

THE GENERAL SCIENCE OF THE FUTURE.¹

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The future of general science can only be written in terms of present and immediately past tendencies. If these prove unreliable there is no other guiding principle. General science in the past has evidenced three stages of growth. The first courses and texts were of the encyclopedic or hodge-podge variety; seemingly little more than an assemblage of condensed texts of a half dozen special sciences, and of doubtful value from the standpoint of arrangement of materials, but, at the same time, excellent handbooks for beginning students. This sort of teaching was super-saturated and committed to the false doctrine that the differences between ninth grade pupils and college students were purely quantitative in that a process of condensation and elimination of a few difficult topics would produce suitable high school courses from existing college texts.

The second chapter in the evolution of the general science course was the formulation of what might be called "unity" courses. This was a reaction to the charge of soft pedagogy and is characterized by the efforts to secure unity by building in the diverse materials about some one special science as a matrix. Some schools and most textbooks of general science at the present time show such biases toward physiology, physics, agriculture, etc., as the case may be. Perhaps this type of course was most prevalent up to the year 1918, and is by no means completely eliminated at the present time.

The last stage in this development is not so easily given a suggestive name. Perhaps, the term "Environmental Problem Courses" is most satisfactory. This type of course has definitely thrown all logical organization to the winds and is attempting to substitute a series of problems or projects bearing directly upon the school, home, and community life, from the standpoint of practical applications rather than "fundamental principles." This is the most comprehensive attempt in the history of science teaching to make the principles of science subservient to and somewhat incidental to the applications of these generalizations. Moreover, this practice has forced a complete reversal of the order of presentation of materials and by very nature of the situation *has made inductive teaching an enforced reality*. If general science has done nothing more it has made a very considerable contribution to the advancement of inductive methods in

¹An abstract of a paper read before the Science and Mathematics Section of the Oregon State Teachers Association, Dec. 31, 1919.

the classroom. This point leads at once to the central theme of this paper—viz., *the future of general science is very largely a question of its ability to devise a suitable method.* The question of content, although not to be neglected, is of minor importance since general science cannot hope to present much content that is new, quite on the contrary much that is valuable must be omitted, but what might be done is that such content could be organized and presented in a more suitable form from the standpoint of pedagogical requirements. It is not at the door of the factual aspect of science materials that the blame for present unsatisfactory conditions must be laid, for to do so would practically be a denial of the educational values of science teaching, but, the practice of introducing eighth and ninth grade children to a technical, formal, analytical, brass-plated, electrically controlled, agate-bearinged sort of science must be deplored. It has too often come to be a case of the child losing sight of the forest for the trees. These things are the conveniences of science, not the realities. They are the man-made aspects of science. They serve to confuse, not to educate, and they often forget completely the main thing in the whole scheme of education—the mind of the child. Technique, valuable as a means, must not be substituted in educational beginnings for psychological organizations more in harmony with actual mental processes in the pupil.

This brief critical discussion opens the way to the more constructive suggestions of the future.

THE CHARACTERISTICS OF THE GENERAL SCIENCE OF TOMORROW.

If the tendencies of the present and immediate past are to be relied upon to continue, the general science of the future will be pretty sure to involve a method whose broad outlines will be characterized by widespread use of certain principles, which can here be grouped as five in number.

1. Wider use of the inductive method with the added possibility that the laboratory approach to all topics will be religiously adhered to.
2. The selection of immediate environmental problems will be the chief criterion in the determination of the content of such courses.
3. The general science course will probably be pushed back into the junior high school grades and may in cases be expanded to cover two or even three years about grades 7-9 inclusive; thus articulating with the nature study of the grades and the purer science of the higher years.
4. The general science of tomorrow will probably be problem or project science to a large extent.
5. The results obtained in general science teaching will be subjected to measurements by the use of standardized tests similar to those used in elementary school practice.

DISCUSSION.

All of the foregoing principles are already present in some degree in the teaching of general science, although usually not all in any one school, some specializing in one, others in another. The task is to assemble these tools into a consistent method and a few suggestions as to how this is to be done will be taken up in order.

I. INDUCTIVE, LABORATORY METHOD.

This has long been the ideal in all science. Practically everyone is agreed upon the superiority of such over pure text book or pure lecture methods, although, rather curiously, such a superiority has never actually been proved. Apart from F. C. Ayer's² study of the psychology of drawing with special reference to laboratory drawing and Edward J. Maynard's³ comparative study of the relative efficiency of the book, lecture, and combination lecture—demonstration method, little experimental evidence exists. So even the laboratory method rests chiefly upon consensus of opinion. However, the fact that no absolute experimental justification of this method has ever been made is probably not to be seriously considered as casting doubt upon the superiority of inductive laboratory practice, rather, showing a curious anomaly in that science has never thought to apply its own ideas of procedure to its own internal problems.

Granting the superiority of the inductive laboratory method, there remains a practical situation to be considered, namely, that in spite of the fact that it has generally been assumed that this method is in widespread use, it is very doubtful whether true inductive laboratory teaching has ever prevailed to any considerable extent. Doubtless most of you will take issue with this bold assertion, but the actual conditions obtaining in the vast majority of schools are such as to place the most serious limitations upon any very extended use of this ideal of method. Leaving aside the very open question as to whether inductive thinking is psychologically possible over any sustained period as a question for pure psychology to answer when it may be able, there are certain purely mechanical difficulties in the administration of most of our schools which effectually block our efforts at inductive teaching. In the high schools of this state, with very few exceptions, the laboratory periods are fixed at certain

²Ayer, F. C.: *The Psychology of Drawing with Special Reference to Laboratory Practice*, 19, Warwick and York.

³Maynard, Edward J.: *Teaching Elementary Science in Elementary Schools*, Pub. 13, Div. of Reference and Research, N. Y. City Schools.

days of the week for reasons connected with the scheduling of the school program. This practically severs any close connection between the work of the classroom and that of the laboratory. Of course the text work can, in general, precede or follow the experimental exercises of the laboratory at the option of the teacher, but it is decidedly doubtful whether any teacher can ever give a truly organic connection between the two elements of instruction in opposition to this administrative handicap. Nor is this point a petty criticism, for the very nature of the inductive-laboratory method demands that *all* laboratory work on a given topic *must precede* the textbook work. As conditions exist, the best we can do is to develop our recitation work as nearly inductively as possible, while at the same time we are throwing away the best aid to inductive teaching—the laboratory—and falling back upon the much inferior plan of using the laboratory for proving the truth of the principles presented in the class recitation proper. This type of teaching is in reality nothing more than the time-honored plan of the laboratory as a place to test the truths handed out in the classroom—a method which is the exact reverse of that demanded by induction.

The difficulty here is so purely mechanical in the great majority of cases that no adequate excuse can be given for the continuation of a program which sacrifices a good method for administrative reasons. The teacher must be free to decide which days are to be utilized in the laboratory and which in the recitation room. At times, it is desirable that for weeks no textbook should be opened at all and that the entire period be spent in the development of a topic by experimentation in the laboratory. Probably, almost without exception, *laboratory work must precede textbook work in general science*. This means that the plan of double periods for laboratory work must give way to equal periods of somewhat longer length—a demand that is quite in harmony with modern administrative tendencies in that this very thing is coming as a result of the induction of supervised study which, in itself, calls for longer class periods. The advantage of this has been emphasized here and should be utilized by teachers of science as a way out of one serious difficulty.

But there is a second obstacle to be overcome that is more serious. The first was purely mechanical; the second, largely pedagogical... To teach inductively, the textbooks must be inductive in spirit and construction. As far as I am aware very

few textbooks in secondary school science can be fairly called inductive. Some teachers are succeeding in spite of the texts. We hope a good many are. What the facts are cannot be determined. It is a hopeful sign that textbooks are appearing which do develop the subject matter by a procedure working from a mass of applications of a familiar sort to the fundamental principles underlying. This method is rigidly demanded by true induction—not the reverse as characterizes the procedure of most of our texts. Recent books like VanBuskirk and Smith, Hodgdon and Trafton, to confine the discussion to general science alone, are making considerable strides in the right direction. From a nucleus like these, the future is very hopeful, even if these beginnings are still crude and unpolished. These books and a few others of their type lead one to think that there is probably more thought being devoted today to the writing of suitable textbooks from a psychological standpoint, in the field of general science, than in that of any other single science subject. Analysis of a half dozen recent texts has really made me optimistic for the future.

In the University high school, at Eugene, we have made some beginnings in the way of inductive teaching. We have adopted the plan of five equal periods per week with laboratory days falling at the will of the teacher. The subject matter has been organized as a series of fifteen problem topics, each of which involves from three to ten laboratory experiments. All of the last precede any textbook work—and no exceptions are allowed. In this way the first difficulty mentioned above has been completely obviated. The second handicap to inductive teaching has also been overcome in part since the course of study does not follow any particular text and hence there is greater freedom of method allowed. The fifteen units follow each other for the most part in related order, although each is an organic unit. The separate experiments are designed so that each contributes one bit of data to the solution of the general problem topic. The textbook work is merely that of supplementing the knowledge gained by actual experimentation and takes the nature of reading rather than study although some time is spent in recitations proper. The readings are in part assigned and in part unassigned. The former are checked up by class recitation, the latter by written abstracts handed in, a minimum limit of ten pages per week being observed. In such a course, the textbook may be highly influential in the success of the work, but it is scarcely a vital element.

II. IMMEDIATE, ENVIRONMENTAL PROBLEMS.

The second characteristic of the general science of the future grows out of the discussion of the preceding one. It is partly a criterion for the selection of subject matter of useful nature and partly a question of suitable method. It is only for the sake of emphasis that it needs further mention. The texts I have just cited illustrate something of what we mean by choosing materials which are correlated with the immediate surroundings and interests of the child. Admittedly far from perfect, each year has brought us nearer to the ideal. Caldwell and Eikenberry were the first to grasp the idea of environmental problems in contrast with formal laws and principles as the point of departure in the study of science. Later came Smith and Jewett, Van Buskirk and Smith, Hodgson, and last, Trafton, an advance copy of which I have brought here today for examination. There is nothing new in the method of these books—it is rather a question of a more extended use of a recognized pedagogical fact, viz., that everyday applications of scientific laws form better starting points than purely hypothetical applications of those same laws. The mystery is here the same as in other points that I have discussed, i. e., when everyone is agreed upon a thing, and we heatedly advocate it at every opportunity, *why don't we do it ? ? ? ?* Instead, we go ahead writing our books as we have always done. It looks suspiciously like the kiss of Judas and that we lack the courage of our convictions. Here, again, I believe that the recent textbooks in general science will gain rather than suffer by comparison with science texts in general.

III. GENERAL SCIENCE FOR JUNIOR H. S. GRADES.

This, like point one, is largely a question of administrative needs, but concomitant with these are certain deeper and more psychological relations of subject matter and method. With the growth of either the 6-3-3 or the 6-6 plan, there is to be a great need of science instruction through the grades 7-9 inclusive. Geography is finished in modern practice in about grade 6, or 7 at latest, leaving either two or three years without any comprehensive and unified science program. Agriculture and physiology receive a certain emphasis but are a disgraceful example of teaching science by ignoring all scientific procedure in their method of presentation. It is an open question whether such subjects can be considered a success in this position. There is,

therefore, an unfilled space in our science curriculum. The sciences of the senior high school are furnishing a pressure downwards with the special sciences of botany, physiography, biology, zoology, geology, physics, chemistry and physiology all clamoring for a place.

All this in addition to the fact that general science is in its psychological nature suited to adolescent years. Its concrete rather than abstract nature, its generalizations from immediate applications to the laws themselves, its bird's-eye view rather than the logical classificatory treatment of data, and the like, all serve to make general science the proper science for the junior high school. The expansion of the course over 2-3 years will surely follow as a matter of course, and in so doing will tend to eliminate another criticism of the subject, viz., its tendency toward superficialism due to its wide range nature. There will be less need to rush from one topic to another as some seem to think is necessary as if there were some divinely set goal to be reached by the end of the term, in contrast with a few things well taught. In the country school and rural high school, the science will be largely colored by the problems of the farm environment and life. This adaptability of general science to local needs is in reality a source of strength since it is free to conform to the community rather than be bound to follow a formal set of principles and experiments as in biology, physics or chemistry.

Lastly, general science should furnish aid to the junior high school movement to a considerable extent in that exploratory aim of this reorganized school unit which is so committed to vocational guidance.

There is little question that "problem" or "project" teaching is one of the leading questions in the field of methods of instruction today. Originating, perhaps, in the field of the social sciences, it became almost simultaneously a storm center in natural science. Thus far the problem or project has escaped definition, being concealed in a fog of theory and ideals in the camp of the educational theorists on the one hand and lying humbled and bleeding in the camp of the vocationalists on the other. The former would demand standards impossible of immediate attainment, the latter would degenerate the problem into mere pieces of handwork. A problem reduced to the operation of turning out a piece of wood on a lathe, or the like, surely offers little new to methods of teaching as this is almost uni-

versal practice in the manual arts. If there is such a thing as a problem and if it offers educational possibilities, it must present a series of psychological processes which bear a close relation to those nervous activities of creative thinking. In a phrase, the problem, if valuable and a new contribution, must involve the higher thought centers rather than the lower neuro-muscular functions. So much for a fleeting glance at the psychology of the project.

Another point of view is that of John Dewey. The five steps in the thought act of Dewey is virtually an analysis of the problem method as it appears psychologically. Like the preceding discussion I have given, Dewey's scheme offers little of directly practical value in getting problem teaching under way in our classrooms.

Somewhat more concrete is Snedden's attempt at formulating the evolution of the problem or project. He recognizes four stages, as follows:

1. The Question.
2. The Lesson.
3. The Topic.
4. The Project.

1. The question, the smallest unit ever devised, was partly pedagogical and partly logical in nature. It is the most easily used by the unskilled teacher and is best suited to the age of authority and memorization.

2. The lesson was a pseudo—pedagogical unit; being based upon the sheer physical learning capacity of the child. Hence, it largely measures duration of attention, fatigue effects, etc. It tends to be purely arbitrary as, e. g., like cutting off two yards of cloth or one hundred feet of rope.

3. The topic is characterized by some logical relation to some larger unit of subject matter. At the same time it takes account of the limit of the focusing of attention power of the child. It is more suited to inference and processes of reasoning than to memorization.

4. The project is characterized by concrete achievement, thus taking its unity. There is always a clearly foreseen end to be reached and the process of reaching that goal must be objective enough to permit of evaluation. It calls for the application of past knowledges and skills together with the acquisition of some views, knowledges and skills. Even in the case of the project, while it is somewhat final from the pupils' standpoint, to the teacher it is a step to some larger goal.

From a biographical viewpoint, there is probably no better illustration of the problem method than that of the life of Pasteur. Starting out with a purely chemical problem in the stereochemistry of racemic acid, he studied successively crystallography, polarized light and rotation effect in solutions, the nature of fermentation, the liquor industry of Belgium, micro-organisms, disease, etc., etc., in a brilliant series of projects covering a life time.

We have seen efforts at formulation of the meaning of the project from three viewpoints, the psychological, evolutionary and biographical. The general idea is fairly evident, the exact definition impossible, the application uncertain. Of the five characteristics of general science teaching of tomorrow, this is the most visionary, but perhaps at the same time the most promising. The literature on the subject is fairly extensive but falls sharply into two groups: (1) purely theoretical, (2) practical but falling far short of the ideal. A few textbooks like VanBuskirk and Smith have made a noticeable gain in this direction.

Before leaving the project question, it may be to the point to restate one thought previously mentioned, for the sake of emphasis. The project, whatever it may look like when viewed objectively, is intended to stimulate a certain sequence in thought processes—those usually termed the reasoning processes. This virtually reduces the psychology of the project to that of induction. The difference seems to be of a structural sort, more related to the content concerned in the development of a project; e. g., such matters as the ignoring of formal boundary lines of special science and the concrete, practical product produced incidentally to the play of those higher observational and inferential mind processes. To the writer's mind, the project is little more than a new cloak for the inductive method, but has a new value in that it is applied to concrete achievement rather than over-difficult abstract principles. Such concrete problems of the wiring of a door bell, or the dyeing of a doll's hair and clothing from coal tar products obtained in candy from the corner grocery store, are never chiefly valuable in themselves as a commercial matter, the practicability and concreteness being chiefly useful in that they form a means to strike the responsive chords in the child's thinking. It is for this reason that the problem method will continue to be explored and eventually form a most valuable instructional tool.

V. STANDARD MEASUREMENTS.

As Professor Eliot R. Downing, of the University of Chicago, has pointed out in *School and Society* for November 15, 1919, science teachers, rather strangely, have been most loath to adopt the newer scientific methods of measuring results. This is without doubt a part of the conservatism demanded by scientific procedure.

The growth of standard tests is a feature of modern educational progress in many school subjects, although little, comparatively, has been done for high school subjects. A few beginnings have been made, notably the Starch test for physics, although this has not attained as much attention as it deserves. Grier has a range of information test for physiology and zoology, and Downing one for secondary science in general. F. T. Jones devised a test for physics and chemistry, and within the past year Hanor A. Webb and J. Carleton Bell have each attempted tests for chemistry. Lackey and Witham have tests for elementary geography.

General Science Quarterly for November, 1919, has an account of the writer's, "Range of Information Test in General Science," begun two years ago but interrupted by the war. A preliminary standardization of this last is now under way.

CONCLUSION.

In conclusion, it may fairly be stated that general science has demonstrated the right to further experimentation in our schools, and that the opposition to such courses is gradually dying out as the aims, methods, and results are becoming better known.

For the future, general science seems to have one chance, and perhaps only one chance, viz., its ability to work out a better method of instruction than the special science of the past has produced—a method that I have tried to characterize in five ways as involving:

- I. Inductive, laboratory teaching.
- II. Selection of materials to form environmental problems.
- III. Junior rather than senior high school science.
- IV. Project science.
- V. Use of standard tests.