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Some Philosophical and Educational Thoughts On The Nature of Scientific Inquiry

By Prince A. Jackson, Jr.

PROLOGUE

The Great American Dilemma

At this moment the King, who had been for some time busily writing in his note-book, called out "Silence!" and read out from his book, "Rule Forty-two. All persons more than a mile high to leave the court."

> Everybody looked at Alice.
> "I'm not a mile high," said Alice.
> "You are," said the King.
> "Nearly two miles high," added the Queen.
> "Well, I sha'n't go, at any rate," said Alice: "besides, that's not a regular rule: You invented it just now."
> "It's the oldest rule in the book," said the King.
> "Then it ought to be Number One," said Alice.
> The King turned pale, and shut his note-book hastily. "Consider your verdict," he said to the jury, in a low trembling voice.

—Lewis Carroll, ALICE IN WONDERLAND

The greatest American dilemma today, is the critical scientific manpower shortage. The literature pertaining to science is replete with references to the dire lack of scientists, engineers, technicians, and good science teachers. Yet prior to the mid-1950's, the warning cries of those who were keenly aware of our predicament, were generally ignored. Today, twelve years since the advent of Sputnick I, we are deluged with proposals for better science curricula.

Since the enactment of the National Defense Education Act of 1958, we, the taxpayers, have been spending hundreds of millions of dollars each year in science and mathematics training programs, based on the hypothesis that our educational institutions can turn out more scientists, engineers, technicians, and dedicated science teachers if we put enough money into these programs. The programs being pursued at present include science faculty fellowships and scholarships for science and mathematics teachers, scholarships for "bright" students, the construction of modern curricula in science and mathematics, the writing of textbooks in modern scientific and mathematical terms, plus proposals for the subsidization of science and mathematics teachers' salaries. Why are we so illogical? Why do we continue to believe so strongly that money alone will solve our problems?

Many of our leading scientists are of the opinion that our schools, colleges, and universities cannot solve, alone, our present dilemma of the critical scientific manpower shortage. While it is true that they may make a contribution to the solution, the entire dilemma will not be resolved until we have a citizenry which has an understanding of science, what science can do, and what science cannot do. Dr. James B. Conant, a very prominent scientist and former president of Harvard University, has described the situation in the following words:

> I have seen repeated examples of such bewilderment (lack of scientific knowledge) of laymen. If I am right in this diagnosis (and it is the fundamental premise of this book), the remedy does not lie in a greater dissemination of information among nonscientists. Being well informed about science is not the same thing as understanding science, though the two propositions are not antithetical. What is needed are methods for imparting some knowledge of the tactics and strategy of science to those who are not scientists.[1]

Dr. Conant's book poses the following questions in the writer's mind:

1. What are these methods of which Dr. Conant writes?
2. Will these methods increase our understanding of science?
3. Will these methods alleviate our critical scientific manpower shortage?
4. What are the educational implications of these methods?
5. Will the enlightened laymen be able to apply these methods in the solutions of human problems?
6. Why is scientific education of the masses really important?

The remainder of this paper will be devoted to the discussion and the answers to these questions.

Part I of the paper discusses the nature of science and the necessity of a scientific education for the masses.

Part II of the paper discusses the nature of the method that we call "scientific inquiry," how it will increase our understanding of science, and alleviate our scientific manpower shortage.

The Epilogue will discuss how the enlightened laymen will be able to use "scientific inquiry" in the area of human problems.

A complete bibliography may be found at the end of the paper.

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[1]James B. Conant, *Science and Common Sense,* (New Haven: Yale University Press, 1962), p. 4.

Part I

THE NATURE OF SCIENCE

> "Every new theory believes that at last it is the fortunate theory to achieve the 'right' answer. When will we learn that logic, mathematics, physical theory, are all only our inventions for formulating in compact and manageable form what we already know, and like all inventions do not achieve complete success in what they were designed to do, much less complete success beyond the scope of the original design, and that our only justification for hoping to penetrate at all into the unknown with these inventions is our past experience that sometimes we have been fortunate enough to be able to push on a short distance by acquired momentum?"
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> —P. W. Bridgman, 1936

The dropping of the atom bomb on the Japanese city of Hiroshima during World War II in 1945 was the greatest single event, perhaps, in making the masses of the world conscious of science and its awesome destructive power. Although man had been inventing weapons of destruction with the aid of science for hundreds of years before, the use of the power of science for evil had escaped, virtually, the masses of the world. But at Hiroshima, more than 40,000 were killed in probably less than five seconds. It is said that the skeletons of some of the factory buildings were pushed backwards and sidewards as if by a giant hand. In an issue of a national magazine of a few years ago, a man who was several miles away from Hiroshima told of how his clothes were blown, literally, off of him. The effects of radiation on those who survived, are still being written up in many medical journals today.

On the other hand, technology, the main product of science, has made life far more comfortable, livable, and abundant, even beyond our wildest dreams. Examples of this are far too numerous to include in this paper. Although many laymen think of science and technology synonymously, they are quite different due to the vastly dissimilar motivations of the two. Technology[2] must not be equated with science. Henry D. Smith made the distinction in the following words:

> The object of scientific and engineering research is to augment and clarify our knowledge of the natural world. Our eagerness to pursue such knowledge arises from two sources, either an intellectual interest in understanding the law of nature or a desire to use natural forces for the material improvement of man's living conditions. These two motives can be crudely characterized as a desire for enlightenment and desire for utility. In the scientist the first is dominant, in the engineer the second. This distinction of motivation remains important even though the methods and specific problems of science and engineering have become increasingly similar.

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[2]Technology is interested in the practical. This is not prime interest of science.

What is science? The writer concludes that the definition of science by Jacob Bronowski is a typical one. Professor Bronowski defines science in the following words:

> Science is the creation of concepts and their exploration in the facts. It has no other test of the concept than its empirical truth to fact. Truth is the drive at the center of science; it must have the habit of truth, not as a dogma but as a process.[3]

The nature of science is such that one phenomenon is enough to disprove a hypothesis, but a million million do not suffice to prove it.[4] Professor Joseph J. Schwab of the University of Chicago estimates that at the present tempo of research in the Western world, the duration of revisionary cycle in some of the branches of science to be on the order of fifteen years. Thus a body of knowledge acquired in the conventional way by a graduate of 1956 is likely to be inadequate in 1971 and, by 1978, as obsolete as notions of the ether, or the impenetrable atom. No better example of this non-dogmatic characteristic of science can be cited than the theory of Classical Mechanics and the theory of Relativity.[5] The general aim of science is to progress towards and construct empirical theories that can explain an enormous range of natural phenomena. Scientists can never say that any theory is final or corresponds to absolute truth, because at any moment new facts may be discovered and compel them to modify or construct a new theory. All science is the search for unity in hidden likenesses and the scientist looks for order in the appearances of nature by exploring such likenesses. It is a history of magnanimous victories as well as a myriad of tragic defeats for the human intellect in its endless war against nature, ignorance, childish superstitions, and baseless fears. If to be a humanist is to respond perceptively to all dimensions of man's life, an informed study of the findings and of the development of science must surely be an integral part of humanistic education.[6]

Albert Einstein once said, "World War III will be fought with rocks." Of course the implication is that the great powers of the world have nuclear and biological weapons so powerful, that if World War III ever started, civilization will be destroyed. This one fact, more than any, makes it imperative and paramount, that the masses must have a scientific education. All of our people must understand what science

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[3]Jacob Bronowski, *Science And Human Values*, (New York: Harper Torchbooks, 1959), p. 77. The interested lay reader who is interested in the nature of truth should read Bertrand Russell's *The Problems Of Philosophy*, (New York: Oxford University Press, 1959), and St. Thomas Aquinas' *Summa Theologica* (1265-1273) and *Expositio super librum Boethii de Trinitale* (1258-59).

[4]Sir James Jeans, "*The New Background of Science*, (New York: Macmillan, 1933), p. 46.

[5]The implication here is not that Classical Mechanics is obsolete. In fact Albert Einstein said in 1948, "No one must think that Newton's great creation can be overthrown by (Relativity) or any other theory. His clear and wide ideas will forever retain their significance as the foundation on which our modern conceptions of physics have been built."

[6]Ernest Nagel, "*Science And The Humanities*" *in Education In the Age of Science*, edited by Brand Blanshard, (Basic Books, New York 1959), p. 189.

can do and what science cannot do. Our masses must become scientifically literate, and acquire such attitudes, understandings, and hopefully aptitudes, so that they will be able to participate in the decision making process efficiently with scientists to construct the kind of life in this world which is now available to us. Without this basic structure of science they are scientific illiterates who cannot make intelligent decisions in the most important area of their life.[7] It is generally agreed now that the future of civilization depends on how the vast storehouse of scientific knowledge is used.[8] The use of this knowledge must be a joint decision of all men.

Part II

THE NATURE OF SCIENTIFIC INQUIRY

> "What hopes and fears does the scientific method imply for mankind? I do not think that this is the right way to put the question. Whatever this tool in the hand of man will produce depends entirely on the nature of the goals alive in this mankind. Once these goals exist, the scientific method furnishes means to realize them. Yet it cannot furnish the very goals. The scientific method itself would not have led anywhere, it would not even have been born without a passionate striving for clear understanding."
>
> —A. Einstein, *Out of My Later Years*

According to most of our prominent science educators the traditional courses in science have failed to give our students a firm understanding of science. As a result of this indictment, other methods of science teaching have been discussed and one of the most important ideas to come out of these discussions is the idea of inquiry. In a (February, 1963) paper delivered as a portion of a Symposium of the National Association for Research in Science Teaching, Thirty-sixth Meeting, Washington, D. C., the method of scientific inquiry was described as a worthwhile objective, and something that our various educational efforts should deliberately try to achieve.[9] The great progress of modern science has been made possible only because the scientific mind is an inquiring mind. The inquiring mind of Newton correlated the force pulling an apple from an apple tree with the force holding the moon in its orbit as it revolves about the earth. As a result of this inquiry and further inquiries, the Law of Universal Gravitation was born. The analytical mind of Michael Faraday discovered the relationship between electricity and magnetism. Clerk Maxwell's inquiring research revealed a relationship among electricity,

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7Edward K. Weaver, "Science and Curriculum," *School Science and Mathematics,* February, 1959, pp. 138-50.

8The Power of science is not to be underestimated. Rene Descartes recognized this in 1640 when he said, "Give me matter and motion, and I will construct the universe."

9Robert M. Gagne, "The Learning Requirements for Enquiry," (American Institute For Research).

magnetism, and light. The *Harvard Case Histories in Experimental Science*[10] gives a detailed account of how inquiry led to some of our most important scientific discoveries. From the incipiency of modern science during the century of genius[11] scientific inquiry has been used by scientists to bring about astonishing results in the physical and biological sciences. To the scientist, it is a process. Summing it up in the words of Paul F. Brandwein,[12] "it embodies an aim. In it is posture, individual liberty, and humility. It develops a mistrust of one's brain to reach grand conclusions. Inherent in it is a self-correcting attempt to defeat one's own conclusions, and the knowledge that the only certainty is uncertainty." In listing the advantages of using scientific inquiry through the case history approach, James B. Conant wrote:

> The advantages of this method of approach are twofold: first, relatively little factual knowledge is required either as regards the science in question or other sciences, and relatively little mathematics; second, in the early days one sees in clearest light the necessary fumblings of even intellectual giants when they are also pioneers; one comes to understand what science is by seeing how difficult it is in fact to carry out glib scientific precepts..[13]

The use of scientific inquiry as a teaching method will infuse into the student, the vicissitudes of research and a better understanding of the conditional nature of truth in science. As a result, the student will begin to analyze more severely and critically, the soundness of his conclusions. In addition he will develop for himself, the structure of science and the habits necessary for remaining scientifically literate long after the termination of his formal education.[14] The use of scientific inquiry will demonstrate the veracity of Roger Bacon's principle[15] of "Sine experintia nihil sufficienter sciri potest."

Sir Percy Nunn wrote:

> Encourage the love of observing and investigating natural phenomena, which is the mainspring of scientific life. Given that love, the mastery of scientific method becomes a natural incident of . . . progress; without it, scientific method, however scrupulously "cultivated," is sterile . . . The student must learn . . . what it is to face problems in the position of a real investigator, left largely to his own wits to wrest from nature the answers to the questions he puts to her.[16]

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[10]J. B. Conant and L. K. Nash, *Harvard Case Histories in Experimental Science*, (Harvard University Press, Cambridge, 1961).

[11]The seventeenth century.

[12]Paul F. Brandwein, *The Teaching of Science*, Harvard University Press, Cambridge, 1962, pp. 112-113.

[13]James B. Conant, *On Understanding Science*, Yale University Press, New Haven, 1947, p. 18.

[14]Joseph J. Schwab, "Science Education" in *School Review*, 1960. pp. 176-194.

[15]Without experience, nothing can be certainly known.

[16]Sir Percy Nunn in *The New Teaching*, 1918.

Thomas Aylesworth said that "the most successful teachers are often those who let the students behave as practitioners of a given discipline." With the use of this method, science teaching discards its old identity of "memorizing facts from the text book" and becomes a new and delightful experience. The "science inclined" student becomes apparent years earlier and can be given proper guidance in time to begin his development. As a result of this early start, many of these students will become the future "Newtons, Einsteins, and Galileos."

In our scientific age, an understanding of the methods of scientific inquiry must be a part of each student's education. This "grounding" in inquiry must be infused throughout the student's entire education if he is to receive the full benefits of it. Inquiry will develop wisdom as well as knowledge. It is this wisdom that will provide us with a scientific literate citizenry. Without this wisdom, we will continue to flounder as in past years. It would do well for all of us to keep in mind, the maxim expressed by Horace:

Brute force, unsupported by wisdom, falls of its own weight.[17]

EPILOGUE

A Philosophy of Scientific Inquiry

"This is indeed a mystery," (remarked Watson). "What do you imagine that it means?"

"I have no data yet. It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit fact."

—A. Conan Doyle, "Sherlock Holmes"

The methods of scientific inquiry have produced astonishing results in the physical and biological sciences. The twentieth century has brought the airplane, which has changed the definition of "neighbor" from terms of distance to terms of time. The twentieth century has miracle drugs and the polio vaccine. The twentieth century has brought the hydrogen bomb, which can and will wipe out civilization in less than one day if another world war comes. The twentieth century has brought technological advances in both weaponry and modern comforts that amaze even the scientific man. The twentieth century has brought the landing of terrestrial man on an extraterrestrial body. This achievement is bound to have theological and philosophical impacts on the future thinking of man. One of the most amazing stories of the astonishing feats of modern technology is the story that appeared in the January 25, 1963 issue of *LIFE* magazine about color film and the Polaroid Camera Company in Cambridge, Massachusetts. The manufacturing of self-developing color film for many years had been termed an impossible feat. Polaroid's scientists not only destroyed this myth, but invented the molecule that was necessary to do the job.

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[17]Horace, *Odes, III*, 4.

When the late President John F. Kennedy committed this nation to landing a man on the moon by 1970, the commitment was not taken seriously at the time because of its seemingly insuperability. Yet this feat was accomplished on July 20, 1969, with the aid of technological methods unknown when the commitment was made in 1962. Our research in agriculture has produced methods, so efficient, that we are now growing twice as much food on one-half of the land as we used only fifteen years ago.

Three great problems of mankind are racism, poverty, and increasing growth in human population. These problems must be solved if humanity is to survive. There are many social scientists who claim that these three problems are but variations of the same problem. There are much empirical data to support this hypothesis. The high correlation between poverty and dark peoples cannot be attributed to chance alone. It has been said that the problem of population is not too many births rather the inability of man to share the available bread at the table. The problem of feeding the masses of the world is not one of abundance of food but the inability of man to share. It is only natural then after reviewing some of the amazing results of scientific inquiry, to ask the question, "Can the method of scientific inquiry be utilized in the solution of human problems?" The answer to this question is not unanimous by any means. There is even disagreement among many prominent scientists. Perhaps the reason for the disagreement is because of the almost unanimous agreement that there is no one set of rules of inquiry that will provide the answers to any given science problem. The most widely quoted statement of support is the now famous statement of P. W. Bridgeman:

> "The scientific method, as far as it is a method, is nothing more than doing one's damnedest with one's mind, no holds barred."[18]

The great difficulty to be encountered in applying the scientific method to human affairs is the very preciseness of science. Lord Kelvin, the great English scientist, said:

> ". . . when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science.[19]

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[18]P. W. Bridgman, "Prospect for Intelligence," *Yale Review*, New Haven, 1945, p. 44. Francis Bacon (1600) advocated a scientific method as follows: Make and record many observations of a given problem, perform many experiments pertaining to the problem and record the results, and then construct theories on the basis of induction. Today, Bacon's procedure has been formulated into five steps: (1) Define the problem to be solved; (2) collect data relevant to the problem; (3) formulate hypotheses; (4) perform experiments to test the hypotheses; and (5) formulate conclusions on the basis of the experiment.

[19]Lord Kelvin, *Popular Lectures and Addresses*, Macmillan S. Company Ltd.

However, there is a fair degree of agreement among scientists that the procedure of inquiry is the only one they are certain will yield the results of reliable knowledge, valid explanation and predictions, if such results can be achieved.[20] Are there any implications from the preceding statement for the utilization of scientific inquiry by the layman in human affairs? This question can be answered by taking another brief look at scientific inquiry with Ernest Nagel:

> The procedure of scientific inquiry promotes a habitual sense of the difference between competent and doubtful evidence, and between well-grounded conclusions and those that have a precarious foundation.
>
> Scientific inquiry is a procedure of applying logical canons for testing claims to knowledge. These logical canons have been adopted neither as arbitrary conventions, nor because they can be established by appeals to self-evidence. They are themselves the distilled residue of a long series of attempts to win reliable knowledge, and they may be modified and improved in the course of further inquiry.[21]

With the above statements as support, the writer concludes that the utilization of scientific inquiry in the solution of human problems is the most logical method to use. After all, this technique of thought and attitude of mind, has had unparalleled success in certain areas of human endeavor.

In closing, the writer wishes to emphasize that good science teaching develops in each child of our classes, functional knowledge, understanding, and power of critical thinking, that will serve to increase his stature, in public and private life as long as he lives. In light of the great advances in science and its effects on humanity, we can no longer justifiably speak of science and the humanities as two widely separate entities. In setting the goals of science education the National Science Teachers Association has selected as its position the following statement:

> The primary goals of science education should be intellectual. What is required is student involvement in an exploration of important ideas of science. The mental stimulation and satisfaction of exploring one's environment, learning about its past and probable future, examining man's role in the scheme of things, discovering one's own talents and interests—these are reasons enough for the study of science, just as they are for the study of most disciplines. Science is one of man's major intellectual accomplishments, a product of the mind which can be enjoyed—not for its material fruits alone but for the sense which it provides of the order in our universe.[22]

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[20]Herbert Feigal, "Naturalism and Humanism" in *Readings in the Philosophy of Science*, edited by Herbert Feigal and May Broadbeck, Appleton-Century-Crafts, New York, 1953, pp. 8-18.

[21]Nagel, *op. cit.*, p. 189.

[22]*The National Science Teachers Association Position on Curriculum Development in Science.*

Bibliography

"For it is not knowing, but the love of learning, that characterizes the scientific man; while the 'philosopher' is a man with a system which he thinks embodies all that is best worth knowing. If a man burns to learn and sets himself to comparing his ideas with experimental results in order that he may correct those ideas, every scientific man will recognize him as a brother, no matter how small his knowledge may be."

Barber, Bernard and Hirsch, Walter. *The Sociology of Science.* New York: The Macmillan Co., 1962.

Blanshard, Brand. *Education in the Age of Science.* New York: Basic Books, Inc., 1959.

Bloom, Benjamin et al. *Taxonomy of Educational Objectives.* New York: Random House, Inc., 1957.

Brandwein, Paul F., Watson, Fletcher G. and Blackwood, Paul E. *A Book of Methods.* New York: Harcourt, Brace and World, Inc., 1958.

Bridgman, Percy W. "Prospect for Intelligence," *Yale Review.* New Haven, Conn. 1945.

Bronowski, Jacob. *Science and Human Values.* New York: Harper and Brothers, 1959.

Butterfield, Herbert. *The Origins of Modern Science.* New York: Collier Books, 1957.

Cohen, I. Bernard and Watson, Fletcher G. *General Education in Science.* Cambridge: Harvard University Press, 1952.

Conant, James B. *Science and Common Sense.* New Haven: Yale University Press, 1962.

Conant, James B., and Nash, Leonard K. *Harvard Case Histories in Experimental Science.* Cambridge: Harvard University Press, 1961.

Conant, James B. *On Understanding Science.* New Haven: Yale University Press, 1947.

Danto, Arthur and Morgenbesser, Sidney. *Philosophy of Science.* New York: Meridian Books, Inc., 1960.

Eddington, Sir Arthur. *The Philosophy of Physical Science.* New York: The Macmillan Co., 1939.

Feigal, Herbert and Brodbeck, May. *Readings in the Philosophy of Science.* New York: Appleton-Century-Crofts Co., Inc., 1953.

Frank, Phillip. *Modern Science and Its Philosophy.* Cambridge: Harvard University Press, 1949.

Gagne, Robert M. "The Learning Requirement For Enquiry," American Institute for Research.

Hall, A. R. *The Scientific Revolution.* Boston: The Beacon Press, Inc., 1954.

Huxley, Sir Julian. "Evaluation in the High School Curriculum," *School Review.* Summer, 1960.

Jeans, Sir James. *The New Background of Science.* New York: The Macmillan Co., 1933.

Nagel, Ernest. "On the Science and the Humanities" in *Education in the Age of Science.* Edited by Brand Blandshard, New York: Basic Books, Inc., 1959.

Newman, James R. *What Is Science?* New York: Simon and Schuster, Inc., 1955.

Northrop, F. S. C. *The Logic of the Sciences and the Humanities.* New York: The Macmillan Co., 1947.

Rogers, Eric. *Physics for the Inquiring Mind.* Princeton: Princeton University Press, 1960.

Scheffler, I. *Philosophy and Education.* Boston: Allyn and Bacon, Inc., 1958.

Schwab, Joseph J. and Brandwein, Paul F. *The Teaching of Science.* Cambridge: Harvard University Press, 1962. 68:176-195.

Taylor, F. Sherwood. *Science Past and Present.* London: William Heinemann, Ltd., 1945.

Watson, Fletcher G. "Science Teaching" in *Education in the Age of Science.* Edited by Brand Blanshard, New York: Basic Books, Inc., 1959.

Weaver, Edward K. "Science and Curriculum," *School Science and Mathematics.* February 1959.

Whitehead, Alfred N. *The Aims of Education.* New York: The New American Library of World Literature, Inc., 1961.

Whitehead, Alfred N. *Science and the Modern World.* New York: The New American Library of World Literature, Inc., 1956.

". . . all science as it grows towards perfection becomes mathematical in its ideas."

—A. N. Whitehead