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A Proposal for Modifying General Studies Science*

By Ollin J. Drennan

The theme of this series of lectures—SCIENTIFIC KNOWLEDGE AND THE WELFARE OF MAN—seeks to capture in a short phrase one of the concerns that has manifested itself dramatically and vocally among students in recent months. Although the students may not recognize the historical age of this concern—it has been discussed with various degrees of passion since the age of the Greeks—the very fact that it can appear in the guise of a new concern—of a new generation—that is at odds with the present concerns of the older generation, points out the continual necessity for reexamining those ideas that we hold to be true without question.

An earlier lecturer in this series began with the statement that science, by definition, is not concerned with the welfare of man. His statement may or may not stand the challenge of contemporary thinking. But, whether or not science is concerned with the welfare of man, certainly a General Studies program is concerned—and with no qualifications. The dominant thrust of General Studies activities lies in the direction of awakening and deepening the student’s individual awareness to the welfare of man—individually and collectively—in the 1970’s and beyond.

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A concern for the welfare of man, if it is to be translated into

*This was originally presented as one of a series of lectures sponsored by the School of General Studies at Western Michigan University dealing with Scientific Knowledge and the Welfare of Man.—Ed.
action, involves choices and decisions. Choices between possible goals; and decisions as to which of a number of courses of action should be taken to reach those goals. It is at this point of making choices and decisions that several of our earlier lecturers in this series contended that science should not be expected to be involved. If that is the case, and if it is also the case that in the total picture of General Studies the concern for building an adequate basis for making decisions and choices is fundamental and perhaps central, then we must seriously entertain the notion that perhaps science occupies a too prominent place in the program of General Studies.

I would not and could not defend that point. Rather, I will contend that there are aspects of our culture which strongly affect the lives of everyone today, aspects not usually considered to be aspects of science, but which can best be understood through a study of science-as-it-has-been and science-as-it-now-is. Such a contention will require a broader conception of science than is usually accepted by most scientists; they may view this broadening as being detrimental. But, from the viewpoint of general education, the broadening is not only desirable but necessary if the goals of general education are to be achieved. I make this contention as one who is committed, first, to the cause of general education, and then to the cause of science. And it is on the basis of a primary concern for the response of students to the conditions of their lives, that I will consider science and its role in general education.

So, I propose to consider what science is, or what it has become during the last several centuries, in its relationship to the broader culture which we all share; then, to consider what ramifications this relationship has for a General Studies program; and finally, to consider a set of requirements that might represent an improvement over the present requirements in the Science Area of a particular General Studies program.

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It is generally accepted, today, that NATURE is the subject matter of concern to the practicing scientist. And, while there are differences of opinion concerning exactly what establishes the boundaries of nature and exactly which topics lie within nature and which without, it is also generally accepted that the criterion which must be used to decide such issues is the process in science that has often been called “The Scientific Method.” I have some difficulty in using this phrase because it seems to me to speak of a single, monolithic procedure into which something is inserted at the beginning and out of which something different emerges at the end, something that represents a finished product of science—and such a model isn’t true to science. The practical, physical techniques employed by the different scientific disciplines—such as chemistry and mechanics, for instance—
are often very different, simply because the physical characteristics of the subject matter being studied are very different. There is a greater similarity in the logical or theoretical processes employed because these processes are determined by the nature of logic and not by the subject matter being discussed. But, even so, the nature of the subject matter determines the kinds of questions that the scientist asks, and these questions determine the manner in which logic is used to implement the securing of answers.

Having cast some doubt, I hope, on the legitimacy of suggesting that all scientists proceed in unison, or in lockstep, with a single method that is scientific, I hasten to add that there are some considerations that allow the differentiation of science from non-science.

Let me describe, and thereby define, science in the following way. I will begin with the individual because I believe that there is no other place to start. Each and every observation of nature must be made by some individual. Each individual develops very early in his life an understanding of his world in which he separates himself from the rest of his environment. This internal-external dichotomy allows each individual to conceptualize himself in a world external to himself—a world of inanimate objects of various shapes and sizes, and of living objects, also of various shapes and sizes. The individual becomes aware of the objects in this external world through his sense experiences, and he constructs his common-sense view of that world, and his common-sense expectations of it, through inferences he makes from the many varied and, perhaps chaotic seeming, sense data.

He learns at some point in his development that he stands in a peculiar relationship with certain of the other objects he finds in his surroundings: namely, other human beings. Individuals learn early in their lives that they can communicate with one another and the growth of their ability to use language allows them to exchange ideas. It is this ability to exchange ideas that is at the heart of science. Statements are made by one individual, but a second individual must interpret the meaning and test the truthfulness of them. The problem of establishing personal meaningfulness is one that is of great importance in general education, but is, perhaps, outside of our concern in this discussion. The establishment of truthfulness, on the other hand, is precisely our concern. Those statements or assertions that are accepted as truthful are accepted as being warranted, to use a term used often by John Dewey. The accumulated knowledge about nature that we call science consists of a body of knowledge that is warranted by a carefully developed technique that includes two elements: 1) the development of a theoretical framework into which each experience is fitted; and 2) refined techniques for describing each experience so that it can be recognized as part of the common experience of all men.

Thus we might accept as a definition of science the statement
that science is that set of assertions about human experience that are warranted through the process of science. This warranting process consists of organizing experiences—objectified through measurement—into empirical laws; then through a non-logical step of creation, the proposing of a theoretical model or scheme to explain the empirical laws; and finally, through logical processes, the development of consequences of the theory which can be compared point by point with the empirical laws. The success of the theory lies in the adequacy of the comparison of the deduced consequences with the empirical summary of experience.

This very brief, and perhaps too abstract, discussion of the nature of science has been included to allow me to speak about the aims or purposes of science with some assurance that we will have a common understanding of what I am referring to when I use the term, science. Traditionally philosophers of science describe the aims of science as being essentially three in number: description, explanation and prediction.

Experiences are described accurately and clearly so that each scientist can see in the description a similarity with his own experience—or a difference, as the case may be. The process of providing such clear, unambiguous descriptions is constituted by abstracting from each experience that element of the experience that runs through the experience of all mankind. It is in this way that science becomes "objective," and therefore free from the idiosyncrasies of individual experience.

Explanation consists of relating individual and unique experiences to an accepted framework of knowledge. The web of events and occurrences that make up science constitutes the means of explanation by relating all experience to it. Thus, explanation consists of making the unexpected expected by means of a theoretical world viewpoint.

Finally, prediction is the projecting into the future the framework of explanation that has sufficed in the past so that the future can be anticipated and viewed with expectations that are secure. When one predicts or forecasts, one gives a more or less reliable picture of the future and, thus, allows planning and decision-making to proceed on much firmer ground.

So far there seems to be little connection between what I have been describing as science and the problems of the welfare of man. Decisions concerning man’s welfare, if consciously made, involve judgments of relative value. Often the judgments are made in terms of what ought to be done or ought to happen. These are ethical decisions. It has become traditional for scientists to claim that science does not have an ethical or moral side. Such considerations are not rightly a part of science. Although such decisions must be made, they are not a part of science and science ought not be taxed with the
responsibility. Most decisions, they continue, that are made about the use of scientific knowledge are made by the technologists—the engineer, the physician or the politician—and they are not scientists.

This view has much in it that is reflected in practice, but it is also much too simple because it seems to divorce, entirely, the role of the acquisition of knowledge—that is, science—from the role of the application of that knowledge—that is, technology. One noted historian, Professor Lynn White, Jr., at UCLA, makes this comment with respect to such a divorce:

"But it was not until about four generations ago that Western Europe and North America arranged a marriage between science and technology, a union of the theoretical and the empirical approaches to our natural environment. The emergence in widespread practice of the Baconian creed that scientific knowledge means technological power over nature can scarcely be dated before about 1850..."\(^1\)

I suppose a marriage must precede a divorce, but Professor White believes the interrelationship has grown steadily closer, not farther apart.

Before 1850, if we accept Professor White's authority to set a dividing line, technological decisions were made through the practice of empirical, trial and error knowledge and a considerable amount of art. The practice of science was slowly passing from infancy into adolescence, soon to make its mark in the world of man's affairs but not yet doing so.

Let us consider further, for a moment, the relationship that existed between science and technology. This is an important consideration today because technological decisions are decisions of relative value; they are ethical, and perhaps moral, decisions. In the affairs of man alternative courses of action become available to individuals and to groups of individuals almost daily. Decisions must be made, and are made, on any basis that can be viewed as relevant. Prior to 1850, or thereabouts, such decisions about problems concerning nature were made through the application of lore, superstition and tradition. It should be made clear that the insights supplied by scientists, or natural philosophers as they were called, into the workings of nature were too fragmentary and incomplete, too uncertain to be trusted in any great practical sense. This may be illustrated by the example of the steam engine. Although there were a number of scientific studies made of the steam engine prior to 1850, little was produced that led to improvements in the practical steam engine

\(^1\)Science, 10 March, 1967, Volume 155, pp. 1203-1207, "The Historical Roots of our Ecological Crisis"—Lynn White, Jr.
until the formalization of thermodynamics in the 1850’s. The steam engine was being steadily improved, and this improvement was an aid to the scientists who were laying the foundations for heat theory. In fact the direction of influence was from technology to science rather than the reverse. Some years after the First and Second laws of thermodynamics were enunciated, theoretical analyses produced suggestions that did lead to practical improvements in the steam engine; and this consummated the marriage between technology and science in the instance of this one basic element used in coping with our environment.

What about ethical and value problems resulting from scientific discoveries in this period before 1850? We must conclude that most of the questions raised about science were of a philosophical or a theological nature. The questions that developed the most interest and concern lay in whether or not to accept the very intellectual basis of science as being capable of producing acceptable knowledge. In the seventeenth century the burning question that occupied most minds when they thought of the fledgling science was: “By what authority does the natural philosopher propose his truth?” The day to day ethical or moral decisions were not immediately involved.

By the middle of the nineteenth century the burning question had become, “Has or has not man come to his present place in the world through a slow and unpredictable process, that is, through evolution?” Again the day to day ethical or moral decisions or choices were not immediately involved.

After the so-called marriage of science with technology, ethical decisions concerned with the use or application of scientific knowledge became more directly necessary and they have grown in importance until, now, these kinds of decisions are regarded as among the most important that face mankind.

* * * *

In the first decades of the seventeenth century Francis Bacon attempted to give a new direction to science. He believed that the purpose of science was to give new power and greatness to mankind. Science was to minister to the arts—medicine, navigation, industry of all kinds. This was an almost new conception among natural philosophers, this belief that science should contribute to the control of his environment by man through the application of scientific knowledge. For Bacon, the use of knowledge was the justification for the search for it. He did not believe that knowledge was important and valuable in and of itself.

Bacon’s “new method” and aim for science came to have a large following in England in the seventeenth and eighteenth centuries. It led indirectly to the many applications of scientific knowledge that marked those centuries and led, eventually, to the marriage of science
to technology in the middle of the 19th century as described by Professor White. The expectation that science could lead to control of the environment is a characteristic of science that I did not list when I gave my earlier description of science. I stated that science led to unambiguous description of experience, a coherent and connected explanation of that experience and a successful prediction of many kinds of future actions and events. Now we must add the expectation that science will lead to the ability to control the environment, which is at least one step beyond experiencing, describing, explaining and predicting.

Also, as I have suggested earlier, it introduces into the discussion of science an element, or aspect, in which value judgments are inherently involved. If the aspects of science that I detailed earlier were comparatively free from ethical judgments, the ability to control aspects of our environment, and the subsequent attempt to do so, places the questions of what should be done, what should be controlled, which of several possible controls should be exercised, in a constant and influential position in making technical decisions.

It is precisely because of this abrupt change in the character of the activity—when problems of control are introduced—that many scientists separate science and technology so religiously. That is, they separate the acquisition of knowledge from the application of that knowledge. There is some of this division of labor inherent in the phrase RESEARCH AND DEVELOPMENT. Research, especially that which is called basic or pure research, is the province of scientists, while development, that is, the development of the applications of scientific knowledge, is the province of engineers or technologists. I would hold, however, that since the “marriage” between science and technology in the middle of the nineteenth century, this division has been artificial and tends to separate jobs and responsibilities in a way that is arbitrary, and that it would be more fruitful to speak of science and technology as two ends of a continuum rather than two separate and different and distinct activities. Much, if not all, of research is undertaken because a problem has been encountered; information is sought in order to use it as a means for solving the problem.

The kinds of problems that stimulate the scientist and the engineer differ only in the immediacy of the intended use of the desired solution: engineers seek solutions to problems that have immediate application while scientists seek solutions to problems that will increase an accumulated reservoir of facts and knowledge against the need, at some future time, of an immediate problem.

Thus it has become apparent that at least some of the decisions that affect the welfare of man fall into a category of decisions concerning the application of scientific knowledge. If this is technology,
then I would contend that today, and ever since the middle of the last century, technology has been, inevitably, bound up with the process of producing or creating that knowledge. That is, modern technology is an important aspect of science and it affects all people—often whether the people like it or not.

* * *

This discussion of science has led to the possibility of sorting out three distinctly different aspects of science that have had their effects on the lives of contemporary man—and thus, on students.

The first, because of historical priority, is the effect that the development of science has had on what we call truth and how we establish it to be truth. This effect is apparent in the skepticism that greets many statements based on faith; in the almost universal demand that "truth" in any field be supported by demonstrable evidence; in the supreme confidence that man has in being able to solve the problems that face him with the use of only his collective intellect, his ingenuity, and his experience. This effect has become such an integral part of our culture that to remark about it seems to belabor the obvious. Nevertheless the thought patterns and intellectual habits that are common today can be appreciated, in their potential and in their limitations, best by a consideration of the contributions made by the development of science during the last several centuries. Techniques are continually improving. And machines, such as the computer, have contributed new possibilities for thinking within the last generation. It would be foolish to contend that the change in potential in our thought processes has come solely as the result of the development of science. But to consider the contemporary intellectual mood and practice without taking clear note of the contributions of science would be far more foolish. Thus we have one aspect of science that is of great importance to a complete general education.

A second aspect of science that emerges from our discussion is the fabric of theories and principles that make up the theoretical framework of each of the individual sciences. Our ability to account for the experiences we have with the world of nature depends on our ability to fit those experiences into the framework of theory. The sophistication of the interlocking theoretical structures cannot be exaggerated. They represent one of the greatest achievements of mankind and as such are of great importance to a complete general education. It is these theoretical frameworks of assumptions, deductions, and verifying data that bring coherence to our many and varied experiences. The total of all such theoretical structures makes up the positive knowledge—only a part of which is known and understood by any single individual—that has accumulated through the efforts of many, many individuals. It is this structure of theories, data and current problems, together with the techniques and methods used to
solve those problems, that is usually referred to as “science.”

A third aspect of science that we must recognize from our discussion is technology. Although technology is often contrasted with science, as I have indicated, in the twentieth century the two are interrelated and interdependent to an extent that makes it difficult, if not impossible, to separate them. The conditions of our daily life are set by the level of technology that exists in our portion of civilization. It is impossible to over-estimate the importance of those technological conditions for our understanding, and solving satisfactorily, the problems we encounter. The technological conditions have evolved as decision after decision has been made concerning the exploitation of information that has become available. And, the fact that our environment has become intolerably polluted speaks to the manner in which decisions concerning the application of scientific knowledge have been made in the past. The critical degree of pollution now suggests most strongly that we give immediate attention to altering the manner of decision-making in the areas dealing with our environment. The range of decisions that concern the use or the application of scientific knowledge has grown, until these kinds of decisions are regarded as among the most important that face the human race.

To relate the problem of decision-making to science in a more direct way, let me digress for a moment to consider decision-making. Decisions that are rationally made seem to follow a pattern that goes something like this:

A decision is not necessary unless and until at least two alternative paths of action, or possible choices, present themselves. The rational consideration that precedes the decision consists of choosing, tentatively, one of the alternatives and then projecting the consequences of that choice into the future with as much accuracy as is possible. Then, keeping those consequences in mind, the other alternative is assumed and its consequences are predicted. If the consequences are the same, there is really no basis on which to choose and the decision becomes trivial as far as long-term consequences are concerned. If the consequences of the two alternatives are different, the choice will be made in favor of that set of consequences that are most desirable. Which set is most desirable can be determined only in terms of some previously set goal, or aim—or perhaps in terms of a hierarchy of values.

If this is a true picture of the decision-making process, the role of science is plain. The predictive capability of the scientific process is one of its most cherished characteristics and the development of this capability has provided all men who but choose to use it with the most reliable means of projecting the consequences of a particular
action or choice into the future—whether it is a short term projection or a long term one.

On the other hand, science, as I have described it, is not normative. It does not, and cannot, specify what should be the goals of mankind, or even of a particular individual. Thus ethical decisions are made, with the help of science, but in terms of a value hierarchy that precedes the application of science—or is at least independent of it.

If it is the case that questions concerning the proper application of scientific knowledge stand in the forefront of the critical problems faced by our own and by future generations, it becomes obvious, I think, that the actual decisions must be made in some other arena of human activity than the scientific arena.

Thus I conclude that three separate and distinct aspects of science are to be distinguished. But, what implications do they hold for a General Studies program?

I have characterized a major thrust of General Studies as lying in the direction of awakening and deepening individual awareness of the conditions affecting man’s welfare—individually and collectively. With respect to this goal, a General Studies program should find each of the three aspects of science that I have outlined to be of importance. It may seem improper to scientists, and to some outside of science, to label the three aspects “aspects of science,” because there is certainly an overlap in at least two of them from science into other areas of enquiry; the problems of epistemology that are contained in the first aspect are as much a part of the humanities and social science as they are a part of science; the characteristics of critical thinking are as indispensable to any one of the areas as they are to the other two. Whether or not it is proper to say that the development of such techniques was the result of the growth of science, it is certainly true that the growth of science and the growth of analytic thought paralleled one another. If we are willing to view science as the conscious segregation of that portion of experience, out of all possible experience, which responds to analytical thought, and is supported by demonstrable evidence, then we would find the development of critical thinking to be a result of scientific development.

In the same vein, the problems of decision-making and value judging that are involved with technology are important to the humanities and social science as much as to science. In fact, as I have tried to show, there is an input to making decisions that must come from some activity outside of science. The consequences of past decisions concerning the technical use of scientific information have obviously become of great concern to social scientists in the last few years. These concerns are balanced by the realization that many present technological problems would not have become problems, had it not
been for the scientific knowledge that was continuously supplied by scientists without concern for its application. On the other hand it must be realized equally that any hope of the current problems being solved, or at least minimized, depends upon present scientific understanding and knowledge, and the creation of additional such knowledge by the current efforts of scientists. Thus, the problems of technology find their origin and, in a real sense, the possibility of their solution, in science.

The ramifications of the above analysis can be summarized in two points: 1) there are three aspects of science, taken in the general way that I have defined it, that are important to a complete general education and that should be included in a General Studies program if its objectives are to be achieved; and 2) it seems possible that the objectives of a General Studies program might not be served best by the arbitrary division of courses into humanities, social science and science; to require that every course offered in a General Studies program fit the characterization of either a humanities course, a social science course or a natural science course may be so restrictive that legitimate concerns of General Studies cannot be satisfied.

A course designed to treat either the first or third aspect of science that I have developed here could not do so, adequately, if it were confined to the resources, viewpoints, and techniques of the natural sciences; perhaps these courses should be called simply “General Studies courses” without classifying them according to area. A designation of this sort would enable a General Studies program to respond flexibly to stresses in our society, which become abiding concerns of the students as they arrive at and leave our university. These stresses, like the current problems of pollution of our environment, cut across departmental lines and even cut across area lines as they now exist in most General Studies programs.

* * * *

Finally I come to a proposal that I would like to present. It is a proposal for three requirements, which coincide with the three aspects of science I have developed this evening, that might replace the present science portion of a General Studies program.

For example, the present requirements in the science area at Western Michigan University are at the Freshman-Sophomore level. Each student must select two courses from the following list:

<table>
<thead>
<tr>
<th>Course</th>
<th>Hours</th>
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<tbody>
<tr>
<td>105 Physical Geography or 112 Geological Science</td>
<td>4 semester hours</td>
</tr>
<tr>
<td>107 Biological Science</td>
<td>4 semester hours</td>
</tr>
<tr>
<td>108 Physical Science</td>
<td>4 semester hours</td>
</tr>
<tr>
<td>110 Aims and Achievements of Science</td>
<td>4 semester hours</td>
</tr>
</tbody>
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The instructors for the first four courses listed are drawn from the different science departments in the College of Arts and Sciences. The
instructors for the last course, Aims and Achievements of Science, are generally drawn from the General Studies Science Area staff.

Instead of that present requirement, I would propose the following three requirements:

REQUIREMENT I:

A **General Studies Course**

3 semester hours

Required of all freshmen: The subject matter to be the techniques of critical thinking, analysis, problem solving, use of data, techniques aiding reason such as the computer, use of statistics. Material for study would be selected from natural science, social science and the humanities. A course designed to make clear the nature of scientific “truth” and the criteria necessary to establish it.

This requirement is outlined to parallel generally the first aspect that I have described for you. It would take a place in the Freshman year with courses that concentrate on aiding students to become aware of their personal identity and their role in the social, political, and aesthetic worlds. It would provide a balance to the natural drive on the part of students to become personally involved and committed to a variety of activities.

This course would seek to show the value of disengaging oneself from activity, occasionally, for the purposes of making critical judgments and evaluations.

REQUIREMENT II:

A **Science Area Course**

4 semester hours

A single selection of one course from the following:

- 105 Physical Geography
- 107 Biological Science
- 108 Physical Science
- 112 Geological Science

A point to be stressed in each course to be the manner in which the subject matter covered provides an explanatory structure for personal experience in that segment of man's total experience.

This requirement parallels the second aspect of science that I have described. It is the body of explanatory principles and the facts that support them that constitute the various scientific disciplines. It continues the course structure that is now in existence with a minor change in emphasis that should represent little alteration in the present formats of those courses.

REQUIREMENT III:

A **General Studies Course**

3 semester hours

A course concerned with the application of scientific knowledge.
Problems of the physical and biological environment would be raised in order to study how they came to be problems and to study the technical solutions that are possible. The manner in which decisions concerning these problems have been made and might be made in the future will be considered. Political and social factors affecting such decisions will be studied.

This course parallels the third aspect of science, technology, that I have described. It is intended that the course go beyond establishing that there are problems with our environment; the difficulties involved with providing satisfactory solutions will be examined and attention will be focused on possible lines of action that can be adopted individually and as groups in our society and by society as a whole. The problems that we, and the rest of our society, face in this area are so critical that we must begin to pay attention to them in our General Studies program. If we do not, I have serious doubts about calling the program a "general" one.

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These three requirements constitute my proposal for modifying one particular General Studies Science program. The rationale for them is the argument that I have presented that there are three distinct and separate aspects of science that are of importance to an adequate general education and therefore to a General Studies program. I hope my argument has stimulated some thought and some concern for the constant necessity for considering improvements in existing programs.

When any program reaches a stage in its history where no improvements are conceivable, that program has long ceased to be responsive to the needs of those it serves. The needs of people are continually changing. And, their changing needs demand responsible modifications in programs designed for their benefit.