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Providing for Individual Differences in the General Science Class

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The success of the teacher of general science, as in fact of all subjects, lies in his ability to adjust the materials of instruction to the individual differences of the pupils. In very small groups, such adjustment is relatively simple; but in large classes, which are coming to be the standard in our high schools, the problem of individual adjustment becomes discouragingly complicated. Large school systems attempt a practical solution of this problem by sectioning the groups on the basis, usually, of intelligence. Smaller systems, however, cannot attempt ability grouping. Such practice even where it is practicable affords only a partial and far from satisfactory adjustment, since homogeneous grouping merely limits the range of individual differences within the group and then with respect only to the one trait which has been made the basis for the grouping. Even in a "dull" or a "bright" group there are as many different individuals as there are pupils, each presenting his own instructional problems.

In most classrooms there is probably little attempt upon the part of the teacher to adjust the work specifically to the individual pupils. The class is usually taught as a whole. In a majority of classes, however, it is common to find the work best adjusted to the sub-average intelligence level within the class. Such individual adjustment as is made is usually in the form of "special help" for the dullest members. The least intelligent pupils most frequently receive this special favor not only because the brighter ones learn the materials without extra help, but also because in the too common opinion both of teachers and patrons of the school, it is considered the more praiseworthy pedagogical practice for the teacher to devote most of his time and energy to those least capable of profiting by this help.

Merely to deplore the deficiencies of individualized instruction serves no purpose. The question immediately arises, How can the situation be improved? It is impractical to suggest that this problem can be solved by segregation because segregation is impossible in the great majority of schools; whatever is done must be accomplished within each class, however large the class may be. We must look to the results of educational research for practical ways and means of making individualized instruction effective. Fortunately, although scientific investigation (in the modern sense) in the teaching of science is barely twenty years old, some light has already been thrown upon practical ways and means of meeting individual differences. The following discussion aims to deal very briefly with a few of these.

SUBJECT-MATTER. The earlier textbooks in general science were relatively thin books, in many of which most of the space was devoted to the particular branch of science in which the author had specialized. With the attempts to make of general science a better "exploratory course" by including in it an adequate introduction to a wide variety of scientific courses, authors of more recent books in this subject have of necessity expanded their materials several hundred pages. The result is that it is probably not possible for even the brightest pupils in the class to master all of the materials in any modern general science text, while the average pupil can hardly be expected to master much more than half of it. Yet the teacher, because of administrative pressure or because he does not know what else to do, often attempts to "teach everybody everything in the book" with the inevitable result that the pupils fail to secure optimum values from the course.

The fault lies not in the amount of material in the textbook but in the way in which it is used. The remedy lies in providing for each pupil an amount appropriate to his abilities, judged not by an intelligence test administered beforehand, but by his success in mastering the materials as he progresses through the course.

Before the term starts, the teacher or a committee of teachers of the subject should decide upon a core of minimal essentials of subject-matter. These minimal essentials should be chosen in terms of topics rather than of pages of text; a list of topics to serve as a basis of selection will be found in a recent research monograph.[1] With a dull group the list of required topics for the course should be relatively short, since all the pupils should be expected to master it; with a bright group it can be made much longer.

Where a single textbook is used, the paragraphs dealing with the selected list of essential topics should be marked in the teacher's desk-copy. This statement does not mean that these paragraphs should be picked out of the body of the text, to be taught separately, one at a time. Such a practice would not only render the subject meaningless and uncoördinated, but it would make difficult, if not impossible, adequate provision for the needs of the abler pupils in the class. Every pupil, as the course progresses, should *read* the entire book in order to gain a proper orientation and conception of the subject as a whole. But as the material is studied, the teacher should indicate to the pupils exactly which paragraphs they are *all* expected to master as minimal essentials. It is his business then to insure that these minimal essentials for the dullest pupils do not become the maximal goal for all the pupils. As he becomes acquainted with his class by working with them he begins to assign to the more capable members additional paragraphs and sections, for a complete and accurate knowledge of which they will be held responsible.

Where a syllabus is used instead of a single textbook, it will probably be found most satisfactory to have the syllabus follow some one basic textbook, or at least the general organization of one text, and to use other textbooks and supplementary materials for enrichment and extension. Such a plan provides a more coherent thread of continuity than is possible, and prevents much confusion which is inevitable, when the pupils are directed first to one book and then to another, each of which makes use of and reference to a different selection and sequence of preceding topics. However, the same plan of indicating the minimal ssentials for all and of assiging mate-

1 Francis D. Curtis, "A Synthesis and Evaluation of Subject-Matter Topics in General Science" (Boston: Ginn & Co., 1929)

rials to be mastered by the more capable ones, should be followed with the syllabus as with the single textbook.

Thus in the course of the year, while all the pupils will have covered and become familiar with the entire book or syllabus, they will have been required to master amounts varying with the teacher's estimate of their capabilities. All will have mastered the minimal essentials, but the average pupil will have mastered a considerable body of subject-matter in addition to these, while the brightest will have been kept working up to their capacities in mastering most of the contents of the course. urther provision for individual differences can be made at the same time through the assignment of special reports, problems, experiments and extra readings to correlate with the text materials.

This plan is, of course, essentially a modification of the contract plan; but it provides perhaps a more elastic adjustment of goals to specific capacities.

TESTING. At least two distinct kinds of tests are needed for measuring progress in general science: The first should aim to measure only the mastery of factual material; the second should test power, that is, reasoning and judgment—the ability to apply in problem situations the scientific facts and principles learned. The ability to reason from facts and principles, however, is a far more important product of the general science course than the mere possession of a knowledge of facts and principles. Yet the dullest pupils have practically reached the limits of their abilities when they have learned the facts; they can do little in the way of abstract reasoning from these facts.

A test over the minimal essentials for a group containing both very dull and very bright pupils should therefore have as its *core,* test items covering the essential facts all are expected to have learned. Every pupil should be expected to answer all of these items correctly. The remainder of the test should consist of items requiring the application of these facts and principles to problem situations. These power items should vary in difficulty from simple to relatively abstruse reasoning situations. The duller pupils will probably be able to score the correct responses on only a few of these power items but the brighter ones should reason out most of them. If the test be properly constructed, no pupil will score either zero percent or a hundred percent upon the section involving reasoning; either score would indicate that the pupil had not been tested adequately, since, in the first case, the test had no items sufficiently simple to come within his ability to reason with the material, while in the second case the test had failed to measure the upper limits of his ability to deal abstractly with the materials.

Additional fact and power items should cover the text material beyond the minimal essentials; but since the amount of material beyond the essentials which has been studied for mastery varies with the different pupils, a wide variation in scores should be expected, both in the factual and the power items.

DIRECTED STUDY. It is a common observation among teachers of general science that pupils do not study effectively. Part of this difficulty can be laid to the inability of some of the pupils to read with facility and comprehension. There is little doubt that earlier textbooks contributed to this reading difficulty by including a vocabulary much too advanced for the majority of the pupils whom the book was intended to serve. The authors of recent textbooks in general science, influenced by the results of two outstanding investigations by Powers,[2-3] have used a relatively simple vocabulary.

Simplifying the vocabulary of the general science textbooks has greatly helped, but it has not solved this problem of study disabilities. Most of the pupils still fail to study effectively: The reason is in most cases that they do not know how to study because they have not been *taught* how to study. The general rules which have been formulated and widely disseminated as advice to pupils in establishing effective study habits have likewise failed to any considerable extent in solving the problem: A recent critical evaluation of a number of investigations of the study habits of pupils[4] revealed significant "discrepancies between precept and practice."

The solution of this problem of teaching pupils how to study, like all others in education, apparently lies not in giving the pupils generalized directions, valuable though these doubtless are, but in giving them training in specific tech-

2 S. R. Powers, "The Vocabularies of High School Science Text-books," Teachers College Record, XXVI (1925), 368-82

3 S. R. Powers, "A Vocabulary of Scientific Terms for High School Students," Teachers College Record, XXVIII, (1926), 220-245

4 Percival Symonds, "Methods of Investigation of Study Habits," School and Society, XXIV, (1926), 145-152

niques and skills. Recent research investigation, most notably one by Beauchamp,[5] indicate unmistakable values gained from teaching and drilling pupils in certain simple study techniques, which any teacher with a little practice can successfully impart to his pupils. Among the most practical of these techniques for directing study are: (1) teaching the pupils to skim through a paragraph or a unit for general orientation preceding intensive study of the materials; (2) teaching the pupils to look for and to mark in their books "guide-post sentences" (the topic sentence or the summary sentence, usually) in the paragraph; (3) teaching the pupil to summarize paragraphs briefly and to make summary paragraphs of sections; (4) teaching the pupils to split large topics and problems into smaller ones and then to attack the smaller units one at a time as a means of mastering the larger ones; (5) teaching the pupils to prepare questions of various sorts upon material which they read; (6) furnishing the pupil guide sheets in the form of conventional old-type questions and new-type test items the answers to which the pupils can find by studying the text.

All of these techniques will not serve all pupils equally well; but the pupil who has been taught *how* to study in all these ways is practically certain to find one or more of them especially effective for his own purposes.

LABORATORY WORK. At the beginning of this century the individual laboratory method was the prevailing practice in the secondary schools in which laboratory work was offered. When general science developed, about twenty years ago, it was natural that the individual laboratory method should be favored for this course; but the expense of equipment made this plan impracticable in all but the largest and most heavily endowed schools. Within the last ten years a number of studies, chiefly those of a group of investigators under the able direction of Dr. Elliot R. Downing, have shown that the demonstration method of laboratory work, in which the teacher performs the exercises before the pupils, imparts some sorts of knowledge and perhaps even some elementary skills better and more economically, both in time and money, than the individual method. A recently published dissertation by

5 Wilbur L. Beauchamp, "A Preliminary Experimental Study of Technique in the Mastery of Subject-Matter in Elementary Physical Science," Studies in Secondary Education I, Supplementary Educational Monographs, No. 24. (The University of Chicago Press, 1923) pp. 47-87

Horton,[6] however, presents evidence to show that, in the field of chemistry at least, the individual method contributes more largely than the demonstration method to the acquirement of manipulative skills and to problem solving through projects.

The results of these numerous research investigations would seem to indicate clearly that neither the individual nor the demonstration method of teaching laboratory work should be used exclusively in the general science class. Considering the immaturity of the pupils and the introductory nature of the course, it seems sensible that a majority of the laboratory exercises, especially those requiring expensive or complicated apparatus, should be performed as demonstrations by the teacher; and that a considerably smaller number, those requiring apparatus which is simple and easily provided, should be performed individually by the pupils. The pupils should be encouraged to perform, voluntarily and individually, additional experiments at home, and to work out projects to be recorded and subsequently reported upon before the class.

Individual pupils undoubtedly gain much by being allowed before and after class to play with and manipulate apparatus used in demonstrating experiments. The teacher needs to supervise these activities to prevent horseplay and to insure that the more selfish pupils do not appropriate the apparatus to the detriment of the more timid ones. It is to be expected, moreover, that some apparatus will be broken in the course of such free manipulation, but this breakage is not likely to be great. The individual values gained from such pupil activities, moreover, doubtless justify such incidental breakage.

LABORATORY REPORTS. The pupils should be required to make some sort of record of every experiment as soon as it has been completed, whether it has been performed by the pupil himself or by the teacher. Unless such a record is made, the experiment will subsequently be found to have served many of the pupils chiefly as "effortless entertainment." The types of record should probably vary considerably, depending upon the complexity of the experiment: In some cases a brief statement or paragraph accompanied by a rough diagram will suffice; in others, a complete and formal record may seem

6 Ralph E. Horton, "Measurable Outcomes of Individual Laboratory Work in High School Chemistry" (New York: Bureau of Publications, Teachers College, 1928)

desirable. A recent study by Stubbs[7] showed that the method of filling blanks gave results only slightly inferior to those secured from writing up a complete and formal report, but with a great saving of time over the formal method. The recently reported "moving picture" method[8] of recording experiments, in which the pupils substitute a series of labeled diagrams for the conventional description of manipulations and observations, showed slight superiorities over the formal method, especially with respect to economy of time.

The successful teacher of general science will probably find that he secures best results with the laboratory reports if he uses as wide a variety of methods of reporting exercises as possible. After the pupils have mastered the technique of reporting by the formal essay method and the "moving picture" method, it will frequently be found advisable to allow them to decide for themselves the type of report they wish to use, and to give full rein to their individual capacities for expressing what they have observed. The teacher passes among the pupils as they work, correcting individual errors in English, and pointing out deficiencies or inaccuracies of observation. The able pupils who finish first, can be stimulated to apply in problem situations the scientific principles learned from the experiment.

QUESTIONING. Skilful questioning is an art which too few teachers possess but which all may acquire. The average teacher of general science probably uses only a few types of questions, chiefly these involving observation or pure memory. Such questions are well adapted to the less able members of the class but if the individual capacities of the pupils are to be developed maximally, a wide variety of questions, demanding reasoning and judgment and developing the scientific attitudes, must be introduced. In an analysis of textbooks and laboratory manuals of general science Cunningham[9] found twenty-two distinct types of question appropriate to the general science course. The teacher of general science should be familiar with all these types and should master

7 Morris F. Stubbs, "An Experimental Study of the Methods for Recording Laboratory Notes in High School Chemistry," School Science and Mathematics XXVI (1926), 233-239

8 Fred W. Moore, Claude J. Dykhouse and Francis D. Curtis, "A Study of the Relative Effectiveness of Two Methods of Reporting Laboratory Exercises in General Science," Science Education, XIII (1929), 229-235

9 Harry A. Cunningham, "Types of Thought Questions in General Science Textbooks and Laboratory Manuals," General Science Quarterly, IX (1925), 91-92

the technique of formulating and using a considerable number of them in his daily class work. The relatively recent introduction of new-type tests gives the teacher a valuable means of varying the types of question still further, by substituting true-false, completion, multiple-response, matching, and other forms for the conventional form of question. The pupils should be encouraged to formulate questions for the other members of the class to answer; moreover, they easily learn the technique of making simple new-type test items and enjoy using these along with the conventional types of questions.

The Contract Plan in General Science

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The contract plan has often been used by many teachers in various subjects. Perhaps it has not been called the "contract plan," but the principles involved have undoubtedly been the same. However, it is certainly not a stereotyped form of teaching; the best definition which I have found for it is "a means of releasing potentiality in wholesome ways for every boy and girl," by Harry Lloyd Miller in his book, "Creative Learning and Teaching." Mr. Miller also says, ". . . the Contract Plan will become precisely what we make it." Keeping this last statement and the definition of it in mind, think what we can make it!

I have observed and used the plan in teaching general science both in Denver, Colorado, and Oakland, California, with results which are most gratifying to both teachers and students. However, no two teachers have used exactly the same plan as it "bends" itself to meet the needs of the individual student, and cannot therefore be stereotyped. At present, I am using a form which Miss Dorothy Osburn contrived and find it very satisfactory. It is interesting to note that although we teach in the same building, using the same form, attaining the same objectives, we "bend" the plan for our own interpretations and students, so that we do not use it in the same way. "No two schools should be expected to produce identical patterns."

I shall explain my procedure in the High 7 work which includes the study of Body and Health. First, I divided the