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CHAPTER 1

SCIENCE AND THE SCIENTIFIC APPROACH

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To understand any complex human activity one must grasp the language and approach of the individuals who pursue it. So it is with understanding science and scientific research. One must know and understand, at least in part, scientific language and the scientific approach to problem-solving.

One of the most confusing things to the student of science is the special way scientists use ordinary words and, to complicate matters, they even invent new words. There are good reasons for this specialized use of language, which will become evident later. For now, suffice it to say that we must understand and learn the language of social scientists. When investigators tell us about their independent and dependent variables, we must know what they mean. When they tell us that they have randomized their experimental procedures, we must not only know what they mean—we must understand why they do as they do.

Similarly, the scientist's approach to problems must be clearly understood. It is not so much that this approach is different from the layperson's. It *is* different, of course, but it is neither strange nor esoteric. This is quite the contrary. When understood, it will seem natural and almost inevitable what the scientist does. Indeed, we will probably wonder why much more human thinking and problem-solving are not consciously structured along such lines.

The purpose of chapters 1 and 2 of this book is to help the student learn and understand the language and approach of science and research. In these chapters many of the basic constructs of the social, behavioral, and educational scientist will be studied. In some cases it will not be possible to give complete and satisfactory definitions due to lack of background at this early point in the reader's development. In such cases an attempt will be made to formulate and use reasonably accurate first approximations and to progress to more satisfactory definitions. Let us begin our study by considering how the scientist approaches problems and how this approach differs from what might be called a common-sense approach.

Science and Common Sense

Whitehead (1911/1992, p. 157) at the beginning of the twentieth century pointed out that in creative thought common sense is a poor master. "Its sole criterion for judgment is that the new ideas shall look like the old ones." This is well said. Common sense may often be a bad master for the evaluation of knowledge. But how are science and common sense alike and how are they different? From one viewpoint, science and common sense are alike. This view would say that science is a systematic and controlled extension of common sense. James Bryant Conant (1951) states that common sense is a series of concepts and conceptual schemes[1] satisfactory for the practical uses of humanity. However, these concepts and conceptual schemes may be seriously misleading in modern science—and particularly in psychology and education. To many educators in the 1800s, it was common sense to use punishment as a basic tool of pedagogy. However, in the mid-1900s evidence emerged to show that this older commonsense view of motivation may be quite erroneous. Reward appears to be more effective than punishment in aiding learning. However, recent findings suggest that different forms of punishment are useful in classroom learning (Marlow, et al., 1997; Tingstrom, et al., 1997). Science and common sense differ sharply in five ways. These disagreements revolve around the words *systematic* and *controlled.*

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[1] A *concept* is a word that expresses an abstraction formed by generalization from particulars. "Aggression" is a concept, an abstraction that expresses a number of particular actions having the similar characteristic of harming people or objects. A *conceptual scheme* is a set of concepts interrelated by hypothetical and theoretical propositions. A *construct* is a concept with the additional meaning of having been created or appropriated for special scientific purposes. "Mass," "energy," "hostility," "introversion," and "achievement" are constructs. They might more accurately be called "constructed types" or "constructed classes"; classes or sets of objects or events bound together by the possession of common characteristics defined by the scientist. The term "variable" will be defined in a later chapter. For now let it represent a symbol or name of a characteristic that takes on different numerical values.

First, the uses of conceptual schemes and theoretical structures are strikingly different. The common person may use "theories" and concepts, but usually does so in a loose fashion. This person often blandly accepts fanciful explanations of natural and human phenomena. An illness, for instance, may be thought to be a punishment for sinfulness (Klonoff & Landrine, 1994). Jolliness is due to being overweight. Scientists, on the other hand, systematically build theoretical structures, test them for internal consistency, and put aspects of them to empirical test. Further, they realize that the concepts they use are man-made terms that may or may not exhibit a close relationship to reality.

Second, scientists systematically and empirically test their theories and hypotheses. Non-scientists test "hypotheses," too, but they test them in a selective fashion. They often "select" evidence simply because it is consistent with the hypotheses. Take the stereotype: Asians are science and math oriented. If people believe this, they can easily "verify" their beliefs by noting that many Asians are engineers and scientists (see Tang, 1993). Exceptions to the stereotype are not perceived: the non-science Asian or the mathematically challenged Asian. Sophisticated social and behavioral scientists knowing this "selection tendency" to be a common psychological phenomenon, carefully guard their research against their own preconceptions and predilections and against selective support of hypotheses. For one thing, they are not content with armchair or fiat exploration of relations; they must test the relations in the laboratory or in the field. They are not content, for example, with the presumed relationships between methods of teaching and achievement, between intelligence and creativity, between values and administrative decisions. They insist on systematic, controlled, and empirical testing of these relations.

A third difference lies in the notion of control. In scientific research, control means several things. For the present, let it mean that the scientist tries to systematically rule out variables that are possible "causes" of the effects under study other than the variables hypothesized to be the "causes." Laypeople seldom bother to control their explanations of observed phenomena systematically. They ordinarily make little effort to control extraneous sources of influence. They tend to accept those explanations that are in accord with their preconceptions and biases. If they believe that slum conditions produce delinquency, they tend to disregard delinquency in nonslum neighborhoods. The scientist, on the other hand, seeks out and "controls" delinquency incidence in different kinds of neighborhoods. The difference, of course, is profound.

Another difference between science and common sense is perhaps not so defined. It was said earlier that the scientist is constantly preoccupied with relationships among phenomena. The layperson also does this by using common sense for explanations of phenomena. But the scientist consciously and systematically pursues relationships. The layperson's preoccupation with relationships is loose, unsystematic, and uncontrolled. The layperson often seizes, for example, on the fortuitous occurrence of two phenomena and immediately links them indissolubly as cause and effect.

Take the relation tested in the classic study done many years ago by Hurlock (1925). In more recent terminology, this relation may be expressed: Positive reinforcement (reward) produces greater increments of learning than does punishment. The relation is between reinforcement (or reward and punishment) and learning.

Educators and parents of the nineteenth century often assumed that punishment was the more effective agent in learning. Educators and parents of the present often assume that positive reinforcement (reward) is more effective. Both may say that their viewpoint is "only common sense." It is obvious, they may say, that if you reward (or punish) a child, he or she will learn better. The scientist, on the other hand, while personally espousing one or the other or neither of these viewpoints, would probably insist on systematic and controlled testing of both (and other) relationships, as Hurlock did. Using the scientific method, Hurlock found incentive to be substantially related to arithmetic achievement. The group receiving praise scored higher than the reproofed or ignored groups.

A final difference between common sense and science lies in different explanations of observed phenomena. The scientist, when attempting to explain the relations among observed phenomena, carefully rules out what have been called "metaphysical explanations." A metaphysical explanation is simply a proposition that cannot be tested. To say, for example, that people are poor and starving because God wills it, or that it is wrong to be authoritarian, is to talk metaphysically.

None of these propositions can be tested; thus they are metaphysical. As such, science is not concerned with them. This does not mean that scientists would necessarily spurn such statements, say they are not true, or claim they are meaningless. It simply means that *as scientists* they are not concerned with them. In short, science is concerned with things that can be publicly observed and tested. If propositions or questions do not contain implications for such public observation and testing, they are not scientific propositions or questions.

Four Methods of Knowing

Charles Sanders Peirce as reported in Buchler (1955) said that there are four general ways of knowing or, as he put it, fixing belief. In the ensuing discussion, the authors are taking some liberties with Peirce's original formulation in an attempt to clarify the ideas and to make them more germane to the present discussion. The first is the *method of tenacity*. Here people hold firmly to the truth, the truth that they know to be true because they hold firmly to it, because they have always known it to be true. Frequent repetition of such "truths" seems to enhance their validity. People often cling to their beliefs in the face of clearly conflicting facts. And they will also infer "new" knowledge from propositions that may be false.

A second method of knowing or fixing belief is the *method of authority*. This is the method of established belief. If the Bible says it, it is so. If a noted physicist says there is a God, it is so. If an idea has the weight of tradition and public sanction behind it, it is so. As Peirce points out, this method is superior to the method of tenacity because human progress, although slow, can be achieved using this method. Actually, life could not go on without the method of authority. Dawes (1994) states that as individuals, we cannot know everything. We accept the authority of the U.S. Food and Drug Administration in determining that what we eat and drink is safe. Dawes states that the completely open mind that questions all authority does not exist. We must take a large body of facts and information on the basis of authority. Thus, it should not be concluded that the method of authority is unsound; it is unsound only under certain circumstances.

The *a priori method* is the third way of knowing or fixing belief. Graziano and Raulin (1993) call it the *method of intuition*. It rests its case for superiority on the assumption that the propositions accepted by the "a priorist" are self-evident. Note that a priori propositions "agree with reason" and not necessarily with experience. The idea seems to be that people, through free communication and intercourse, can reach the truth because their natural inclinations tend toward truth. The difficulty with this position lies in the expression "agree with reason." Whose reason? Suppose two honest and well-meaning individuals, using rational processes, reach different conclusions. Who is right? Is it a matter of taste, as Peirce puts it? If something is self-evident to many people—for instance, that learning difficult subjects trains the mind and builds moral character, that American education is inferior to Asian and European education—does this mean it is so? According to the a priori method, it does—it just "stands to reason."

The fourth method is the *method of science*. Peirce says:

> To satisfy our doubts, . . . therefore, it is necessary that a method should be found by which our beliefs may be determined by nothing human, but by some external permanency—by something upon which our thinking has no effect. . . . The method must be such that the ultimate conclusion of every man shall be the same. Such is the method of science. Its fundamental hypothesis . . . is this: "There are real things, whose characters are entirely independent of our opinions about them . . ." (Buchler, 1955, p. 18).

The scientific approach has a characteristic that no other method of attaining knowledge has: self-correction. There are built-in checks all along the way to scientific knowledge. These checks are so conceived and used that they control and verify scientific activities and conclusions to the end of attaining dependable knowledge. Even if a hypothesis seems to be supported in an experiment, the scientist will test alternative plausible hypotheses that, if also supported, may cast doubt on the first hypothesis. Scientists do not accept statements as true, even though evidence may at first look promising. They insist on testing them. They also insist that any testing procedure be open to *public* scrutiny. One interpretation of scientific method is that there is no one specific scientific method. Rather, there are a number of methods that scientists can and do use, but it probably can be said that there is one scientific approach.

As Peirce says, the checks used in scientific research are anchored as much as possible in reality lying outside the scientist's personal beliefs, perceptions, biases, values, attitudes, and emotions. Perhaps the best single word to express this is *objectivity*. Objectivity is agreement among "expert" judges on what is observed or what is to be done or has been done in research (see Kerlinger, 1979 for a discussion of objectivity, its meaning and its controversial character). According to Sampson (1991, p. 12) objectivity "refers to those statements about the world that we currently can justify and defend using the standards of argument and proof employed within the community to which we belong—for example, the community of scientists." But, as we shall see later, the scientific approach involves more than both of these statements. The point is that more dependable knowledge is attained because science ultimately appeals to evidence: propositions are subjected to empirical testing. An objection may be raised: Theory, which scientists use and exalt, comes from people, the scientists themselves. But, as Polanyi (1958/1974, p. 4) points out, "A theory is something other than myself." Thus a theory helps the scientist to attain greater objectivity. In short, scientists systematically and consciously use the self-corrective aspect of the scientific approach.

Science and Its Functions

What is science? This question is not easy to answer. Indeed, no definition of science will be directly attempted. We shall instead talk about notions and views of science and then try to explain the functions of science.

Science is a misunderstood word. There seem to be three popular stereotypes that impede understanding of scientific activity. One is the white coat–stethoscope–laboratory stereotype. Scientists are perceived as individuals who work with facts in laboratories. They use complicated equipment, do innumerable experiments, and pile up facts for the ultimate purpose of improving the lot of humanity. Thus, while somewhat unimaginative grubbers after facts, they are redeemed by noble motives. You can believe them when, for example, they tell you that such-and-such toothpaste is good for you or that you, should not smoke cigarettes.

The second stereotype of scientists is that they are brilliant individuals who think, spin complex theories, and spend their time in ivory towers aloof from the world and its problems. They are impractical theorists, even though their thinking and theories occasionally lead to results of practical significance, like atomic energy.

The third stereotype erroneously equates science with engineering and technology: the building of bridges, the improvement of automobiles and missiles, the automation of industry, the invention of teaching machines. The scientist's job, in this stereotype, is to work at the improvement of inventions and artifacts. The scientist is perceived to be some sort of highly skilled engineer working to make life smooth and efficient.

These stereotypical notions impede student understanding of science, the activities and thinking of the scientist, and scientific research in general. In short, they make the student's task harder than it would otherwise be. Thus they should be cleared away to make room for more adequate notions.

There are two broad views of science: the static and the dynamic. According to Conant (1951, pp. 23–27) the *static view*, the view that seems to influence most laypeople and students, is that science is an activity that contributes systematized information to the world. The scientist's job is to discover new facts and to add them to the already existing body of information. Science is even conceived to be a body of facts. In this view, science is also a way of explaining observed phenomena. The emphasis, then, is on the *present state of knowledge* and *adding to it* and on the present set of laws, theories, hypotheses, and principles.

The *dynamic view*, on the other hand, regards science more as an activity, what scientists do. The present state of knowledge is important, of course. But it is important mainly because it is a base for further scientific theory and research. This has been called a *heuristic view*. The word *heuristic*, meaning "serving to discover or reveal," now has the connotation of self-discovery. A heuristic method of teaching, for instance, emphasizes students' discovering things for themselves. The heuristic view in science emphasizes theory and interconnected conceptual schemata that are fruitful for further research. A heuristic emphasis is a discovery emphasis.

It is the heuristic aspect of science that distinguishes it in good part from engineering and technology. On the basis of a heuristic hunch, the scientist takes a risky leap. As Polanyi (1958/1974, p. 123) says, "It is the plunge by which we gain a foothold at another shore of reality. On such plunges the scientist has to stake bit by bit his entire professional life." Michel (1991, p. 23) adds "anyone who fears being mistaken and for this reason studies a 'safe' or 'certain' scientific method, should never enter upon any scientific enquiry." Heuristic may also be called problem-solving, but the emphasis is on imaginative and not routine problem-solving. The heuristic view in science stresses problem-solving rather than facts and bodies of information. Alleged established facts and bodies of information are important to the heuristic scientist because they help lead to further theory, further discovery, and further investigation.

Still avoiding a direct definition of science—but certainly implying one—we now look at the function of science. Here we find two distinct views. The practical person, generally the non-scientist, thinks of science as a discipline or activity aimed at improving things, at making progress. Some scientists, too, take this position. The function of science, in this view is to make discoveries, to learn facts, to advance knowledge in order to improve things. Branches of science that are clearly of this genre receive wide and strong support. Witness the continuing generous support of medical and meteorological research. The criteria of practicality and "payoff" are preeminent in this view, especially in educational research (see Kerlinger, 1977; Bruno, 1972).

A very different view of the function of science is well expressed by Braithwaite (1953/1996, p. 1):

> The function of science . . . is to establish general laws covering the behaviors of the empirical events or objects with which the science in question is concerned, and thereby to enable us to connect together our knowledge of the separately known events, and to make reliable predictions of events as yet unknown.

The connection between this view of the function of science and the dynamic–heuristic view discussed earlier is obvious, except that an important element is added: the establishment of general laws—or theory, if you will. If we are to understand modern behavioral research and its strengths and weaknesses, we must

TABLE 1.1 *Sampson's Two Views of the Science of Social Psychology*

	Traditional (Quantatative)	Nontraditional (Sociohistorical) (Quantatative)
Primary Goal	Describing the reality of human social interactions and functions.	Describing the variety of human social experience and activity through social and historical information and the roles they play in human life.
Philosophical Position	Reality can be discovered independently by nonpositioned observers. Reality can be grasped without occupying any particular biasing standpoint.	Reality can be discovered only from some standpoint; thus, the observer is always a positioned observer.
Metaphoric Statement	Science can be perceived to be like a mirror. It is designed to reflect things as they really are.	Science is perceived to be a storyteller. It gives different or personal accounts and versions of reality.
Methodological Considerations	Methods created and used to control or eliminate factors that would weaken the researcher's ability to discover the true shape of reality.	The researcher's understanding of reality is shaped by broad social and historical factors. The methods can yield a richer and deeper understanding of reality based on encountering the diverse accounts used by people in making sense of their lives.

explore the elements of Braithwaite's statement. We do so by considering the aims of science, scientific explanation, and the role and importance of theory.

Sampson (1991) discusses two opposing views of science. There is the conventional or traditional perspective and then there is the sociohistorical perspective. The conventional view perceives science as a mirror of nature or a windowpane of clear glass that presents nature without bias or distortion. The goal here is to describe with the highest degree of accuracy what the world really looks like. Here Sampson states that science is an objective referee. Its job is to "resolve disagreements and distinguish what is true and correct from what is not." When the conventional view of science is unable to resolve the dispute, it only means that there is insufficient data or information to do so. Conventionalists, however, feel it is only a matter of time before the truth is apparent.

The sociohistorical view sees science as a story. The scientists are storytellers. Here the idea is that reality can only be discovered by the stories that can be told about it. Here, this approach is unlike the traditional–conventional view in that there is no neutral arbitrator. Every story will be flavored by the storyteller's orientation. As a result there is no single true story. The author's interpretation of Sampson's table comparing these two is shown in Table 1.1.

Even though Sampson gives these two views of science in light of social psychology, his presentation has applicability in all areas of the behavioral sciences.

The Aims of Science, Scientific Explanation, and Theory

The basic aim of science is theory. Perhaps less cryptically, the basic aim of science is to explain natural phenomena. Such explanations are called "theories." Instead of trying to explain each and every separate behavior of children, the scientific psychologist seeks general explanations that encompass and link together many differing behaviors. Rather than try to explain children's methods of solving arithmetic problems, for example, the scientist seeks general explanations of all kinds of problem-solving. It might be called a general theory of problem-solving.

This discussion of the basic aim of science as theory may seem strange to the student who has probably been inculcated with the notion that human activities have to pay off in practical ways. If we said that the aim of science is the betterment of humanity, most readers would quickly read the words and accept them. But the *basic* aim of science is *not* the betterment of humanity. It is theory. Unfortunately, this sweeping and really complex statement is not easily understood. Still, we must try to grasp it because it is important. More on this point is given in Chapter 16 of Kerlinger (1979).

Other aims of science that have been stated are: explanation, understanding, prediction, and control. If we accept theory as the ultimate aim of science, however, explanation and understanding become subaims of the ultimate aim. This is because of the definition and nature 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.*

This definition says three things: (1) a theory is a set of propositions consisting of defined and interrelated constructs, (2) a theory sets out the interrelations among a set of variables (constructs), and in so doing, presents a systematic view of the phenomena described by the variables, and (3) a theory explains phenomena; it does so by specifying which variables are related to which variables and how they are related, thus enabling the researcher to predict from certain variables to certain other variables. One might, for example, have a theory of school failure. One's variables might be intelligence, verbal and numerical aptitudes, anxiety, social class membership, nutrition, and achievement motivation. The phenomenon to be explained, of course, is school failure or, perhaps more accurately, school achievement. That is, school failure could be perceived as being at one end of the school achievement continuum with school success being at the other end. School failure is explained by specified relations between each of the seven variables and school failure, or by combinations of the seven variables and school failure. The scientist, successfully using this set of constructs, then "understands" school failure. He or she is able to "explain" and, to some extent at least, "predict" it.

It is obvious that explanation and prediction can be subsumed under theory. The very nature of a theory lies in its explanation of observed phenomena. Take reinforcement theory, for example. A simple proposition flowing from this theory is: If a response is rewarded (reinforced) when it occurs, it will tend to be repeated. The psychological scientist who first formulated some such proposition did so as an explanation of the observed repetitious occurrences of responses. Why did they occur and reoccur with dependable regularity? Because they were rewarded. Although this is an explanation, it may not be a satisfactory explanation to many people. Someone else may ask why reward increases the likelihood of a response's occurrence. A full-blown theory would have the explanation. Today, however, there is no really satisfactory answer. All we can say is that, with a high degree of probability, the reinforcement of a response makes the response more likely to occur and reoccur (see Nisbett & Ross, 1980). In other words, the propositions of a theory, the statements of relations, constitute the explanation, as far as that theory is concerned, of observed natural phenomena.

On prediction and control, it can be said that scientists do not really have to be concerned with explanation and understanding. Only prediction and control are necessary. Proponents of this point of view may say that the adequacy of a theory is its predictive power. If by using the theory we are able to predict successfully, then the theory is confirmed and this is enough. We need not necessarily look for further underlying explanations. Since we can predict reliably, we can control because control is deducible from prediction.

The prediction view of science has validity. But as far as this book is concerned, prediction is considered to be an aspect of theory. By its very nature, a theory predicts; that is, when from the primitive propositions of a theory we deduce more complex ones, we are in essence "predicting." When we explain observed phenomena, we are always stating a relation between, say, class *A* and class *B*. Scientific explanation inheres in specifying the relations between one class of empirical events and another, under certain conditions. We say: If *A*, then *B*, *A* and *B* referring to classes of objects or events.[2] But this is prediction, prediction from *A* to *B*. Thus a theoretical explanation implies prediction. And we come back to the idea that theory is the ultimate aim of science. All else flows from theory.

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[2] Statements of the form "If *p*, then *q*," called *conditional statements* in logic, are the core of scientific inquiry. They and the concepts or variables that go into them are the central ingredient of theories. The logical foundation of scientific inquiry that underlies much of the reasoning in this book is outlined in Kerlinger (1977).

There is no intention here to discredit or denigrate research that is not specifically and consciously theory-oriented. Much valuable social scientific and educational research is preoccupied with the shorter-range goal of finding specific relations; that is, merely to discover a relation is part of science. The ultimately most usable and satisfying relations, however, are those that are the most generalized, those that are tied to other relations in a theory.

The notion of generality is important. Theories, because they are general, apply to many phenomena and to many people in many places. A specific relation, of course, is less widely applicable. If, for example, one finds that test anxiety is related to test performance. This finding, though interesting and important, is less widely applicable and less understood than finding a relation in a network of interrelated variables that are parts of a theory. Modest, limited, and specific research aims, then, are good. Theoretical research aims are better because, among other reasons, they are more general and can be applied to a wide range of situations. Additionally, when both a simple and a complex theory exist and both account for the facts equally well, the simple explanation is preferred (Occam's Razor). Hence, in the discussion of generalizability, a good theory is also parsimonious. However, a number of incorrect theories concerning mental illness persist because of this parsimony feature. Some still believe that individuals are possessed with demons. Such an explanation is simple when compared to psychological and/or medical explanations.

Theories are tentative explanations. Each theory is evaluated empirically to determine how well it predicts new findings. Theories can be used to guide a research plan by generating testable hypotheses and to organize facts obtained from the testing of these hypotheses. A good theory is one that cannot fit all observations. One should be able to find an occurrence that would contradict it. Blondlot's theory of N-rays is an example of a poor theory. Blondlot claimed that all matter emitted N-rays (Weber, 1973). Although N-rays were later demonstrated to be nonexistent, Barber (1976) reported that nearly 100 papers were published in a single year on N-rays in France. Blondlot even developed elaborate equipment for the viewing of N-rays. Scientists claiming they saw N-rays only added support to Blondlot's theory and findings. However, when a person did not see N-rays, Blondlot claimed that the person's eyes were not sensitive enough or the person did not set up the instrument correctly. No possible outcome was taken as evidence against the theory. In more recent times, another faulty theory that took over 75 years to debunk concerned the origin of peptic ulcers. In 1910 Schwartz (as reported in Blaser, 1996) claimed that he had firmly established the cause of ulcers. He stated that peptic ulcers were due to stomach acids. In the years that followed, medical researchers devoted their time and energies toward treating ulcers by developing medications to either neutralize or block the acids. These treatments were never totally successful and were expensive. However, in 1985, J. Robin Warren and Barry Marshall (as reported in Blaser, 1996) discovered that the helioc bacter pylori was the real cause of stomach ulcers. Almost all cases of this type of ulcer were successfully treated with antibiotics, and for a considerably lower cost. For seventy-five years no possible outcome was taken as evidence against this stress-acid theory of ulcers.

Scientific Research: A Definition

It is easier to define scientific research than it is to define science. It would not be easy, however, to get scientists and researchers to agree on such a definition. Even so, we attempt one here: *Scientific research is systematic, controlled, empirical, amoral, public, and critical investigation of natural phenomena. It is guided by theory and hypotheses about the presumed relations among such phenomena.* This definition requires little explanation since it consists mostly of a condensed and formalized statement of much that was said earlier or that will soon be said. Two points need emphasis, however.

First, when we say that scientific research is systematic and controlled, we mean, in effect, that scientific investigation is so ordered that investigators can have critical confidence in research outcomes. As we shall see later, scientific research observations are tightly disciplined. Moreover, among the many alternative explanations of a phenomenon, all but one are systematically ruled out. One can thus have greater confidence that a tested relation is as it is than if one had not controlled the observations and ruled out alternative possibilities. In some instances a cause-and-effect relationship can be established.

Second, scientific investigation is empirical. If the scientist believes something is so, that belief must somehow or other be put to an outside independent test. Subjective belief, in other words, must be checked against objective reality. Scientists must always subject their notions to the court of empirical inquiry and test. Scientists are hypercritical of the results of their own and others' research. Every scientist writing a research report has other scientists reading what is being written while he or she writes it. Though it is easy to err, to exaggerate, to overgeneralize, when writing up one's own work, it is not easy to escape the feeling of scientific eyes constantly peering over one's shoulder.

In science there is peer review. This means that others of equal training and knowledge are called upon to evaluate another scientist's work before it is published in scientific journals. There are both positive and negative points concerning this. It is through peer review that fraudulent studies have been exposed. The essay written by R. W. Wood (1973) on his experiences with Professor Blondlot of France concerning the nonexistence of N-rays gives a clear demonstration of peer review. Peer review works well for science and promotes quality research. The system, however, is not perfect. There are occasions when peer review has worked against science. This is documented throughout history with people such as Kepler, Galileo, Copernicus, Jenner, and Semelweiss. The ideas of these individuals were not popular with their peers. More recently in psychology, the works of John Garcia on the biological constraints on learning went contrary to his peers. Garcia managed to publish his findings in a journal (*Bulletin of the Psychonomic Society*) that did not have peer review. Others who read Garcia's work and replicated it found Garcia's work to be valuable. In the large majority of cases, peer review of science is beneficial.

Third, knowledge obtained scientifically is not subject to moral evaluation. The results are neither considered "bad" nor "good," but in terms of validity and reliability. The scientific method is, however, subject to issues of morality; that is, scientists are held responsible for the methods used in obtaining scientific knowledge. In psychology, codes of ethics are enforced to protect those under study. Science is a cooperative venture. Scientific information is available to all, and the scientific method is well-known and available to all who choose to use it.

The Scientific Approach

The scientific approach is a special systematized form of all-reflective thinking and inquiry. Dewey (1933/1991), in his influential *How We Think*, outlined a general paradigm of inquiry. The present discussion of the scientific approach is based largely on Dewey's analysis.

Problem–Obstacle–Idea

Scientists may experience obstacles to understanding, a vague unrest about observed and unobserved phenomena, a curiosity as to why something is as it is. The first and most important step is to get the idea out in the open, to express the problem in some reasonably manageable form. Rarely or never will the problem spring full-blown at this stage. The scientist must struggle with it, try it out, and live with it. Dewey (1933/1991, p. 108) says, "There is a troubled, perplexed, trying situation, where the difficulty is, as it were, spread throughout the entire situation, infecting it as a whole." Sooner or later, explicitly or implicitly, the scientist states the problem, even if the expression of it is inchoate and tentative. Here the scientist intellectualizes, as Dewey (p. 109) puts it, "what at first is merely *an emotional* quality of the whole situation." (Italics added.) In some respects, this is the most difficult and important part of the whole process. Without some sort of statement of the problem, the scientist can rarely go further and expect the work to be fruitful. With some researchers, the idea may come from speaking to a colleague or observing a curious phenomenon. The idea here is that the problem usually begins with vague and/or unscientific thoughts or unsystematic hunches. It then goes through a series of refinement steps.

Hypothesis

After intellectualizing the problem, referring to past experiences for possible solutions, observing relevant phenomena, the scientist may formulate a hypothesis. A hypothesis is a conjectural statement, a tentative proposition about the relation between two or more phenomena or variables. Our scientist will say, "If such-and-such occurs, then so-and-so results."

Reasoning–Deduction

This step or activity is frequently overlooked or underemphasized. It is perhaps the most important part of Dewey's analysis of reflective thinking. The scientist deduces the consequences of the hypothesis he or she has formulated. Conant (1951), in talking about the rise of modern science, says that the new element added in the seventeenth century was the use of deductive reasoning. Here is where experience, knowledge, and perspicacity are important.

Often the scientist, when deducing the consequences of a formulated hypothesis, will arrive at a problem quite different from the original one. On the other hand, deductions may lead to the belief that the problem cannot be solved with present technical tools. For example, before modern statistics were developed, certain behavioral research problems were insoluble. It was difficult, if not impossible, to test two or three interdependent hypotheses simultaneously. It was next to impossible to test the interactive effect of variables. We now have reason to believe that certain problems are insoluble unless they are tackled in a multivariate manner. An example of this is teaching methods and their relationship to achievement and other variables. It is likely that teaching methods, per se, do not differ much if we study only their simple effects. Teaching methods work differently under different conditions, with different teachers, and with different pupils. It is said that the methods "interact" with the conditions and characteristics of teachers and of pupils. Simon (1987) stated another example of this: A research study on pilot training proposed by Williams and Adelson in 1954 could not be carried out using traditional experimental research methods. The study proposed to examine thirty-four variables and their influence on pilot training. Using traditional research methods, the number of variables under study was too overwhelming. Over twenty years later, Simon (1976) and Simon and Roscoe (1984) deomonstrated how such studies could be effectively undertaken using economical megafactor designs. An example may help us understand this reasoning–deduction step.

Suppose an investigator becomes intrigued with aggressive behavior. The investigator wonders why people are often aggressive in situations where aggressiveness may be inappropriate. Personal observation leads to the notion that aggressive behavior seems to occur when people have experienced difficulties of one kind or another. (Note the vagueness of the problem here.) After thinking for some time, reading the literature for clues, and making further observations, the hypothesis is formulated: Frustration leads to aggression. *Frustration* is defined as prevention from reaching a goal and *aggression* as behavior characterized by physical or verbal attack on other persons or objects.

What follows from this is a statement like: If frustration leads to aggression, then we should find a great deal of aggression among children who are in schools that are restrictive, schools that do not permit children much freedom and self-expression. Similarly, in difficult social situations assuming such situations are frustrating, we should expect more aggression than is "usual." Reasoning further, if we give experimental subjects interesting problems to solve and then prevent them from solving them, we can predict some kind of aggressive behavior. In a nutshell, this process of moving from a broader picture to a more specific one is called *deductive reasoning*.

Reasoning may, as indicated above, change the problem. We may realize that the initial problem was only a special case of a broader, more fundamental and important problem. We may, for example, start with a narrower hypothesis: Restrictive school situations lead to negativism in children. Then we can generalize the problem to the form: Frustration leads to aggression. While this is a different form of thinking from that discussed earlier, it is important because of what could almost be called its heuristic quality. Reasoning can help lead to wider, more basic, and thus more significant problems, as well as provide operational (testable) implications of the original hypothesis. This type of reasoning is called *inductive reasoning.* It starts from particular facts and moves to a general statement or hypothesis. If one is not careful, this method could lead to faulty reasoning due to the method's natural tendency to exclude data that do not fit the hypothesis. The inductive reasoning method is inclined to look for supporting data rather than refuting evidence.

Consider the classical study by Peter Wason (Wason & Johnson-Laird, 1972) that has been a topic of much interest (Hoch, 1986; Klayman & Ha, 1987). In this study, students were asked to discover a rule the experimenter had in mind that generated a sequence of numbers. One example was to generate a rule for the following sequence of numbers: "3, 5, 7." Students were told that they could ask about other sequences and would receive feedback on each sequence proposed as to whether it fit or did not fit the rule the experimenter had in mind. When the students felt confident, they could put forth the rule. Some students offered "9, 11, 13," and were told that this sequence fit the rule. They then followed with "15, 17, 19," and again were told that this sequence fit. The students then offered as their answer: "The rule is three consecutive odd numbers," but were told that this was *not* the rule. Others that would be offered after some more proposed sequences are "increasing numbers in increments of two," or "odd numbers in increments of two." In each of these, they are told that it is not the rule that the experimenter was thinking of. The actual rule in mind was "any three increasing positive numbers." Had the students proposed the sequences "8, 9, 10" or "1, 15, 4500" they would have been told that these also fit the rule. Where the students made their error was in testing only the cases that fitted their first proposed sequence that confirmed their hypothesis.

Although oversimplified, the Wason study demonstrated what could happen in actual scientific investigations. A scientist could easily be locked into repeating the same type of experiment that always supported the hypothesis.

Observation–Test–Experiment

It should be clear by now that the observation–test–experiment phase is only part of the scientific enterprise. If the problem has been well stated, the hypothesis or hypotheses adequately formulated, and the implications of the hypotheses carefully deduced, this step is almost automatically assuming that the investigator is technically competent.

The essence of testing a hypothesis is to test the *relation* expressed by the hypothesis. We do not test variables, as such; we test the relation between the variables. Observation, testing, and experimentation are for one large purpose: putting the problem relation to empirical test. To test without knowing—at least fairly well—*what* and *why* one is testing is to blunder. Simply to state a vague problem, like "How does Open Education affect learning?" and then to test pupils in schools presumed to differ in "openness"; or to ask: "What are the effects of cognitive dissonance?" and then, after experimental manipulations to create dissonance, to search for presumed effects, could only lead to questionable information. Similarly, to say one is going to study attribution processes without really knowing why one is doing it, or without stating relations between variables, is research nonsense.

Another point about testing hypotheses is that we usually do not test hypotheses directly. As indicated in the previous step on reasoning, we test deduced implications of hypotheses. Our test hypothesis may be: "Subjects told to suppress unwanted thoughts will be more preoccupied with them than subjects who are given a distraction." This was deduced from a broader and more general hypothesis: "Greater efforts to suppress an idea leads to greater preoccupation with the idea." We do not test "suppression of ideas" or "preoccupation," we test the relation between them—in this case the relation between suppression of unwanted thoughts and the level of preoccupation (see Wegner, Schneider, Carter, & White, 1987; Wegner, 1989).

Dewey emphasized that the temporal sequence of reflective thinking or inquiry is not fixed. We can repeat and reemphasize what he says in our own framework. The steps of the scientific approach are not neatly fixed. The first step is not neatly completed before the second step begins. Further, we may test before adequately deducing the implications of the hypothesis. The hypothesis itself may seem to need elaboration or refinement as a result of deducing implications from it. Hypotheses and their expression will often be found inadequate when implications are deduced from them. A frequent difficulty occurs when a hypothesis is so vague that one deduction is as good as another; that is, the hypothesis may not yield to precise testing.

Feedback to the problem, the hypotheses, and, finally, the theory of the results of research is highly important. Learning theorists and researchers, for example, have frequently altered their theories and research as a result of experimental findings (see Malone, 1991; Schunk, 1996; Hergenhahn, 1996). Theorists and researchers have been studying the effects of early environment and training on later development. Kagan and Zentner (1996) reviewed the results of 70 studies concerned with the relation between early life experiences and psychopathology in adulthood. They found that juvenile delinquency could be predicted by the amount of impulsivity detected at preschool age. Lynch, Short and Chua (1995) found that musical processing was influenced by the perceptual stimulation an infant experienced at age 6 months to 1 year. These and other research have yielded varied evidence converging on this extremely important theoretical and practical problem. Part of the essential core of scientific research is the constant effort to replicate and check findings, to correct theory on the basis of empirical evidence, and to find better explanations of natural phenomena. One can even go so far as to say that science has a cyclic aspect. A researcher finds, say, that *A* is related to *B* in such-and-such a way. Then more research is conducted to determine under what other conditions *A* is similarly related to *B*. Other researchers challenge this theory and research, offering explanations and evidence of their own. The original researcher, it is hoped, alters his or her work in the light of new data. The process never ends.

Let us summarize the so-called scientific approach to inquiry. First, there is doubt, a barrier, an indeterminate situation crying out to be made determinant. The scientist experiences vague doubts, emotional disturbance, and inchoate ideas. There is a struggle to formulate the problem, even if inadequately. The scientist then studies the literature, scans his or her own experience and the experiences of others. Often the researcher simply has to wait for an inventive mind leap. Maybe it will occur; maybe not. With the problem formulated, with the basic question or questions properly asked, the rest is much easier. The hypothesis is then constructed, after which its empirical implications are deduced. In this process the original problem and, of course, the original hypothesis, may be changed. It may be broadened or narrowed. It may even be abandoned. Last, but not finally, the relation expressed by the hypothesis is tested by observation and experimentation. On the basis of the research evidence, the hypothesis is supported or rejected. This information is then fed back to the original problem, and the problem is kept or altered, as dictated by the evidence. Dewey pointed out that one phase of the process may be expanded and be of great importance, another may be skimped, and there may be fewer or more steps involved. Research is rarely an orderly business. Indeed, it is much more disorderly than the above discussion may imply. Order and disorder, however, are not of primary importance. What *is* important is the controlled rationality of scientific research as a process of reflective inquiry, the interdependent nature of the parts of the process, and the paramount importance of the problem and its statement.

CHAPTER SUMMARY

1. To understand complex human behavior, one must understand the scientific language and approach.
2. Science is a systematic and controlled extension of common sense. There are five differences between science and common sense:
   a. Science uses conceptual schemes and theoretical structures,
   b. Science systematically and empirically tests theories and hypotheses,
   c. Science attempts to control possible extraneous causes,
   d. Science pursues relations consciously and systematically,
   e. Science rules out metaphysical (untestable) explanations.
3. Peirce's Four Methods of Knowing
   a. method of tenacity—influenced by established past beliefs;
   b. method of authority—influenced by the weight of tradition or public sanction;
   c. a priori method (also known as the method of intuition)—natural inclination toward the truth;
   d. method of science—self-correcting; notions are testable and objective.
4. The stereotype of science has hindered understanding of science by the public.
5. Views, functions of science
   a. Static view sees science contributing scientific information to world; science adds to the body of information and present state of knowledge.

   b. Dynamic view is concerned with the activity of science (what scientists do). With this comes the heuristic view of science. This is one of self-discovery. Science takes risks and solves problems.
6. The aims of science are:
   a. develop theory and explain natural phenomenon,
   b. promote understanding and develop predictions.
7. A theory has three characteristics:
   a. set of properties consisting of defined and interrelated constructs,
   b. systematically sets the interrelations among a set of variables,
   c. explains phenomenon.
8. Scientific research is a systematic, controlled, empirical, and critical investigation of natural phenomenon. It is guided by theory and hypotheses about presumed relations among such phenomenon. It is also public and amoral.
9. The scientific approach according to Dewey is made up of the following:
   a. Problem–Obstacle–Idea—formulate the research problem or question to be solved
   b. Hypothesis—formulate a conjectural statement about the relationship between phenomena or variables
   c. Reasoning–Deduction—scientist deduces the consequences of the hypothesis. This can lead to a more significant problem and provide ideas on how the hypothesis can be tested in observable terms.
   d. Observation–Test–Experiment—This is the data collection and analysis phase. The results of the research conducted are related back to the problem.

Study Suggestions

Some of the content of this chapter is highly controversial. The views expressed are accepted by some thinkers and rejected by others. Readers can enhance understanding of science and its purpose, the relationship between science and technology, and the differences between basic and applied research, by selective reading of the literature. Such reading can be the basis for class discussions. Extended treatment of the controversial aspects of science, especially behavioral science, is given in the first author's book, *Behavioral Research: A Conceptual Approach* (New York: Holt, Rinehart and Winston, 1979, chaps. 1, 15, and 16). Many fine articles on science and research have been published in science journals and philosophy of science books. Here are some of them. Also included is a special report in *Scientific American*. All are pertinent to this chapter's substance.

Barinaga, M. (1993). Philosophy of science: Feminists find gender everywhere in science. *Science* 260: 392-393. Discusses the difficulty of separating cultural views of women and science. Talks about science as a predominantly male field.

Hausheer, J., & Harris, J. (1994). In search of a brief definition of science. *The Physics Teacher* 32(5): 318. Mentions that any definition of science must include guidelines for evaluating theory and hypotheses as either science or nonscience.

Holton, G. (1996). The controversy over the end of science. *Scientific American* 273(10): 191. This article is concerned with the development of two camps of thought: the linearists and the cyclists. The linearists take a more conventional perspective of science; the cyclists see science as degenerating within itself.

Horgan, J. (1994). Anti-omniscience: An eclectic gang of thinkers pushes at knowledge's limits. *Scientific American* 271: 20-22. Discusses the limits of science.

Horgan, J. (1997). *The end of science*. New York: Broadway Books.

Miller, J. A. (1994). Postmodern attitude toward science. *Bioscience* 41(6): 395. Discusses the reasons some educators and scholars in the humanities have adopted a hostile attitude toward science.

Scientific American. Science versus antiscience. (Special report). January 1997, 96-101. Presents three different antiscience movements: creationist, feminist, and media.

Smith, B. (1995). Formal ontology, common sense and cognitive science. *International Journal of Human-Computer Studies* 43(5-6): 641-667. An article examining common sense and cognitive science.

Timpane, J. (1995). How to convince a reluctant scientist. *Scientific American* 272: 104. This article warns that too much originality in science would lead to nonacceptance and difficulty of understanding. It also discusses how scientific acceptance is governed by both old and new data and the reputation of the scientist.