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The Cultural Understanding and Appreciation of the Scientific Approach

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REGARDLESS OF HOW SOON a National Science Foundation becomes a reality, the fact that support of scientific investigation by society as a whole, through its government, is being seriously considered is a significant development. It is doubtful whether such a proposal could have gained serious support before the war except among scientists.

If a democratic society is to continue to support scientific research, however, there must be an understanding of its place and an appreciation of its needs by leaders and representatives and ultimately by the population at large. Those who are to vote intelligently on how much of its resources society is to give to scientific work must have some understanding of how dependable knowledge is obtained, what it costs to establish reliable results, and how we are handicapped in achieving the kind of life we wish to achieve by the present limits of knowledge. The purpose of this paper is to provide some data indicating that such understanding may not be sufficiently widespread to insure continued support once the lessons of the war are in the process of being forgotten; and that, unless certain changes are made in the dissemination of scientific knowledge, such understanding may not develop rapidly. It will be shown that, because of the operation of various influences in the past, we would not expect a very intelligent lay attitude toward the scientific method.

An appreciation of the nature of research involves a conception of the general method by which scientific results are obtained, the nature of these results, and what is needed to establish dependable findings. One may know what has been discovered without knowing much about how the knowledge was obtained.

When we analyze the various dissemination activities of present-day science, it seems that they are concerned mainly with informing their audiences about the scientific findings that have been developed. The textbooks used in schools, the newspaper and magazine articles, and the motion picture and radio reports tend to center their emphasis on what is known. Three ideas seem to be characteristically absent. The first of these is the nature of the method by which the findings have been derived. There is little or almost no discussion of the peculiar characteristics of the scientific method or of the cost in human hopes and disappointments, as well as in money and other resources, by which these findings were developed. Consider, for example, the typical high school textbook in science. There may be short descriptions of the men who made scientific contributions and there may be names and dates; but there is little which helps the student to develop an appreciation of what it means to control the significant variables, the price that must be paid to apply this method, the difference between a good experiment and a poor one, or some of the difficulty man has experienced when he has tried to interpret and use the findings from studies in which the significant variables were not controlled. What is true of the typical high school textbook in science also tends to be true of other dissemination materials. As a result, we would expect that the vast majority of our population has grown up without even an elementary understanding of what the method really is and how long it takes to establish knowledge with a high degree of dependability.

The second omission that appears from our analysis of current dissemination activities is that of the probability character and especially the limits of knowledge. Scientific knowledge, as every investigator knows, exists in all degrees of refinement ranging from relationships that have been established with a high degree of probability (or a low probable error in the basic measurements) through less well-established generalizations to untested hypotheses. The degree of refinement determines the extent to which we can predict the probable result when knowledge is used in planning how to control the environment and ourselves. It determines the extent to which we can plan a course of action which will have the result we desire. For example, in the present state of knowledge there appears to be some relationship in young children between diet and tooth decay. It also appears that factors other than diet are involved in the production of caries. But what these factors are is not definitely known. An important one may be fluorine. The details of the relationships are, however, not clear. If the parent wishes to produce good teeth in his child he cannot logically expect that careful control of diet will certainly assure that the child will have perfect teeth when he takes him for his first visit to the dentist. Neither can the dentist assume that, because the child has many imperfections or cavities, the parent has neglected dietary principles. The parent may have been neglectful, but before one can infer this from the condition of the child's teeth the probable errors of the data expressing the relation of frequency and extent of caries to the food eaten must be reduced considerably.

Furthermore, as every scientist knows, as long as scientific activity continues there is constant change in our knowledge. Hypotheses are subjected to test and changed into generalizations of known probability. More precise measuring instruments may be developed or more complete control of conditions may be achieved, with the result that generalizations having a relatively large probable error are replaced with generalizations having a small probable error, and so on.

These concepts of the fundamental nature of scientific knowledge and the peculiar growth characteristics are not included in the typical dissemination materials. As a result, we would expect that they are also not operative in the thinking of the community leaders and representatives who play such a large part in the democratic process. Only when an individual realizes the serious gaps, how we are handicapped by them, and what the results may be if these gaps are not filled, will he have some motivation for supporting further investigation. Without such motivation the attempts to obtain continued social support may not meet with success. But present-day dissemination tends to omit the consideration of the gaps and the resulting handicaps.

The above observations would lead us to the hypothesis that the activity we call research is not well understood by the ordinary lay leader and that it is not considered by him as a particularly important function to be supported by society.

We may extend our analysis further. If we consider that the vast majority of persons in their daily activities see and otherwise experience relatively unscientific approaches to problems, especially social problems, we would expect that they would not learn to look upon research as an important method for solving problems.

We have, then, several hypotheses which we can subject to test: (1) that the activity we call research is not well understood either by community leaders or by the students coming up through our schools; (2) that research is not considered as an important function in society; and (3) that scientific research is not looked upon as an important method of solving social problems.

Data relative to these three hypotheses will now be presented. These data will consist of two parts. The first concerns the results obtained when a group of 50 community leaders were interviewed. This study was carried out in the spring of 1946. The second set of data consists of the results obtained when high school juniors and seniors were studied as to their understanding of various aspects of scientific research.

In the interview with the 50 community leaders it was desired to obtain data on four major questions. The first was the meaning of research, *i.e.* the ideas which community leaders attached to this term. Secondly, we wanted to know how important the community leaders regarded research. To make this concrete, data were sought concerning the importance which they attached to research as an enterprise of a university in contrast with other functions that a university might perform in society. Then one problem, namely, child development, was selected, and two types of data were sought relative to it: the source of the most dependable, refined knowledge about child development in the thinking of community leaders, and whether research in child development is needed. Child development lends itself rather well for such an investigation, since it embraces both the natural and social sciences and at the same time is of rather widespread interest.

In the interview eight major questions were formulated and used as a guide. Each question was followed through until the interviewer was satisfied that he had explored the concept thoroughly. The data were gathered by trained persons who themselves were engaged in scientific investigation.

An example or two may serve to show how the interview was conducted. In attempting to obtain data concerning the importance attached to research as an enterprise of a university in contrast with other functions that a university might perform, three questions were asked:

Let us look at various parts of the university for a moment. You know that medicine is important for all persons, children as well as adults. You also know that at the college of medicine there are many professors on the university staff. How do you think these professors should spend their working day? What do you think they should do?

Now I want to ask you about the Child Welfare Research Station. (The interviews were made in an Iowa community and this unit of the university was reasonably well known.) It is made up of several people. When you put them all together, they are interested in children of different ages, parents, orphans, etc. How do you think these people should spend their working day? What would you expect them to do?

Let us take another area of the university. Name an area with which you are most familiar, such as chemistry, botany, zoology, mathematics, physics, or any other. In this department (after subject had named a department), there are many professors. How would you expect them to spend their day? What would you expect them to do?

The answers to the three questions were combined and the results expressed on a seven-point scale ranging from "1—research is the prime function of a university" to "7—teaching is the principal function (with no mention of research)." Step 4 puts teaching and research about equal in importance.

In the group of 50 community leaders, which included the outstanding citizens in a midwest Iowa community of 15,000, the following distribution of scores relative to the importance of research was obtained:

Scale value	"*f*"
1	0
2	1
3	2
4	8
5	12
6	14
7	13

From this distribution it can be seen that 78 per cent rated teaching as more important than research, and 54 per cent hardly mentioned research or did not mention it at all as a function of a university.

Furthermore, the term research has relatively little meaning. On a seven-point scale on which Step 1 represents considering research as involving study through controlled variables and Step 7 represents practical inability to describe much of anything about the concept, the following distribution was obtained:

Scale value	"*f*"
1	1
2	3
3	22
4	2
5	......
6	22
7	......

Approximately half of the group were able to describe research as finding out new things or attempting to get new knowledge by study, but few (scale values 1 and 2) were able to suggest that the most dependable type of study is one in which known variables are controlled. For the other half of the group the term had little or no meaning beyond simple reading, study, or laboratory work without their being able to describe the nature of such work.

To determine what method these community leaders tend to rely on for the solution of a social problem, several questions were asked relative to the source of the best or most dependable knowledge about child development. On a seven-point scale on which Step 1 represents systematic research as the most dependable source and Step 7 represents statements by lay persons, such as teachers, parents, and the like, as the best source, the following distribution was obtained:

Scale value	"*f*"
1	0
2	5
3	3
4	6
5	10
6	4
7	22

It is quite clear that the proportion considering research as the most dependable source is extremely small, only 16 per cent being on the research side of the distribution (below scale value 4). These data support rather strongly the hypothesis that the level of development of the concepts relating to the nature and function of research is quite low.

A study of the growth of scientific concepts in high school juniors and seniors shows much the same picture as that for community leaders. The development at the high school level was studied by preparing tests consisting of problems requiring for their solution the application of the basic concepts with which we are here concerned. Problems were developed to test the ability to apply the idea that at any given moment scientific knowledge exists in different degrees of refinement, that the degree of refinement of the knowledge used in making a prediction sets the limits of the accuracy obtainable in the prediction, that knowledge grows by research and only by research, and that the function of research is to extend the boundaries of knowledge.

In constructing the test situations an effort was made to present simple, everyday problems so that the student would have no difficulty in understanding the situation and could make full use of whatever knowledge he possessed. For example, in testing the individual's conception of the nature and function of research, he was given three types of situations. In one he was given a series of five statements and asked to check the one that gave his idea of the principal function of research. In another he was asked to take some limited area of knowledge, such as the effect of different metals on the strength of alloy steel, the effect of smoking upon physical growth, or the influence of "cold shots" in preventing colds, and to mention one fact about the area chosen that had been demonstrated to be true and one question that had not been investigated to any great extent. The subject was given a wide variety of areas from which to make his choice. In the third situation he was asked to give an example of a scientific investigation in any field which has been made within the last 10 or 20 years and to show what effect this investigation has had on our knowledge of the field. A method of scoring was carefully worked out and tested for reliability.

Several investigations of high school juniors and seniors have been made. These used a variety of testing situations and different samples, but the findings are strikingly similar. The results from the most recent investigation, a study of 176 students, reported by Fitzgerald and Ojemann (*Child Developm.*, 1944, **15**, 53–62), will be summarized here. In the following table the per cent of subjects in this study achieving 75 per cent or more of the total possible score on the various groups of items is presented:

Group	*Per cent*
Nature and function of research	18
Dependence of growth of knowledge on research	34
Awareness of the growth characteristic of knowledge	42
Knowledge of effect of error in basic data on error in prediction	7
Awareness of different degrees of refinement or probability characteristic of knowledge	29

In interpreting these data it is helpful to take into account that the per cent for each group is the proportion achieving three-fourths or more of the total possible score. Thus, if the subject was presented with four situations, he would have to solve three of them to be counted in the above tabulation. A score equal to 75 per cent of the total possible score seems a reasonable minimum, however, for if the subject understood the nature of the scientific approach, he would easily be able to achieve this minimum. From the above tabulation, it will be noted that only approximately 1 in 5 is aware of the nature and function of research; about 1 in 3, that knowledge grows by research; about 2 in 5, the simple fact that knowledge grows; about 1 in 14, that the degree of accuracy in prediction is limited by the error in the basic knowledge; and finally, 3 in 10, that knowledge exists in different degrees of refinement.

These data tend to indicate that not only are present-day adult community leaders far from understanding and appreciating the scientific approach, but we seem to be developing another generation with somewhat the same characteristics. It is also interesting to note that when studies were made of the relationship between such experiences as the number of semesters of mathematics or of science which the pupil had taken in his high school career, no significant relationship between these experiences and the development of these basic concepts could be found. One might think that mathematics would be a good area in which to point out the probability characteristic of knowledge and the effect that this characteristic has in the use of knowledge in planning future action. Similarly, one might expect that training in science should help the pupil to develop a conception of the nature and function of research and the dependence of growth of knowledge on research. In this group of 176 juniors and seniors the number of semesters of science varied from zero to seven, but the correlation between the number of semesters of science and scores on the tests of basic scientific concepts was .07, or practically zero. The number of semesters of mathematics varied from two to five, but no relationship between amount of mathematics and test scores was found.

Thus, it appears that, with present methods of educating and guiding youth and adults, the basic appreciation of the scientific approach is not especially well developed. This is not encouraging if we expect society to give increasing support to scientific endeavors. Fortunately, we are not restricted to present methods of developing youth. We can change those methods.

In a pilot study using high school students, Musgrove (*Univ. Ia. Stud. Child Welf.*, 1939, **17**, 115–128) was able to bring about a significant increase in the understanding and appreciation of the scientific approach. To conduct the study, however, it was necessary for her to prepare her own reading and teaching materials, since the kinds of materials needed were not available. This gives some indication of what will have to be done to bring about a higher level of development throughout society. If all of the various dissemination media, including textbooks, newspaper and magazine features, motion picture reports, and radio presentations will give more attention to the basic concepts involved, the job may be done before the lessons of the war recede too far in popular indicated by the data presented. How soon the change thinking. That such a change is needed seems to be can be made remains the challenge.

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