THE ROLE OF SCIENCE IN MODERN CIVILIZATION

JOHN M. COULTER, UNIVERSITY OF CHICAGO

At the present time science is being called upon as never before to help this country meet a great emergency. This is merely public recognition of the relation between science and the public welfare that has always existed, but has not been realized.

When President Wilson, in 1916, asked the National Academy of Science to appoint a National Research Council, it was because of his conviction that the aid of science was necessary to develop the national resources to their maximum. Ever since that time scientific men have been called to the assistance of the government in increasing numbers. In consequence, the practical men of affairs are beginning to realize the debt of civilization to science, a debt incurred during the times of peace in much more fundamental service than in meeting the emergencies of war. Such men understand now that all they have been able to do in the past, and all hope of future material progress depends upon the results of scientific research. It is high time that the service of science should be more generally understood. not so much that science may be appreciated, but chiefly that it may be enabled to render a still greater service. Now that science has come into public notice in connection with war, it is a fitting time to call attention to its more fundamental service to a civilization at peace.

The service of science expresses itself in three general ways which are not mutually exclusive, but complementary. Opinions may differ as to the relative importance of these three kinds of service, but there is no difference of opinion as to their value. I wish to present them in what I conceive to be the order of their importance.

I. The first service of science is to extend the boundaries of human knowledge. It sets up as its goal to understand nature. We speak of "conquering nature," and of making her a servant

to minister to our needs, but this first service contains no such thought. To such an investigator nature resembles a huge unexplored continent, whose secrets are gradually discovered. Something of the enthusiasm of the original explorers of our great western territory takes possession of him. Every advance into the new territory impresses him with the fact that it is far more extensive than he had dreamed. Every trail is worth following, for it means additional knowledge. Some trails may lead to rich farm lands and gold mines, but in exploration these are only incidents. To understand the new country, all trails must be followed and mapped. The figure has suggested the fact that this service of science is the service of the explorer, the service which makes all exploration worth while. Without it this nation would have had the Alleghanies for its western boundary. Without it nature would have remained a region of mystery, prolific in superstition, and of no service to civilization.

This general exploration of the unknown was once more appreciated than it is now. The original explorations of nature appealed to the wonder instinct of a people to whom the new territory was a revelation; but after the new territory became mapped in its rough outlines, the wonder instinct subsided, and people turned their attention to the farm lands and gold mines; and began to demand that exploration should stand primarily for these things.

Recently, however, the tide has turned and exploration in science is coming into its own again. This is indicated perhaps most significantly by the change of attitude in the scientific work of the government. Using my own subject as an illustration, the Bureau of Plant Industry, under the Department of Agriculture, has recently been adding to its staff scientific explorers. The reason for this has been a realization of the fact that practical application is sterile unless there is a continuous discovery of something to apply. Practice in an old territory is useful, but the discovery of new territory that demands new practice is far more valuable. If it had not been for exploration of territory we would have been farming in New England today instead of in Illinois; and if it had not been for scientific exploration, our practice would have remained that of a century ago.

This attitude of the government is expressing itself also in the developing ideals of agricultural experiment stations, which were formerly merely schools for apprentices, but which are now rapidly becoming schools of science. Furthermore, the general growth of this ideal is being felt in the universities, those notorious hot-beds of pure science, in the increasing attendance of practical students who have discovered that they must know science and must be able to explore.

A remarkable illustration of the incidental advantage that often follows scientific exploration for its own sake may be obtained from the work of the National Research Council. Through that Council a large number of emergency problems have been referred to the various sciences. In the great majority of cases the necessary information has been available because of previous exploration. Even plant taxonomy, often regarded as a subject most remote from the public welfare, has come into prominence as our surest guide to necessary raw products whose ordinary source of supply is no longer available. To know that a given plant yields a certain product is regarded as practical knowledge; but to know the relatives of that plant and their geographical distribution has proved to be far more valuable knowledge.

That scientific exploration is entering upon an advanced stage of its development is shown by the fact that it is proceeding in its methods from analysis to synthesis. Until recently progress in science was marked by an increasing segregation of subjects, so that scientific men were distributed into numerous pigeon holes and labelled. A man in one pigeon hole knew little of the work of his colleague, and cared less. This segregation was immensely useful in the development of the technique of science, by which results are secured, but now we realize the fact that nature is not pigeon holed, but is a great synthesis; and we know that to understand nature, which is to synthesize our results, all of our so-called sciences must focus upon the problems.

This first service of science, therefore, is that of exploring the unknown, and the result upon civilization is the development of the human race into greater intellectual efficiency, and inci-

dentally the extension of civilization by occupying and using new territory.

II. A second service of science is to apply the results of science to human welfare. It sets up as its goal the service of man, and expresses itself in what has been called "applied science," in contrast with "pure science," which is science at the work of exploration. The public has begun to recognize the fact that pure and applied science are not mutually exclusive fields of activity, but complementary, and therefore public support for pure science has been growing, and as a consequence of the practical achievements of pure science in connection with the war, it bids fair to enter upon its own in public estimation and support.

The idea, however, that there are two kinds of science, pure and applied, not only exists in the public mind, but also is reenforced by published statements from colleges and universities. An analysis of this impression that there is such a difference uncovers the fact that pure science is thought to be of no material service to mankind; while applied science has to do with the mechanism of our civilization. The distinction, therefore, is based upon material output. In other words, pure science only *knows* things, while applied science knows how *to do* things. This impression, rather than distinction, has been unfortunate in several ways. The public, as represented by the modern American community, believes in doing things, and therefore pure science seems to them useless. The reaction of this impression upon opportunities for the cultivation of pure science is obvious.

On the other hand, the universities, as represented by their investigators, believe in knowing things, and therefore applied science seems to them to be a waste of investigative energy, and its devotees appear very unscientific; very useful, but not to be acknowledged as belonging to the scientific cult, the cult of explorers. The reaction of this sentiment sometimes has been to avoid the investigation of problems that have an obvious practical application. In recent years, however, the spirit of service has invaded the universities. The university is no longer conceived of as a scholastic cloister, a refuge for the

intellectually impractical, but as an organization whose mission is to serve the public in the largest possible way.

The actual relation between pure and applied science can be discovered by tracing the history of any notable advance in human practice, which is usually regarded as an advance in civilization. It will be found that credit for the material results of science must be shared by those engaged in pure science, those engaged in applied science, and those not trained in science at all. The distinction, therefore, is not in the result but in the intent. In fact, the difference between pure science and applied science in their practical aspects resolves itself into the difference between murder and manslaughter, it lies in the intention. So long as the world gets the practical results of science it is not likely to trouble itself about the intention. In every end result of science that reaches the public there is an inextricable tangle of contributions. Between the source of energy and the point of application there may be much machinery, and perhaps none of it can be eliminated from the final estimate of values, and yet the public is in danger of gazing at the practical electric light and forgetting the impractical power house. In fact, schemes of what is called education in science have been proposed which would instruct in turning on the switch, and say nothing about the power house.

It is becoming obvious also, that all application must have something to apply, and that application only would presently result in sterility. There must be perennial contributions to knowledge, with or without immediately useful intent, that application may possess a wide and fertile field for cultivation.

The conclusion is safe that all science is one; that pure science is often immensely practical; that applied science is often very pure science; and that between the two there is no dividing line. They are like the end members of a long and intergrading series, very distinct in their isolated and extreme expression, but completely connected. If distinction must be expressed in terms where no sharp distinction exists, it may be expressed by the terms fundamental and superficial. They are terms of comparison and admit of every intergrade. In general, a university devoted to research should be interested in

the fundamental things of science, the larger truths, that increase the general perspective of knowledge, and may underlie the possibilities of material progress in many directions. On the other hand, the immediate material needs of the community are to be met by the superficial things of science, the external touch of more fundamental things. The series may move in either direction, but its end members must always hold the same relative positions. The first stimulus may be our need, and a superficial science meets it, but in so doing it may put us on the trail that leads to the fundamental things of science. On the other hand, the fundamentals may be gripped first, and only later find some superficial expression. The series is often attacked first in some intermediate region, and probably most of the research in pure science may be so placed; that is, it is relatively fundamental; but it is also relatively superficial. The real progress of science is away from the superficial, toward the fundamental; and the more fundamental are the results, the more extensive may be their superficial expression.

A notable illustration of this connection between fundamental science and its superficial expression is that given by the study of organic evolution. Before the beginning of the 19th century evolution was a speculation, which was as old as our record of human thought. During the 19th century it came to be based upon observation, and thus became a science, but its appeal was simply to those who wanted to understand nature. At the beginning of the present century it became a subject for experiment, for observation had reached its limit, and it was necessary to know through experiment whether one kind of organism can produce another kind. This experimental work began to uncover the laws of inheritance, or of heredity, as we have come to call it. The discovery of these laws suggested methods of securing practical results in plant-breeding never dreamed of before, and a revolution in agriculture was the result. It is a far cry from speculation concerning evolution to a solution of the problem of food production, but the continuity is unbroken.

It is the proper balance between the two ideals that must be maintained. The physical needs of man, great as they may be, must never obscure the intellectual needs of man; especially as

the trained intellect is the speediest agent in meeting physical needs. On the other hand, the intellectual needs of man, noble as they may be, must never lose sight of the fact that the speediest results are obtained by the enormous increase of experimental work under the pressure of physical necessity.

III. A third service of science is to develop a scientific attitude of mind. It sets up as its goal a more effective citizen, and expresses itself in the results of science in education. It is not necessary for me to consider the relation of the different sciences to education. This will be presented in the program of tomorrow by those who are in a position to know. Each science may hold its own peculiar relation to the needs of the student, as an educated person and a citizen. I wish to consider, however, the contribution of science in general to education, and through education to civilization. Any substitution of practice for scientific training is substitution of manipulation for knowledge, and is not to be regarded as science. The contribution of science to education is the development of a scientific attitude of mind, which means a way of looking at things rather than a way of doing things. The recognition of this factor in education has been shown recently by the numerous calls for men with scientific training; that is, not apprentices who have learned to do something; but students who have learned to understand something, which will enable them to do many things. It is this attitude of mind which has revolutionized modern thought and resulted in a new type of civilization. It has banished superstition as a controlling motive, and is the hope of our further progress.

It is important for teachers that this mental attitude be analyzed and the method of its attainment realized. There is much teaching in the name of science which does not secure it, and for this purpose there is no substitute for science. The scientific attitude of mind is probably nothing more than trained common sense, but a fuller definition will indicate more clearly the significance of this ideal.

In the first place, it is a spirit of inquiry, which recognizes that we are surrounded by a vast body of established beliefs that need a thorough going over to distinguish heirloom rub-

bish from the priceless results of generations of experience. It is also a spirit that demands a close connection between a result and its claimed cause. Failure to develop this spirit provides the soil in which political demagoguery, destructive charlatanism, and religious vagaries flourish like noxious weeds. It is a spirit that keeps one close to the facts. One of the hardest things in my teaching experience has been to check the tendency to use one fact as a starting point for a wild flight of fancy. Such a tendency is corrected somewhat, of course, when facts accumulate, and flight in one direction is checked by a pull in some other direction. Most of us, however, have the tendency, and the majority are so unhampered by facts that flight is free. There seems to be abroad a notion that one may start with a single well attested fact, and by some machinery of logic construct an elaborate system and reach an authentic conclusion, much as the world imagined for more than a century that Cuvier could do if a single bone were furnished him. The result is bad, even though the initial fact has an unclouded title, but it too often happens that great superstructures have been reared upon a fact that is claimed rather than demonstrated.

Facts are like stepping-stones; so long as one can get a reasonably close series of them, he can make some progress in a given direction; but when he steps beyond them he flounders. As one travels away from a fact its significance in any given conclusion becomes more and more attenuated, until presently the vanishing point is reached, like the rays of light from a candle. A fact is really influential only in its own immediate vicinity; but the whole structure of many a system lies in the region beyond the vanishing point.

Such "vain imaginings" are delightfully seductive to many people, whose life and conduct even are shaped by them. I have been amazed at the large developmnt of this phase of emotional insanity, commonly masquerading under the name "subtle thinking." Perhaps the name is expressive enough if it means thinking without any material for thought. An active mind turned in upon itself, without any valuable objective material, seems to react upon itself, resulting in a sort of mental chaos. In short, the scientific spirit is one that makes for

sanity in thought and action, a spirit which is slowly increasing in its influence, but which as yet does not control the majority of citizens. Of course, the methods introduced by science are now being developed in connection with other subjects, but science gives a training peculiar to itself, and it is this contribution which expresses the service I wish to emphasize.

I shall assume that any peculiar result of science in education must be obtained, not through information in reference to the facts of science, but through contact with the materials of science. However valuable information may be, it can hardly be regarded as a substitute for knowledge. Information is always at least second hand; while knowledge is first hand. The real educational significance of personal experience, which is a better name for what we call the laboratory method, is very commonly overlooked, even by teachers of science.

We were first told that science teaches the laboratory method, the inference being that the content of science is of no particular educational advantage of itself, but is merely useful in teaching a valuable method. Of course this method holds no more relation to science than do algebraic symbols to algebra; they both represent merely useful machinery for getting at the real results.

Then we were told that science cultivates the power and habit of observation. Of course it does, but this is not peculiar to training in science, for it belongs to any subject in which the laboratory method is used. Then it was claimed that the study of science trains the power of anaylsis. This is certainly getting the subject upon higher ground, for the power of analysis is of immense practical importance; but to imagine that analysis is the ultimate purpose of science in education is not to go very much further than to say that the ultimate purpose is the laboratory method. The latter is the method, the former is but the first step in its application, and is by no means peculiar to science.

Beyond analysis lies synthesis, and this certainly represents the ultimate purpose of science. The results of our analysis are as barren as a bank of sand until synthesis lays hold of them;

but even synthesis is not peculiar to science. To pass by the incidental and the temporary, and to reach the real and permanent contribution of science to education is to discover that it lies, not in teaching the laboratory method, in developing the power of observation, in cultivating the spirit of analysis, or even in carrying one to the heights of synthesis. It is in the mental attitude demanded in reaching the synthesis. In this regard the demands of science are diametrically opposed to those of the humanities, for example, using this term to express the great region of literature and its allies. The general effect of the humanities in the scheme of education may be summed up in the single word appreciation. They seek to relate the student to what has been said or done by mankind, that his critical sense may be developed and that he may recognize what is best in human thought and action. To recognize what is best involves a standard of comparison. In most cases this standard is derived and conventional; in rare cases it is original and individual; in no case is it founded on the essential nature of things, in absolute truth, for it is likely to shift. It is the artistic, the esthetic, which predominates, not the absolute. The whole process is one of self-injection in order to reach the power of appreciation. If the proper result of the humanities is appreciation, whose processes demand self-injection, the proper and disinctive result of science is a formula, to obtain which there must be rigid self-elimination. Any injection of self into a scientific synthesis vitiates the result. The standard is not a variable and artificial one, developed from the varying tastes of men, but absolute, founded upon eternal truth.

Two such distinct mental attitudes as self-injection and self-elimination are not contradictory, but complementary. The exclusive development of either one must result in a lopsided development. Persistent self-injection tends to mysticism, a confusion of ideals or even vagaries with realities, a prolific source of all irrational beliefs. Persistent self-elimination narrows the vision to a horizon touched by the senses. The two processes and the two results are so distinct and so complementary, that any scheme of education which does not provide for the definite cultivation of both of these attitudes is in constant danger of resulting in mental distortion.

You have now the reason for the statement that the scientific attitude of mind is trained common sense, and also for the claim that this service of science is related to the better equipment of the race for meeting its increasingly complex problems.

To summarize the whole situation: the service of science is, first to understand nature, that the boundaries of human knowledge may be extended, and man may live in an ever-widening perspective; second, to apply this knowledge to the service of man, that his life may be fuller of opportunity; and third, to use the method of science in training man, so that he may solve his problems and not be their victim. Such results suggest that science, through exploration, through practical service, and through education, is to be regarded as the most important factor in developing civilization.