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The Physical Science Course: Past, Present, and Future

R. RAY HAUN[1]

Abstract. On the basis of a study of 22 articles written recently by college teachers about general education courses in science, the changes which have taken place in such courses since the late twenties and early thirties are summarized. Among these changes are a reduction of the emphasis upon survey and an increase of emphasis on the methods of science. New approaches, such as the historical approach, the problem approach, and the interdisciplinary approach are discussed. Changes in laboratory work to emphasize more the methods of science are noted. It is believed that two types of courses will continue to develop with differences in objectives, content, and outcomes—one specifically for the science major and the other for the non-science major. Physicists should give leadership to these developments rather than leave them to others with less scientific background.

Although one might argue that all courses in the various physical sciences including the early ones in Natural Philosophy of over three centuries ago and those offered by science departments today are courses in physical science, the development of a single inter-disciplinary course under the title of "Physical Science" has come since the late twenties and early thirties. Among the first of these was the course consisting of a series of lectures given at the University of Chicago, subsequently published in 1926 under the editorship of H. H. Newman, with chapters contributed by seventeen different professors. Its title was *The Nature of the World and of Man.* In the preface to this volume Newman says,

> Not only the aims of this volume, but also the plan on which it has been written, have been determined in large part by the fact that it contains the subject matter of a "survey course" given each year by its authors at the University of Chicago to a group of selected first-year students of superior intelligence. The survey course was designd to give capable students a preliminary view of the rich intellectual fields that lie before them so that, on the one hand, all of their work shall have a large measure of unity and coherence, and, on the other hand, they will be able to decide early what particular subjects they may wish more thoroughly to explore.

My own first course in physical science in the mid-thirties used this book as a reference and followed more closely, as a text, a book which appeared in 1934 – *Man and His Physical Universe,* by Jean, Harrah, and Herman of Colorado State College of Education, and Powers of Columbia University. In the preface to this book the authors say:

> . . . thoughtful educators . . . are demanding courses that cut

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> across many sciences. They are calling for courses which develop the understandings that will help the student to locate himself in his universe; that will free him from superstition and prejudice; that will impress him with the importance of relying upon established truth in ordering his own life; and that will enable him to appreciate the careful, logical methods employed by scientists in arriving at trustworthy conclusions. In short, these educators are insisting upon courses in which the generalizations and understandings of science shall be developed in such a way as to influence significantly the beliefs, philosophy, behavior, and attitudes of the future citizens of our democracy.

This past year we collected articles from twenty-two college teachers who are currently offering general education courses in science, and some of the findings from a study of these articles are presented here.

A summary and comparison of the objectives of the present courses with those early courses show that in many ways they are the same, but on the other hand, definite changes have taken place and some new trends are indicated. One notices, for example, that there is now an established recognition for the need of two kinds of courses. These may be distinguished by saying that some courses are designed for students specializing in science and others for non-science or general students. The questions that have been raised concerning the most valuable kind of science experiences for the non-major have also produced a re-examination of the science objectives for the major. A quick summary, needing further explanation and substantiation, is that the traditional courses for the major are taking on more breadth, and the general courses more depth.

This leads to the next most obvious change that has taken place in science for general education. The survey course has been blacklisted. Even the term "survey course," is taboo. I was enthralled by those first Chicago survey courses and I often decry the extent to which the pendulum has swung, since I feel that there is merit in the non-science student's becoming acquainted with the major findings in as many sciences as possible. However, there is no doubt that my own as well as other courses, have attempted in the past to cover too much within the time allowed. Everyone now realizes that it is impossible to cover all the sciences, even all of the physical sciences, within one course. As a consequence there have developed a number of modifications of the old objective to survey the physical sciences. One of the modifications has been the so-called block-and-gap course. This term implies that certain topics are to be discussed and others are to be omitted. Many people, feeling that there is an undesirable implication in the term "gap," have avoided the usage of this term and simply say that certain topics will be selected for the course. There is, however, no agreement among the various people offering such courses as to which topics shall be selected. Apparently different people place different weight and different values to many topics that may be selected for the general course.

There is another area in which science courses in general education have made marked changes. This can best be summarized by saying that they are emphasizing the methods of science, although the term is a dangerous one. The term, "The Scientific Method", has likewise become taboo although the "teaching of the scientific method" has been the major objective argued for including a science course in the liberal arts requirements ever since group requirements came into liberal arts curricula. However, there is now a correct emphasis upon the fact that there is no single, simple method, procedure, or formula by which the scientist grinds out his conclusions. There are many approaches to a problem, many paths which may lead to the end and many facets which reflect and refract the conclusion, principle, law, or construct when it is obtained. This denial of a single, simple scientific method is reflected in th current objectives of science courses which substitute for the statement, "to teach the scientific method", some expression which is more extensive or else emphasizes an aspect which is an essential part of the scientist's procedures. Illustrative of these modifications are such expressions as: the methods of science; the tactics and strategy of science; to demonstrate (and develop in the student) the methods of observation and inference required to reach conclusions in science; to convey some understanding of the scientific enterprise as a means of getting knowledge and solving problems; to develop critical thinking and logical reasoning; to develop the intellectual tools for investigation; to develop a scientific attitude; to understand the scientists point of view and what he does; to analyze scientific data summarized in maps, tables, charts, and graphs; to become acquainted with sources of scientific information; and to give a few glimpses into the evolution of ideas in science.

There is another older objective in the teaching of science that has suffered an extensive metamorphosis. It was said that the student should get an understanding of the scientific applications around him—the pump, the fire extinguisher, the purification of water, the automobile, and the aeroplane. If man now knows too much pure science to teach in one course, it is obvious that any coverage of the practical applications is hopelessly impossible. Many applications are still discussed but as illustrations of principles rather than as an attempt to give explanation to all the gadgetry around us.

However, there is a new emphasis in science general education courses that might well be regarded as a transition from teaching about the engineering applications. This is a trend to discuss more extensively the impact of scientific developments upon society and upon the life of the individual. This trend is substantiated by such statements as the following which are found in the objectives listed by contributors to the volume, *Science in General Education*: to point out personal and social implications of the scientific endeavor; to cultivate those illusive and priceless faculties of reasonableness and thoughtfulness; to understand the role, importance, and limitations of science; to face facts, revise judgments, and change behavior in light of appropriate evidence; to develop an understanding of the contributions of science to the solution of contemporary problems.

Associated with the changes in objectives one also finds changes in the approaches which are being used in the science general education courses. One of these approaches would still be the survey approach. The term may be taboo but the fact remains that many of the courses and most of the books which are written for them approach the course more from a survey view than from any other perspective. These courses were designed to give some comprehension of the natural world to students who otherwise would not get it and with this kind of philosophy the course must have a survey approach. Those opposing the development of the survey courses said the courses could not have depth and, while one might raise the question as to what is meant by depth, a consequence of this accusation has been the development of the block and gap or simply of the selected topics approach mentioned previously. In both of these approaches a fundamental problem arises about a way to tie together the selected topics and the materials from the several disciplines. Within the separate disciplines accepted continuities have developed although it is interesting to note that even these continuities are now being challenged. But in the general education courses no accepted continuities have been established. To me, one of the most interesting discoveries has been that there are sound continuity reasons for all of the many course organization outlines that different people use in physical science courses. This is now being interpreted as another indication that the natural world does not operate in compartments or by disciplines. A search for understanding and explanation at any point in the natural world soon involves one in one or more of our conventional disciplines and if one's questions continue farther and farther the search will undoubtedly lead to everything known in all the separate disciplines.

It is at this point that the integration and interdisciplinary approach appears. By denunciating the departmental lines it is easier to treat more comprehensively and possibly with greater depth a few basic and fundamental topics, principles, or constructs. A number of general education programs stress this aspect by naming their programs and curricula "interdisciplinary studies." Thus, by the use of this term there is obtained not only a reaction against fractionation and specialization but an emphasis upon the interrelatedness of the disciplines and possibly by implication upon the desirability for greater unity of knowledge. This is regarded as a prime function of the courses not only by those institutions which use the term "interdisciplinary studies", but by others as well. It is indicated in many of the stated objectives and by the very fact that the content material is always taken from more than one discipline. In fact it is in this selection of content which requires integration and shows interrelatedness, that the present course contents differ from that of the older "survey courses." Very popular now for this approach is the topic of structure of matter, frequently limited to the structure of the atom. Similar topics for this approach are the conservation principles, the nature of energy, and photosynthesis.

There is another approach to these kinds of topics which is being used with increasing frequency and enthusiasm. This is the historical approach. However, a different objective is generally stressed with this approach. The historical approach is regarded by many as a superior way to show the methods of science. By the use of case histories the student can read about the classical experiments as they were originally performed and consider the kind of reasoning that leads to their interpretations — the interpretations that were tentative and frequently wrong because related ideas were wrong or had not been discovered, as well as final conclusions on the basis of further information. Sometimes the classical experiments are repeated by the instructor or by the students in order to place the student in a better position to understand the interpretation of the original discoverer. However, emphasis here is not upon the experimental procedure, but upon logical reasoning and critical thinking. To express it another way, the historical approach is used to help students appreciate the way scientific concepts develop. Some of the case histories that have been used are Copernicus and the heliocentric system, Robert Boyle and the spring of the air, Lavosier's work on combustion, Pasteur's and Tyndall's studies of spontaneous generation, Harvey and the circulation of the blood.

Another approach which is used is the problems approach. In this approach, no attempt is made to emphasize the history. Emphasis is upon problem solution and the problems to be solved may be either historical or current ones. Some typical problems are: How did the solar system originate? What was the origin of the "Carolina bays"? How are the motions of the celestial bodies explained? Why does the body have useless parts? How is the circulation of the blood controlled? How does life depend upon light? In this approach, it is likewise possible to analyze the problem step by step, to bring in various kinds of data and other information and then to show how logical conclusions can be drawn to find answers to problems. Here, too, some experimentation may be introduced and library reference work required to obtain student participation of an inquiring and reflective nature.

Finally, the discussion of approaches would not be complete without pointing out that laboratory work has always been regarded as an important, generally the most important, approach to an understanding of the methods of science and the work of the scientist. Although it is undoubtedly true that too much student laboratory work has been performed under cookbook instructions with more and more elaborate equipment for greater precision of measurements in order to obtain conclusions already established thousands of times, nevertheless it is a new experience for the student and it not only supplements his reading and listening for learning that well-established conclusion, but it does also give him some comprehension and understanding of the procedures—experimental and reflective—that the scientist uses in his work.

There is a very important development, growing with increasing rate during the past decade, which is adding more value to the laboratory work for the general education student. This new—or revitalized old—approach is to make the laboratory work nore investigative in nature and throw the student more on his own resources. This is being done in three different ways. One is simply to give less instruction with the conventional experiments, that is to give less cooking instructions. The purpose or objective is made clear, the materials are made available under supervision and the students, generally working together, are expected to devise their own procedure and conduct the experiment to a conclusion. A second type of investigative experiment involves the use of problems, generally very simple and restricted, for which answers cannot be found in the books and other literature, and, therefore, the student must make his own investigations. For example a student is given a set of liquids or of solutions, metals, solids of various kinds.

He is given the problem of finding sufficient characteristics of each one that when given an unknown sample of one of them he could determine which one of the original set it is like. Like unknowns in qualititive analysis, these kinds of problems generally intrigue students and with proper selection of materials the instructor can make the problem very challenging for any level of student. A third type, frequently referred to as "open end" experiments, specify no particular problem to be solved but simply that a particular situation be investigated as far as possible within the limits of the student's time, interest, and ability, emphasis being placed only upon obtaining good results. In all of these experiments emphasis is upon the student conducting his own experiment, collecting his own data, and making his own interpretation. Difficulties arise in finding problems or situations which are challenging to the student and at the same time simple enough for him to investigate with his limited background and experience. Also, the time consumption on the part of the instructor as well as the student is exorbitant.

The physical science course for the non-science major should not be, and in my opinion in the future will not be, a watered-down, easy course. In some places it is considered now to be a harder course than the introductory courses in the science departments. Its objectives will be different, its content different, and its outcomes different. And may I add that I think it is extremely important that we, as scientists design the science courses for the non-science major. I am very much disturbed by the possibility that others will take over these courses if we do not face the problem squarely and do something about it. The non-science students must have an experience in science, not just to learn something about science and its effect upon society. I personally hope that it will have some survey aspects and that it will not contain a lot of minutiae or techniques needed by the science specialist, nor a lot of technology. I hope it will be built on the basic concepts in the various sciences, and that it will give the non-science student enough experimental and interpretive experience that he will get at least some comprehension of the methods of science. Only if he does this is he prepared to become an effective citizen in a society where science plays the important part that it does in our civilization.

Another development for the future which I hope will come, and there are some signs of it, is a physical science course for the science major which would be different from the course for the non-science major. This would be an interdisciplinary course, particularly between physics and chemistry, although it might include some other sciences. It should consist of the materials being duplicated in physics and chemistry, partially for the purpose of saving time but more to enable our science students to see the importance of basic principles and of broader generalizations and to develop larger constructs about the natural world. This should be given before the detailed material of our introductory courses so that the various topics in these courses would be seen and better understood as consequences of the broader concepts and constructs. These courses might well include discussions of scientific methods, history and philosophy of science, its impact upon society —all of which I am now lumping together under the title of "The Scientific Enterprise". This latter part may be deferred for science majors to their senior year as is being done in many places now, but there are also some advantages in presenting it first and I think we need experimentation with it both ways.

In my opinion the possibilities for the future in physical science courses and in the several departmental courses look exciting and interesting. I think our biggest problem arises from our tendency to hold on to the traditional courses because of the established sequences we feel we must have for our students who continue with us, who transfer to other schools, or who go to graduate schools. But I believe that as scientists we are able to solve this problem if we face it as a problem and tackle it. I have confidence that we will do so.