional mechanism whereby a cause brings about an effect: we need to state why changes in some variable A should lead to changes in some variable B. Such a functional statement distinguishes between causal relationships (which have such an explanation) on the one hand and mere covariance relationships (which do not) on the other.

Testing Theories with Observable Evidence

This means that any theory will not be regarded as probably true until we have had a chance to test it against some observable reality. It means that we will withhold judgment about the truth or falsehood of a theory until we have been able to determine the extent to which predictions derived from or consistent with our theory mirror observed reality.

The Definition of Concepts

Testing theory with some observable evidence generates this requirement of science. The requirement that we observe the real world brings with it the need to bridge the gap between theory, which is stated at a high level of abstraction, and observation, which takes place at a very concrete level. Bridging this gap is accomplished through a process of defining both the meanings of concepts and the indicators or measures which will be used to capture those meanings. We need to make very clear what the concept means and what it looks like, in concrete terms, when we observe it in the real world.

The Publication of Definitions and Procedures

Because the scientific method is public, all other researchers need to have the ability to carry out the same procedures in order to arrive at the same conclusions. This requires that we be as explicit and objective as possible in stating and publicizing definitions and procedures. There should be no mystery in scientific procedures. This allows research studies to be replicated by independent scientists. It also facilitates the resolution of inconsistencies in research findings which involve the same phenomenon.

Control of Alternative Explanations

Scientific studies have to be designed in such a way that we can rule out alternative causes. When a relationship between two variables is studied, we must be able to isolate the effect of the single causal variable from the effects of all other possible causes. Isolating a true causal variable means that these other *confounding variables* have to be identified and their effects eliminated or controlled.

Unbiased Selection of Evidence

The decision to accept a theory as probably true or probably false will be based on the observation of limited evidence. For example, there are many studies of the concept of communication apprehension (fear when confronted with speaking in public, for example) that use observations of the behavior of a few hundred college students. Since the researcher will wish to generalize beyond this limited sample, science requires that the evidence be selected in such a way as to eliminate biases and thereby be representative of the greater population. In the case of the communication apprehension studies, if the students have been selected in an unbiased way, then the results may be extended to all college students, not just those few hundred who participated in the studies.

Reconciliation of Theory and Observation

The degree of agreement between what theory predicts we *should* observe and what we actually do observe is the basis of the self-correcting nature of the scientific approach. Any disagreement will have to result in careful scrutiny of the method used or in the revision of the original theory. This will lead to the generation of new predictions which will again be subjected a new observational test. This process furthers theory by providing refinements to existing theories, or by substituting a new theory which better explains observed reality than did the old theory.

Limitations of the Scientific Method

The scientific method cannot be used to study all questions. We cannot employ the scientific method when objective observation is not possible. In this case, we must use other methods of fixing belief. For example, if we want to determine whether a social policy is good or bad, we may well want to yield to an authority such as the Bible or the Koran, because objective measurement of "good" and "bad" is not possible.

Basic beliefs or assumptions are not testable propositions, as they can never be disproved, and thus they cannot be investigated scientifically. The statement that "We take these truths to be self-evident … that all men are created equal…." is a wonderful statement of personal truth, but it lies outside the realm of scientific investigation.

The limits of science are clear; the limits of belief are not.

Summary

In this chapter we have distinguished between naive inquiry and the scientific method. All people are naive scientists who try to understand the world around them by observing phenomena and making logical deductions about causes and effects. True scientists have further requirements.

Both the true scientist and the naive scientist create *theories*, which are verbal representations of reality of some *phenomenon*. These theories involve *concepts* or *constructs* which are verbal descriptions of the object or elements of the theory; *variables* which quantify the amount or state of the concept which is present in some instance; and *relationships* which link the concepts and variables together.

But the true scientist must adhere to a more stringent set of rules in testing a theory than does the naive scientist. The true scientist must include within his theory all the concepts which might be involved in a phenomenon and must exclude irrelevant concepts; the naive scientist often selects a simpler set of concepts which are personally attractive. The true scientist must define concepts so that others can agree upon their meaning and can measure them objectively; the naive scientist defines concepts in a way which may make sense only to them. The true scientist must make unbiased measurements and consider all evidence, whether it favors the theory of the scientist or not; the naive scientist often makes inadequate or incomplete measurements, and selects only the evidence which supports her theory.

The reward for adhering to the more stringent set of rules which the scientific method requires is a reduced chance of drawing the wrong conclusions. Since a scientific theory is based on objectively observable evidence, and it can be shared and tested by a group of persons, scientific theory is self-correcting. Incorrect or inadequate theory can be detected by other scientists, and so it can be rejected.

The basic requirements of science will be discussed in great detail in the following four chapters. In these chapters we will present specific strategies for responding to the requirements of the scientific method.

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