Journal of the Minnesota Academy of Science

Volume 30 | Number 1 Article 22

1962

The Role of Natural Science Courses in Liberal Education

Karl D. Fezer
University of Minnesota

Recommended Citation

Fezer, K. D. (1962). The Role of Natural Science Courses in Liberal Education. *Journal of the Minnesota Academy of Science, Vol. 30 No.1*, 97-99.
Retrieved from https://digitalcommons.morris.umn.edu/jmas/vol30/iss1/22

STAKMAN, ELVIN C. 1959. Trends and Needs in Agricultural Education and Research. *Proc. Amer. Assoc. Land-Grant Colleges and State Universities.* 72:61–75.

STAKMAN, ELVIN C. 1960. *The Evolution of Concepts and Practices in Education. I. The Ancient, Classical, and Medieval eras. III. The Renaissance and its Results. III. Modern Education-Attempts at Synthesis of Past Experiences.* (Lectures on education delivered in Mexico).

STODDARD, GEORGE D. 1961. *The Arts and Sciences in the Land-Grant Colleges and State Universities — A critical Appraisal.* (Lecture, Centennial Convocation, American Association of Land-Grant Colleges and State Universities, Kansas City, Mo. 1961).

TRUE, ALFRED C. 1929. *A History of Agricultural Education in the United States.* Washington, United States Department of Agriculture. Miscellaneous publication No. 36.

TRUE, ALFRED C. 1937. *A History of Agricultural Experimentation and Research in the United States.* Washington, United States Department of Agriculture. Miscellaneous publication No. 251.

WORKS, GEORGE A. AND BARTON NORGAN. 1939. *The Land-Grant Colleges.* Washington, United States Government Printing Office.

SCIENCE AND EDUCATION

The Role of Natural Science Courses in Liberal Education

KARL D. FEZER
University of Minnesota, Morris

I.

The purpose of courses in natural science traditionally has been to convey the conclusions of science to the student. Recent proposals, such as the Laboratory Block Program (Glass 1961a, 1961b, Grobman 1961), stress the idea that students should experience science as a process for acquiring knowledge. The thesis of this paper is that the scientific process, and especially the attitudes and concepts that characterize it, are relevant to all human problems that can be considered rationally, even those outside the domains of established scientific disciplines. Critical thinking is part of the scientific process, and courses in the natural sciences, by virtue of the perceptual foundation and ready availability of their subject matter, are at least as well suited for teaching critical thinking as are courses in any other discipline. Science courses have an excellent opportunity, not only to enable students to experience the scientific process, but also to help them see its relevance to everyday life. Therefore, science teachers should help their students develop an automatic scientific response to problems in general.

A list of the components of a scientific response to problems might include the assumptions, attitudes, habits of thought, and concepts mentioned in the paragraphs that follow:

Nearly all science assumes an orderly, law-abiding universe progressing through time. Knowledge of such a universe will aid in the prediction, and possibly control, of events. Although absolute knowledge is not attainable (Royce 1959), useful or interesting tentative knowledge is attainable, and the scientific process has been remarkably successful in producing tentative knowledge, *i.e.*, adequately credible beliefs.

The mental processes involved in a scientific response to problems include the accumulation, synthesis, and analysis of ideas. The scientific "method" is sometimes represented as consisting of these three processes in sequence. Actually, the synthesis of ideas may involve very little "method," and the same is often true for accumulation. Furthermore, the three processes mentioned may be carried on in haphazard sequence or almost concurrently. They may be carried on at various levels; ideas that are accumulated, synthesized, or analyzed may relate to the primary problems being studied or to some subsidiary technique that is useful in the analysis of the primary hypothesis. It should be noted, too, that a process is not scientific merely because it involves the accumulation, synthesis, and analysis of ideas. Rather, it is the manner in which these processes are carried out that is important.

To be scientific, the *accumulation of ideas* should be objective, open-minded, free of prejudice. This requires recognition of the ease with which bias can color human perception. Furthermore, to obtain sufficient ideas for an adequate synthesis, the accumulation must, at least to a degree, be voracious. This implies minds hungry for ideas, minds that know the joy of learning.

The *synthesis of new ideas* is the creative aspect of science. This is the "inductive leap." It may appear as an inescapable generalization from newly observed facts, or as an intuition or hunch, or as sudden enlightenment. The "brainstorming" sessions used in business and elsewhere attempt to create the uninhibited atmosphere that promotes such innovation. Some of the great syntheses of science are claimed to have come about during sleep. The greatest discoveries usually involve the greatest deviations from accepted patterns of thought. This is not inconsistent with the fact that the odds on making a valid discovery also depend on the degree of insight and judgment of the would-be discoverer.

It may be difficult to induce in students (or in oneself!) that combination of creativity and judgment that results in successful scientific synthesis. It should be less difficult to teach some concepts that find wide use in scientific explanation. The concept that the universe is mechanistic and deterministic, that every effect has its causes, is basic to most science. The concept of a non-teleological universe helps scientists avoid explanations that fail to explain, that mislead, and that obscure the operation of natural mechanisms. The concept that natural phenomena can be studied at different levels of organization is most easily illustrated in biology. The description of *what* happens at one level may help explain *how* or *for what reason* something happens at a higher or lower level (Simpson, 1962). Understanding phenomena requires that they be studied at as many different levels as possible, and that the analyses for the different levels remain clearly distinguished. This is important in the definition of terms and in the formulation of hypotheses. Scientists quickly acquire the concept that most effects result from the operation of many factors, and also that quantitative consideration of these factors contributes to better understanding of their roles. When multiple factors act jointly, they may do so in a non-additive manner, as in synergism, dominance, epistasis, and all other kinds of interaction. All these considerations serve to dramatize the fantastic complexity of most natural phenomena. This complexity limits man's ability to control, to predict, or even to understand events and it forces him to resort to the concept of probability. Experimental evidence provides enough information concerning some phenomena, so that the probability of the occurrence of certain events can be known precisely; this makes prediction possible, though at a level less specific than the prediction of specific events. Commonly much less evidence is available, and the concept of probability is also used to quantify an individual's estimate of likely outcome or proper explanation, based on his judgment of the importance and functioning of various factors.

The *analysis of ideas* consists of logically deducing their consequences and then critically evaluating these deductions, preferably by means of experiments. An awareness of the concept of confounding permeates scientific analysis. "Confounding" is here used in its broad sense – *i.e.*, the mingling of elements or factors so that they or their effects cannot be distinguished – not in its limited statistical sense. The mere existence of alternative explanations implies confounding in the broad sense. The concept of bias and the related distinction between precision and accuracy are based on the concept of confounding. The occurrence of uncontrolled variability represents confounding, and scientists must consequently consider questions of sample size and replication and must express their conclusions in probabilistic terms. Confusion of analyses at different levels of organization can also lead to confounding (Grobstein 1962). The concept that falsifiability, rather than verifiability, is the critical attribute of an hypothesis that is capable of being objectively evaluated should be strictly applied only to certain classes of hypotheses. For other kinds of hypotheses, verifiability is a more appropriate criterion. In a broader sense, however, the concept applies to the statement and testing of all hypotheses, because it implicitly stresses that the analyst of an hypothesis must have a real opportunity to reject it. Criteria for the rejection of an hypothesis should be established before it is tested. Another important concept is the distinction between laws and theories, which neatly emphasizes how great a body of evidence is required before an idea can achieve ultimate acceptance in science. The modification of laws illustrates the tentative nature of even the most ultimate acceptance that science can give its findings.

While the criteria for ultimate acceptance of an idea in science are exceedingly stringent, scientists often tentatively accept ideas that seem sensible to them, even on the basis of very limited evidence. Scientists and non-scientists alike believe many things, and the strength with which each belief is held is reflected by the amount of evidence that would be necessary to bring about a reversal in belief. Every man probably believes some things for no adequate reason. With regard to matters requiring decisions, however, men must adopt beliefs, no matter how scanty the information on which beliefs can be based. An example is the physician who, failing to arrive at a definite diagnosis, must nevertheless tell his patient what to do, even if it is merely to wait and see what happens. This concept applies equally to the scientist whose approach to a new problem may have to be based on very inadequately founded beliefs concerning the most promising line of investigation. In science, such beliefs are called "working hypotheses." If men would synonymize this term with "beliefs," they might, without immediately altering their beliefs, be more open to modifying them in the light of further evidence. If absolute knowledge is indeed not attainable, then all human knowledge really consists of beliefs that should be regarded as working hypotheses. This, incidentally, does not exclude the possibility of religious commitment to certain beliefs for as long as those beliefs are held. In general, the adoption of objectively unsubstantiated or unsubstantiable beliefs regarding specific issues should be determined (and is to a considerable extent) by man's need for such beliefs as a guide to his physical and mental behavior.

II.

In the opinion of one biologist, the attitudes and ideas mentioned above are equally relevant to problems of cellular metabolism, juvenile delinquency, or war and peace. Opinions as to what science is and what habits of thought might be transferable from the traditional subject matter of science to the solution of human problems in general will vary, of course, with the individual teacher's field, experience, and philosophy of life. In the light of modern physics, for example, a physicist might question the universal applicability of determinism, or he might wish to stress principles other than those listed. Others might object to complete determinism on the basis of religious faith or social philosophy. A philosopher might question falsifiability as a criterion for evaluating hypotheses. But this does not mean that a teacher should exclude from his courses the opinions he holds concerning the general social applicability of habits of thought cultivated by practice of his discipline. On the contrary, it means that all teachers should include such thoughts in their courses. Of course, they should also attempt to do justice to opposing points of view, and to indicate the degree of acceptance accorded their own beliefs. Students would then be exposed to a wide range of beliefs and attitudes relevant to the important issues of life, and those on which faculty consensus is greatest would be reinforced. Besides providing students with a better basis for reaching their own conclusions, such evidence of faculty concern with the issues of life might awaken the interest of otherwise apathetic students (and citizens) in these issues.

Some of the developments in the social sciences illustrate the potential of the scientific process when applied to problems outside the traditional domain of natural science. One striking example of the widening application of the scientific process is the gradually changing response of the United States to one of the world's greatest problems, the armaments race. There has been considerable activity with regard to the scientific and technical aspects of disarmament. Even more significantly, the study of political and economic aspects of disarmament seems gradually to be acquiring more of the attributes of the scientific process (Lear 1960). In the United States today many groups and individuals, in and out of government, are engaged in an imaginative search for ways of dealing with the arms race, and it is not surprising to find scientists, especially physicists, in the forefront of this search. Proposals ranging from those favoring "pre-emptive" war to those advocating unilateral disarmament and non-violent resistance are being considered. Unrealistically simplistic solutions are being recognized for what they are; instead, a multiplicity of factors is being considered quantitatively. There is a growing recognition that all possible policies must be considered in probabilistic terms, because all involve risks. Attempts are being made to increase the likelihood of a negotiated agreement by determining not only what kinds of disarmament schemes might be acceptable to the United States, but also what kinds might be acceptable to the Soviet Union (Blackett 1962). Wright (1961) goes a step further and advocates the establishment of scientific research institutes devoted to solving problems of disarmament. His example of the kind of problem that such an institute might study is illuminating: how to prevent secret nuclear rearmament and surprise nuclear attack by means of inspection by natives of the country being inspected. This idea seems ridiculous at first and may indeed be unworkable. But Wright proceeds to make a good enough case for the idea to convince the writer that it should be studied further. There may be overwhelming objections to such a proposal, but the scientific response to such a proposal, if it offers any hope of being workable, is to attempt to find ways of overcoming the objections.

III.

In conclusion, it would benefit mankind if the attitudes and concepts presented in this paper as characterizing the scientific process — give or take some from the list — became part of people's way of life. The science teacher, therefore, should consider it his task to both point out the relevance of these ideas to life in general and to provide his students with experiences that will increase the likelihood of their incorporating them into their lives. Descriptions of Utopia often serve as vehicles for the statement of social goals. In the writer's Utopia there would be no shortage of problems. However, most citizens of this Utopia would have adopted the ideas and attitudes discussed above. There would be differences of political opinion, and political parties to match. But these parties would not represent dyed-in-the-wool radicals or conservatives. They would, instead, represent groups of individuals who, after weighing the probabilities and applying their judgment, decided to commit themselves to some working hypothesis, until faced by sufficient contradictory evidence to warrant a change of commitment. Such a society would not be overly fond of the *status quo*, but neither would it be overly eager to overthrow it. It would recognize both the achievements of the past and the opportunities for progress. And to achieve progress, it would be deliberately experimental; it would encourage political, economic, and social experimentation. A challenge to liberal education, and to science courses contributing to it, is to help individuals and society to move in this direction.

LITERATURE CITED

BLACKETT, P. M. S. 1962. Steps Toward Disarmament. *Scientific American* 206(4):45–53.

GLASS, BENTLEY. 1961a. The Laboratory 'Block' Program (BSCS). *Minn. Jour. Sci.* 5(2):6–11.

GLASS, BENTLEY. 1961b. A New High School Biology Program. *Amer. Scientist* 49(4):524–531.

GROBMAN, A. B. 1961. The BSCS: a Challenge to the Colleges. *AIBS (Amer. Inst. Biol. Sci.) Bul.* 11(6): 17–20.

GROBSTEIN, CLIFFORD. 1962. Levels and Ontogeny. *Amer. Scientist* 50(1):46–58.

LEAR, JOHN, *ed.* 1960. Peace: Science's Next Great Exploration. *Saturday Review,* December 10, 1960, pp. 51–60.

ROYCE, J. R. 1959. The Search for Meaning. *Amer. Scientist* 47(4):515–535.

SIMPSON, G. G. 1962. The Status of the Study of Organisms. *Amer. Scientist* 50(1):36–45.

WRIGHT, R. H. 1961. Peace Research. *Chemistry in Canada,* July 1961.