

The Correlation of Growth in Scientific Methodology With Elementary Science Programs

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A subtitle for this paper probably should be "A Proposal of Criteria for the Selection of Subject-matter for Science Courses to Provide Orderly Growth in Control of Scientific Methodology;" this title is much more descriptive of what is to be presented in the paper, but it is much too long to be used as a title. The paper is properly regarded as a report of a line of development which I have been following for some months, following my acquaintance with an unusually provocative paper dealing with the nature of science and its meanings for liberal education, and is therefore not to be regarded as an attempt at a thoroughgoing analysis and systematization of the area which it treats.

It has long since become commonplace to insist that one of the chief aims of science education at any level short of specialized technical training is that of the development of and practice in the scientific method, with scientific method in this sense referring more or less to the empirical characteristics of scientific methodology. In this form, the aim above may be found in almost every list of aims or objectives of science education in grades one through fourteen.

For almost as long as the aim of development of an understanding and control of scientific method has been in evidence among the lists of objectives proposed for science courses, there has been sharp criticism of the obvious over-simplification involved in the statement of the aim in terms of the implied single, simple "scientific method." It has been pointed out frequently that there is no such thing as a "scientific method"; that there is at least a number of methods of science, that in many cases the so-called method of science represents only an idealization from the mass of activities which went on during the work leading up to a particular discovery, and so on. This dissatisfaction with the idea of scientific method as any part of an objective for science education programs has been the source of considerable unwillingness to attempt the development of scientific method as a part of such programs, whose directors therefore fall back into the rather simpler transmission of facts from the field of science.

The effects of the difficulty of establishment of growth in the control and understanding of scientific method as a science course aim is particularly visible when one examines the content and approach of the science courses proposed and used in the elementary and secondary schools, though in many cases, the elementary college courses are as unsatisfactory in this respect as are the lower schools. Particularly the elementary laboratory activities in these courses are often unscientific, if not antiscientific, as for example, in the reporting of oxygen as colorless, odorless and tasteless from an observation of it as it is delivered from the reaction involving potassium chlorate and manganese dioxide, where it is obviously sharp of odor and taste and smoky in appearance; or in the adjustment of the data in a Boyle's Law demonstration until the product of pressure and volume is a constant, in spite of the clear observation that in terms of the apparatus at hand, the product is not a constant. In the lower schools this particular difficulty appears as the reliance upon pictures and text to transmit scientific content, a process which, on closer examination, turns out to be the establishment of the textbook or the teacher, or both, as the primary authority in the field of science. Even for less sensitive teachers, such a travesty of science frequently becomes intolerable, and the turn back to scientific method as a desirable characteristic of all science education appears.

A most provocative and promising approach to the problem of accurate and pedagogically effective establishment of scientific method in science courses has recently been proposed by Professor J. J. Schwab, of the University of Chicago, in a paper entitled *The Nature of Scientific Knowledge as Related to Liberal Education*, which appeared in the July 1949 issue of *The Journal of General Education*. In this paper, Professor Schwab proposes what he calls a "prefatory taxonomy" of scientific inquiries, which he bases upon an examination of the reports of researches as published in their original forms. He finds four relatively clearly identifiable species of scientific inquiries, in terms of their method, which are as follows:

First, taxonomic science, which seeks to establish a classificatory schematism as its form of scientific knowledge. "Its first, raw data are all the members of the objectively delimited universe to which it addresses itself and all the properties of these members which can be discerned. Its method, in theoretic ideal, consists of determining (by 'induction') the one or several 'essential' properties from among the indefinite number presented by the members of the universe. These essential properties then define a set of classes among which each member of the universe will find a place and only one place." Professor Schwab continues, to note that the conditions for this theoretical ideal do not exist, and that there are therefore in actual practical situations substitutes for the ideal characteristics noted above, so that in practice one finds instead of the theoretical ideal, a "practical taxonomic schematism, (which) is verified to the extent that its results are effective tools for the problems in which the classified universe is involved and the degree to which the properties of exhaustiveness and exclusiveness are reached within the system."

Second, measurement science, which has as its aim "the measurement and consequent co-relating of changes in two or more varying, and presumably objective, quantities. . . . This is the kind of science whose fruits are most commonly the referent of the term 'scientific law.'" It will readily be seen that in this schematism, "measurement science" includes "taxonomic science", for without the preceding taxonomic activity there will not be data of sufficient objectivity and sufficient specificity of description to permit their measurement.

Third, causal science, which "is found wherever some system of mutually interacting and mutually determined parts acts as a concerted whole". Mr. Schwab goes to some lengths in his paper to delimit the idea of causal science, finally reaching the definition above, by reassigning to measurement science or to taxonomic science most of those kinds of science which are most frequently called causal science, such as "the (location of) 'the material substratum coexistent with a given bundle of other properties'; the location of the 'invariable antecedent event'; 'a concluding or climactic stage in a process'; or a combination of these. " 'Causal' research, then", in Mr. Schwab's prefatory taxonomy, "upon a subject matter which is a complex of interacting and mutually determined parts constitutes a kind of science with its own problems of procedure and interpretation, differing widely from other patterns of inquiry."

Fourth, relational (analogical) science, which aims "toward knowledge which attempts to 'explain' or 'account for' matters previously known by inventing co-related quantities which do not have one-to-one literal correlation among the phenomena to be accounted for, or by inventing mechanisms not directly accessible to observation but so conceived and applied to the phenomena to be explained that it can be said that certain things behave as if these mechanisms existed." This is the kind of science which results in atom models, the gene theory of inheritance, etc. It will be noted that the type of science described here is one which includes the earlier types identified, for it requires effective taxonomic science, the results of

measurement science, and the total operation of whatever system or model is proposed, as in causal science.

Since each of these four species of scientific inquiry, classified in terms of method, includes those which preceded it, the types of inquiry may be visualized as constituting a hierarchy of scientific methods, in which the lowest position is held by taxonomic science, and the highest is held by relational or analogical science.

It is the proposal of this paper that these four "kinds" of scientific inquiry provide a workable scheme for the development of scientific method in science courses at various childrens' developmental levels, through their use as levels in the growth of control and understanding of scientific methodology. In such a scheme, one would begin young children in taxonomic science, and carry them through measurement science and causal science to relational or analogical science, consciously and deliberately choosing materials and planning curricular experiences to permit learners to develop these skills themselves. Much of the research which has been thought to be necessary to the development of such a program can perhaps be rendered unnecessary through use of the results of the extensive researches already carried out in areas of learning which use the lower levels in this hierarchy—taxonomic and measurement science—in the fields of elementary language studies and elementary arithmetic. Such an approach would determine the levels at which certain levels of reading skills are developed, and then assign to those levels appropriate experiences in taxonomic science. Similarly, an examination of learning in the arithmetic curriculum would provide the basis for the selection and location of learning experiences in measurement science, and so on.

Taxonomic science in its simplest form, the assignment of names to groups of experiences, is basically the refinement and formalization of the early language development of the child. Science which is primarily taxonomic can therefore be correlated directly with the early reading and speaking development of the school child. Such science may be carried steadily forward with other school subjects, as well as in science courses themselves, into the highschool years in some science areas.

Measurement science, with its emphasis on direct relationships, can well be correlated with the corresponding measurement activities in arithmetic, beginning with the earliest use of measurement systems in any context. The use of the lengths of lever arms to predict loads to be carried by lever systems is an example of the kind of science to be developed at these intermediate levels. As was pointed out earlier, the decision to provide experiences for young children in "measurement science" will carry with it necessarily the decision to provide also opportunities in "taxonomic science"; the one includes the other.

Causal science, in such a developmental hierarchy, would first make its appearance toward the later elementary school years—the seventh and eighth grades—where there has been some success already achieved in teaching the complex relationships which render intelligible the observable geographical distribution of peoples and industries, and where the health education programs have located such curricular items as the human endocrine system, the human nervous system, etc.

Relational or analogical science would wait for its introduction until the high school science courses—where one would undertake such things as the atom models, the gene theory, engines, etc. Again, since these taxonomic categories are to be regarded as a series of successively inclusive categories, each one including those lower in the hierarchy than itself, it will be necessary in planning for student growth in relational science to provide for growth in causal, measurement and taxonomic science as well.

Another derivative of this "prefatory taxonomy" of scientific inquiries is its suggestion of proper order for development of new content areas, particularly if the young people involved in the program have not had much experience in science areas, which is the usual case in elementary science in high schools and colleges. This suggestion is that student development in a given scientific field should move from taxonomic science, through measurement science and causal science to relational science.

It should be noted that the scheme here presented merely provides another set of criteria by which to choose content for science-area units of work in school programs. The other usual criteria such as pupil interest, etc, remain unchanged. However, the Schwab taxonomy of scientific inquiries provides at least one way by which one can choose course content to provide orderly curricular growth in scientific method as well as in complexity of generalization, extensiveness of prediction, language skill, arithmetical skills, health skills and attitudes, etc, at all levels of pre-specialization science.
