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ABSTRACT

These proceedings include abstracts of the formal papers presented during a conference in Philadelphia on December 8 and 9, 1967. The conference, sponsored by Research for Better Schools, Inc., was concerned with individualization of science instruction, particularly in elementary schools. Thirty-three scientists and science educators from various sections of the country contributed papers or discussion notes about theoretical and practical aspects of science instruction. The aim of the meeting was to exchange information about current attempts to teach science on an individualized basis, and to provide a center for the accumulation and dissemination of such information. The following papers are presented: "The Case for a Laboratory Approach to Individualized Instruction," Celia Lavatelli; "Learning Theory Applications to the Problem of Individualized Instruction in Science," David Ausubel; "Comments on the Content of the Science Program," Richard Harbeck; "Scientific Method," Michael Scriven; "Individually Prescribed Instruction in Science: The Oakleaf Project," W. Shepler and J. Cohen; "The Intermediate Science Curriculum Study," Ernest Burkman; "The Computer as an Aid to Individualized Instruction," Edward Adams; "Statement of the Role of Standardized Tests in Science Education," Lee Brown; and "The Application of the Continuous Progress Concept to the Natural Sciences in Higher Education," J. William Moore. (Author/TS)

INDIVIDUALIZATION:

AN EMERGENT CONCEPT IN SCIENCE INSTRUCTION

A FORUM ON INDIVIDUALIZATION

IN SCIENCE INSTRUCTION

(December 7, 8, 9, 1967)

SUMMARY OF THE PROCEEDINGS

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INTRODUCTION

These proceedings consist of an abstract of the formal papers presented during a conference in Philadelphia on December 8 and 9, 1967. The conference, sponsored by RESEARCH FOR BETTER SCHOOLS, INC., was concerned with individualization of science instruction, particularly in elementary schools. Thirty-three scientists and science educators from various sections of the country contributed papers or discussion notes about theoretical and practical aspects of science instruction. The aim of the meeting was to exchange information about current attempts to teach science on an individualized basis, and to provide a center for the accumulation and dissemination of such information.

Session I was devoted to the implications of learning theory with regard to individualization of teaching. The guideline questions for Session I follow:

1. What do we mean by individualized science lessons? Do we mean that enrichment materials are available to the student? Do we mean individualized lab work as opposed to teacher demonstration? Do we mean a single nongraded sequence of science material which each student can pursue as fast as he is able to?

2. Does current learning theory have anything to say one way or another about the advantages of a student learning by himself on his own schedule? Are there situations where group dynamics and peer interaction are necessary for efficient learning? Do we know enough about the proper timing of concept formation to preclude acceleration of science studies? Have Piaget type studies also been made to determine the optimum time for concept learning as opposed to the earliest possible time?

3. Is there any evidence that personal laboratory experience is useful or necessary for the understanding of science?

4. To what extent can students do truly independent research in the schools, and is this a necessary part of individualized learning in science?

In a presented paper, Dr. David Ausubel asserted that theorists had many generalities to offer, but few specific rules. There have been no large-scale tests of individualization versus group instruction.

Learning theory does provide some guidelines for any kind of instruction, however. For science study it is particularly important to understand the operational stages of human development. Dr. Celia Stendler Lavatelli presented a paper on "The Case for a Laboratory Approach to Individualized Instruction in Science." In a brief review of the ideas of several theorists, Dr. Lavatelli emphasized Piaget's equilibration model of the acquisition of knowledge. Learning takes place when mental accommodation is made to some challenge to the previous equilibrium. There must be self-activity on the part of the learner for this to happen. One of the best ways to encourage this activity in science learning is to provide laboratory experience for the children. Dr. Joseph Novak then described the rationale for learning sequences that he is creating for individualized study by elementary school students.

Session II was concerned with the content of science programs as well as with the allied question of who should determine that content. The following questions provided the guidelines for this session of the Conference:

1. Is there any uniqueness about the nature of science that especially calls for individualized instruction? How difficult is it to train or retrain teachers to supervise individualized instruction? Is it possible that it is easier to prepare teachers in science to guide rather than pontificate?

2. Are there well known and accepted goals of science learning, either grade-by-grade or overall K-12?

3. Is there some natural sequence to the subgoals of science learning? What relationship is there between our common sequences and the natural ones?

4. Who should decide the goals and content of science lessons? Are there some minimum expectations of the society? What freedoms of choice should students have? Who should choose the fraction of time to be spent on science learning, or the division of time within the various scientific disciplines?

Mr. Richard Harbeck reviewed some of the innovations in science curricula that have been introduced during the past decade and concluded that not enough attention has yet been given to the establishment of objectives in satisfactory performance terms. The new courses themselves do not depart organizationally from those of the past. Dr. Michael Scriven proposed that the question of degree of science emphasis could be settled by introducing core curriculum in the early grades, consisting of exercises in reasoning skills. He pointed out that programmed materials for this and other tasks have scarcely yet been tested, because of the absence of suitable texts. Dr. James Gallagher presented a model for a science curriculum based on four areas: science concepts, processes, technology, and relation of science to society. Dr. Herbert Thier's approach was pragmatic in its insistence that curricula would have to be designed for schools as they now operate. He claimed that the practical way to achieve individualization of instruction was through the proper use of laboratory equipment. Dr. Charles Walcott presented the views of the Elementary Science Study group concerning the value of providing undirected science activities. In the vigorous discussion that followed the prepared statements, the conferees considered the possibility and desirability of spelling out specific behavioral goals for science learning.

Session III was spent in hearing about current practices in individualizing science instruction. The questions around which this session revolved were:

1. What kind of individualized learning exists today?

2. If a school wanted to try individualized science instruction today, what programs or materials now exist for them?

3. What developments are now under way for future use? This includes programs, texts, and technology.

4. Is it possible, in a standard type school, to run individualized instruction in one particular subject area?

Dr. Warren Shepler and Mrs. Jacqueline Cohen described "The Oakleaf Project," an experiment with a public school in the suburbs of Pittsburgh. Now in its third year, this project involves individualization of lessons in math, reading, and science. Dr. Edward Adams summarized some of the uses of computers in instruction. Dr. Ernest

Burkman reported on the current status of the Intermediate Science Curriculum Study. This science program for grades 7, 8, and 9 is being developed so that each student can proceed at his own pace. Seventh- and eighth-grade materials were developed during the summer of 1968, and revision and testing will continue for some years. Dr. J. William Moore described a continuous progress plan that he has helped to institute in several subjects at Bucknell University. Mr. Joseph Klein reviewed the role of industry in providing the hardware for various educational innovations. In the discussion during the rest of this session, there were brief descriptions of several other curriculum developments that allow some individualization.

Necessarily, the following abstracts are greatly shortened versions of the original papers. Care has been taken to reflect both the meaning and the tone of the actual formal presentations, but obviously, many elaborations and qualifications considered vital by the authors may have been missed by the abstracter. In addition to the formally printed papers, many of the participants contributed papers or discussion notes. A list of the conference participants is included with the abstracts.

Clifford Swartz
Marilyn Appel

THE CASE FOR A LABORATORY APPROACH TO
INDIVIDUALIZED INSTRUCTION IN SCIENCE

Celia Stendler Lavatelli

University of Illinois

Since all learning is individualized, it is instruction that must be designed so that each pupil can acquire as much knowledge as he is intellectually ready to absorb. I believe that the laboratory approach to science instruction is the most feasible way of providing that instruction; I propose to make a case for the laboratory approach, first by examining the components of a learning model for science, and second by showing how the laboratory approach fits the model.

Technically I will not be discussing learning theory, of which there are several schools. Gutherie and his school postulate that unless response and stimulus occur together, there will be no learning. Reinforcement is unnecessary. For Hull and his followers, reinforcement is critical; for the response to be learned, the learner must "get" something through reward or success is considered to be more conducive to learning than negative reinforcement through punishment or failure. Skinner's position is somewhat different from that of Hull, although he also belongs in the reinforcement school. Skinner's name is primarily associated with operant conditioning, which is based upon active learning. Through small-step gains, the subject's behavior approximates more and more the desired behavior. Reward rather than punishment is emphasized, with reinforcements carefully timed according to a prearranged schedule. Operant conditioning is being tried in a number of experimental classrooms, and there has been considerable success in shaping the behavior of children with learning disabilities due to motivational or other affective causes. Aside from programmed instruction and the experimental programs employing operant conditioning it is difficult to find much direct application of learning theory to instruction.

Cognitive theory, on the other hand, does make a contribution to our understanding of how children acquire science knowledge. All of the various cognitive theories contain the notion of meditational processes. These processes describe what goes on between a stimulus and its response. For instance, in the TOTE model, a Test presented to an organism elicits input, a re-Test to see if the match is right, and an Exit step when the organism is ready for action. The various mental operations what the mind engages in during the Operation steps are not clear.

Instead of using the term, "learning," Piaget talks about epistemology - the process by which the child acquires knowledge. His equilibration model describes what goes on in the acquisition of knowledge and in the development of logical intelligence. Basic to the acquisition is self-activity; acquisition of knowledge is something that "the pupil had to do himself and for himself." Since Piaget was a biologist before becoming a psychologist, it is not hard to understand that his conception of intelligence is couched in a biological framework as a basic tendency toward equilibrium in mental structures. There is such basic homostatic tendency in to restore it. However, in this case, adjustment is not automatic; the individual exercises some control over the operations of intelligence. Furthermore, mental structures are actually changed by the equilibrium process.

Two mechanisms are important in equilibration: assimilation and accommodation. In reproductive assimilation, one produces an action in cognitive activity; in recognitive assimilation one screens objects that can be assimilated into a particular scheme; in generative assimilation, one permits the enlargement of a scheme to encompass a wider range of objects to be assimilated. The transformation of data by the subject finds its counterpoint in modification of the existing framework of thought which is called accommodation. In accommodation one "makes up one"s mind" about what one believes or accepts as true. Like assimilation, accommodation is an active and orienting process. As a classroom example, suppose that a learner is exposed to data that challenges some previously held notion. Perhaps he sees cylinders of two kinds of metal displace the same volume of water. If his previously held notion was that the cylinder would raise the water level higher, he must either not worry about the contradiction, or else take the stand that his previous ideas were wrong. Through progressive assimilations and accommodations, equilibration proceeds and equilibrium is achieved at a higher level.

Bruner also emphasizes the importance of self-activity in the acquisition of knowledge. He sees the child as he carries on an activity or experiment, building inside himself a mental image of the process. At first the child may have to depend on visible, manipulable materials. Given such direct physical experiences, he will assimilate enough data to build a mental representation of the essence of these experiences and will free himself to deal with abstractions or symbols.

There is no empirical evidence collected in carefully controlled research to prove that acquisition of knowledge depends on self-activity operating according to an equilibration model. Teachers can find evidence of the dependency, however, in the behavior of their pupils. Unless a child has acted upon an explanation to make it his own, equilibration has not occurred and no true understanding follows. Margaret Mead, among others, has observed that the best way to understand something is to teach it. In the process of trying to explain a difficult point to someone else, one acts upon ideas and clarifies one's own thinking.

From the viewpoint of the equilibration theory, several factors might interfere with the acquisition of science knowledge. The learner may not be interested in having his equilibrium disturbed. Even if the student is presented with evidence that challenges his existing notions, he may be unwilling or unable to take the next step of making the necessary changes in mental framework to accommodate new data.

I would like to propose that readiness may be the critical factor in whether or not equilibration occurs. Readiness for those who operate on Piagetian theory is not a matter of maturation alone, but also depends upon the child's existing state of knowledge. For example, before he can acquire the concept of acceleration, the child must have an understanding of the concept of velocity, which in turn depends on first order concepts of distance and time. Gagne in particular among American psychologists has been concerned with the hierarchical organization of component tasks, the successful achievement of each of which is necessary for performance of the final task. Modern curricula in mathematics have, perhaps, made most use of this principle of sequencing instruction. Gagne, himself, has attempted to apply the principle to the processing of sequence skills in science. The goal is not the accumulation of knowledge about any particular domain of science, but rather a competency in hhe use of processes such as observation, classification, measurement, etc. Obviously, sequencing is important in the development of any curriculum but what is sequenced must include not only content (under which skills can be subsumed), but logical thinking processes as well. The child's level of development of logical thinking must be taken into account. While Gagne curriculum is better in teaching operations necessary for classification than for other logical thinking skills, even in this area it falls short because it places emphasis upon perceptual skills which do not demand transformation of data to solve problems posed. A pupil can form a class of red objects shuffling any data about in his head; he can simply make a perceptual judgement. Such operations as reversing a process, establishing an identity between parts, putting two and two together figuratively as well as literally, develop during the elementary school years. Before the onset of these operations, the child is at the mercy of his perception. It is not until about six or seven years of age that the young learner can manipulate data, using logical operations, although even then he does so in a concrete fashion. However, toward the end of the elementary school years, concrete operations are replaced by formal, and abstract reasoning becomes possible. As the pupil goes through the elementary school, science concepts become more complex in terms of the demands they make upon logical thinking. Two broad classes of problems demand more advanced operations: those requiring the use of a combinatorial system is the experimental method in which all variables are controlled while one is being tested according to a systemic plan for combining all variables for testing. Ratio and proportion problems also demand complex operations for solution.

Not all investigators have fully understood the distinction Piaget makes in solving problems at the formal. For example, Anderson rejected Piaget's internal equilibration model in favor of S-R model in which children, through programmed instruction would acquire and transfer a complex problem-solving skill. The skill trained for was that of varying each factor in a problem while holding all other factors constant, a skill which is part of the propositional logic which Piaget and Inhelder found making its appearance at the onset of adolescence. In a six-weeks training program, very young children were given exercises in finding perceptual clues relating to variables. This is, however, not at all what Piaget means by formal thinking; rather it is a lowlevel concrete operation based on perception. Although the children learned to do the particular tasks they were trained for, they failed to show superior performance on other similar tasks where complex operations really were demanded.

In teaching pupils, then, we need to consider problems of sequence not only in terms of hierarchical organization of concepts, but also in terms of hierarchical organization of logical operations essential for acquisition of concepts. In short, complex logical operations have their foundation in simpler operations; complex subject-matter cannot be mastered unless the pupil has available to him ways of thinking about the problem essential to its solution. An adequate program of science instruction should include training in logical processes so that the learner may be able to acquire science knowledge.

To sum up: An adequate theory of science instruction must take into account the fact that self-activity on the part of the learner is essential to the two processes involved in equilibration-assimilation and accommodation. It must also reckon with the fact that readiness for science instruction demands that the learner has acquired both the basic knowledge and the logical operations essential to learning the task. There is a third component which we will now consider; there must be provision for dialogue between learner and learner, and learner and adult.

Should instruction be individualized for most effective learning? With the tremendous increase in both hardware and software of learning aids, complete individualization is already within the realm of possibility, and many enthusiasts think that it would be highly desirable. However, programmed, automated instruction, while effective in teaching subject matter demanding considerable repetition and verbal drill, is not appropriate for teaching most of the subject matter of science. The danger in most computer instruction is premature verbalization. Some learnings have to be built in at the sensory motor or "gut" level. One can be exposed in programmed text to the fact that electrical charges can attract or repel, and one can even pass correctly such an item on an examination, but one does not thereby assimilate its meaning, or accomodate to it.

Piaget has written of the dangers of premature verbllization. For him, logic is not a derivative of language; it is an experience of the actions of the subject, and not an experience of objects themselves." Piaget does not deny the importance of linguistics transmission, but he maintains that the child can receive valuable information via language only if he is in a state to understand the information. In science, direct physical experience, either through demonstration or experimentation is essential to readiness for most concepts in the curriculum.

Recently, verbal learning has undergone some rigorous testing with pre-school children. Bereiter and Engleman have been conducting experiments with disadvantaged four-year-olds, which relied solely upon patterned verbal drill. The children received three periods of twenty-minute instruction each day in three subject matter areas. No toys or other concrete objects were used originally, but instead, children were taught and forced to repeat various sentence responses. The children responded in unison with appropriate combinations of the memorized sentences in answer to specific questions from the teacher. (Teacher: "Is this block red? Children: "No, this block is not red.") During the past year several studies comparing these children with control groups has shown that the system is not very effective. If this is the case with pre-school children using live teachers, one could hardly hope that a programmed test or a machine could do better. Not only must the children try things out, they must also try explaining things to themselves or to others. In a give and take between teacher and pupil, or pupil and pupil, there will be additional assimilation which is needed before accommodation can occur.

The laboratory approach which I advocate provides for each pupil or a team of pupils, physical objects with which the learner can interact in a solution to given problems. Materials for examination or manipulation are distributed to each station, and problems are posed for the class - same problems for all members of the class. For instance, in a fourth-grade class on temperature, twelve laboratory stations have been set up in the classroom, each manned by two pupils. In a series of lessons, pupils investigate the concept of melting point, how thermometers measure temperature, the meaning of thermal equilibrium, and other topics. Let us examine such laboratory lessons to see whether they meet the criteria for learning and whether they provide for individual learning rates. In these particular lessons, this equilibrium was provided by the fact that all the children believed that the melting point of ice varied with the temperature of the surrounding region. It took repeated trials of measuring temperature in hot spots and cold spots before they gave up their erroneous notion and came to see that the temperature of ice-slush is always the same.

Karplus points out the an operational definition is an important technique which scientists use "to specify the meaning of many terms in such a way that their connection with physical reality becomes part of the definition." In the study of temperature, laboratory experience provides meaning for the definition of energy as "the capacity to do work" because students find that the amount of ice melted in a given period of time can vary with the energy expended. Such a definition of energy can then be used to measure the amount of energy expended in other operations.

The laboratory approach meets a second essential for science instruction in that it gives the learner the opportunity to participate at <u>his</u> level of understanding. While all the children engage in the same activity, they assimilate information at different levels of abstraction.

Individual differences in logical processes applied to and developed in the acquisition of knowledge must also be taken into account in assessing instructional methods. Here again, the laboratory approach makes it possible for students to apply logical processes at different levels of sophistication. In a series of laboratory sessions in the temperature unit, children worked with mixture problems. Children were able to use various methods to predict the final temperature, some very simple, some using graphs; and one fourth-grade boy, in terms of a formula.

The laboratory approach also provides a setting for pupil-pupil interaction. This provides an opportunity for disequilibrium to occur and motivation for the learner to assimilate more information through self-activity. The teacher's role is by no means a passive one. By posing the proper questions, he can sharpen the observations, signal discrepancies, stimulate thinking and instigate disequilibrium.

This paper has not considered the usual techniques for attending to individual differences - the use of enrichment materials, assignment of independent research and the like. Such techniques have their place in the science curriculum but they should be for all students, not just the dull or the bright. For empirical evidence on these matters, we need new evaluation instruments that will assess not merely how many facts a student knows, but also what level of understanding he has reached in his study of a particular unit.

LEARNING THEORY APPLICATIONS TO THE PROBLEM OF INDIVIDUALIZED INSTRUCTION IN SCIENCE

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What does learning theory have to say about the problem of individualized instruction in science? Nearly every learning theorist would have a wide range of generalities to offer but little that is specifically relevant to this particular problem. It might be expected that some learning theorists would have collaborated with scientists in the production of curriculum materials in elementary or secondary school science. Unfortunately, this has not been the case. They have been involved only in a peripheral sense, taking the role of after-the-fact critics. Lacking subject-matter competence, they are also disqualified from raform movement. The situation is particularly appalling in biology curriculum reform because there are plenty of psychologists who have excellent training in biology. Yet it apparently never occurs to directors of biological curriculum projects to solicit the cooperation of biologically sophisticated psychologists. Any reasonably comprehensive discussion of learning theory applications to individualized instruction in science would have to consider all of the significant psychological variables that influence the learning of curriculum materials in this realm of knowledge. Since time is limited, this paper can cover only a few of the more salient and controversial issues.

Do improved pedagogic techniques exert a leveling effect on individual differences? Do the achievement levels of more and less able students tend to converge or diverge as improved curriculum materials and pedagogic devices become available? The generally accepted biological principal is that the introduction of an optimal environment increases rather than decreases phenotypic variability for a given population. The evidence provides reassurance that the effect of improvement of the educational environment does not constitute an exception to this relationship. It might be expected that in non-individualized learning situations, improved methods of teaching would tend to benefit the average and the dull student more than the bright student. The bright student, after all, could be expected to structure and organize unfamiliar learning materials by himself. Research evidence tends to be equivocal. A number of studies show that the use of course organizers is more beneficial to low-ability students in the learning of completely unfamiliar material, but it is of no special help when the learning material is related to existing knowledge. Several studies have shown that programmed instruction differentially benefits academically poorer students. If abler students are permitted to learn at their own pace and to complete as many programs as rapidly as they can, individual differences in achievement between the bright and the dull obviously tend to increase. It seems reasonable to conclude, therefore, that improved educational materials and techniques have a leveling effect on the relationship between academic aptitude and educational achievement only in those educational settings where the quantity and difficulty of the curriculum materials are held constant for all pupils.

Self-instruction versus group instruction. On theoretical grounds, it seems rather self-evident that self-instruction is incomparably more efficient than instruction in groups for most aspects of subject-matter learning. Surprisingly enough, however, empirical testing and confirmation of this proposition have been almost totally neglected by educators and educational psychologists. One of the difficulties in such research lies in the very narrow conception of what is meant by individualization of instruction. Adapting to the rate of learning is only one dimension. Any tutor must be able to respond to the other differences that mark the idiosyncratic learning progress of each student. This, of course, does not preclude but rather highlights the desirability of multivariate research designs.

Pacing. One of the more important issues involved in individualized group instruction is the relative value of differential as compared to uniform pacing, and the question of who shall determine the pace that is adopted. Pacing deals with the massing or distribution of different task units as opposed to the massing or distribution of trials of a particular task. Theoretically, it would seem plausible that an optimal, average inner-task interval exists for every kind of subject-matter, given learners of specified, cognitive maturity and subject-matter sophistication. First, sufficient time is necessary to recover from initial "learning shock" before proceeding to new tasks. Second, the learner requires adequate time for contemplating the material in retrospect. Third, it is important to avoid excessive cognitive strain as well as unnecessary redundancy and boredom. Lastly, it is necessary to provide sufficient time for practice. It is apparent that most individuals can be trained to comprehend meaningfully a much more rapid rate of discourse than that to which they are habitually accustomed. Whether material assimilation in this fashion is also retained as well as material presented at more conventional rates still remains to be demonstrated. On logical grounds, it would be reasonable to expect that individualized pacing would be more effective for learning than the imposition of a uniform rate of coverage on all learners. Some individualization could be regulated by either teacher or pupils. The limited experimental evidence available on the relative efficacy of self-regulated pacing does not indicate any superiority over teacher-regulated pacing. This does not mean, however, that differential or individualized pacing is not superior to uniform pacing.

Direct versus Teacher Transmission of Curriculum Materials. There are two controversial issues concerned with enrichment materials for individualized self-instruction: (a) Shall these materials be prepared for direct use by pupils or should they be prepared for the teacher? (b) Should these materials be integrated with a sequentially organized course or should they be prepared apart from such a formal study? In my opinion, curriculum materials should be prepared for pupils rather than for teachers.

I agree with J. D. Novak that when the content of a curriculum program is properly prepared and pretested for learnability and lucidity, and contains adjunctive feedback devices, there is little value in using the teacher as a filter through which the content of subject matter reaches the pupils. Such a method circumvents the conceptual and pedagogic limitations of 999 teachers in 1,000. The teacher's role is not eliminated but is channeled more into the stimulation of interest, the planning and direction of learning activities and the provision of more complete and individualized feedback. Typically, programmed materials consist of texts that are written by subject-matter and learning-theory measurement specialists, in accordance with established psychological principles of presentation and organization; that contain searching tests of genuine understanding plus appropriate feedback after each self-contained subsection; that make provision for overlearning (consolidation) before new material is presented; and provide for adequate review after progressively increasing intervals of time.

Single Unit versus Integrated Curriculum Approach. I do not think that it is pedagogically tenable to produce science curriculum materials apart from an integrated plan encompassing each of the separate scientific disciplines at successively higher levels of difficulty from elementary school through college. Large-scale integrated curriculum planning requires no greater "certainty in the minds of specialists on exactly how science materials should be scheduled to guarantee learnings" than does the system for producing small unintegrated projects stem more, in my opinion, from (a) untenable theoretical ideas about teaching and learning and overemphasis on the importance of discovery in learning and overemphasis on the "basic science," experimental-analytic approach; (b) uncoordinated team effort, resulting in the production of textbooks consisting of unintegrated units, and no pervasive organizing ideas that are organically related to the textual material; (c) failure to try out the materials empirically until the entire series is completed; and (d) lack of active collaboration, on a day-to-day basis, of learning-theory and measurement specialists (who are also sophisticated in the subject matter) in the actual preparation of curriculum and measurement materials.

Individualization of Laboratory Work in Science Instruction. Primary responsibility for transmitting the content of science should be delegated to teacher and textbook, whereas primary responsibility for appreciation of scientific method should be delegated to the laboratory. Yet science courses at all academic levels are traditionally organized so the students waste many valuable hours in the laboratory collecting empirical data which at the very best helps them rediscover principles that the instructor could present verbally in a matter of minutes. Knowledge of methods whereby data in a particular discipline are required also need not always be gained through self-discovery in the laboratory. Laboratory work in the context of this paper should not be confues with demonstrations and simple exercises. Nevertheless, it involves a controved type of discovery that is very different from the truly autonomous discovery activities of the research scholar and scientist. Before the student can discover generalizations efficiently the problem must be structured for him, and the available procedures must be skillfully arranged by others. Personal laboratory experience is both useful and necessary for the understanding of science, but truly independent laboratory research in the schools is useful only occasionally. Individualization of instruction in the laboratory does not necessarily presuppose independent design of experiments by the student. Laboratory methods should be used only where the underlying methodology is thoroughly understood rather than follow methodically in cookbook fashion. What about the assertion of Bruner that a student can best learn science by behaving as a scientist does? In my opinion, the proponents of this approach tend to confuse the goals of the scientist with the goals of a science student. It is the scientist's business to formulate unifying explanatory principles in science. It is the student's business to learn these principles as meaningfully and critically as possible and then, after this background is adequate, to try to improve on them if he can. If he is ever to discover, he must first learn; and he cannot learn adequately by pretending he is a junior scientist. By so pretending, he would fail to acquire the minimal degree of subject-matter sophistication in a given discipline that is necessary for abstract intellectual functioning in that discipline, much less make original contributions to science.

"Basic" versus "Applied" Science Approach. The strong emphasis in the Yellow and Blue BSCS (Biological Sciences Curriculum Study) versions on "basic science" principles, and their relative lack of concern with applications to familiar or practical problems, is in accord with current fashionable trends to overemphasize the "basic sciences" and unwarrentedly to denigrate the role and importance of applied science in general education. Yet the applied sciences constitute a significant aspect of modern man's intellectual environment, and hence an important component of general education. Knowledge about such subjects as medicine, agronomy and engineering should be taught not to make professional physicians, agronomists and engineers out of all students but to make them more literate and intellectually sophisticated about the world in which we live. Although less generalizable than the basic sciences, the applied sciences are also disciplines in their own right, with distinctive and relatively enduring bodies of theory and methodology. Applied sciences also present us with many strategic advantages in teaching and curriculum development. We can capitalize on the student's existing interest in, and familiarity with, applied problems in science. There is also good reason for believing that applied sciences are intrinsically more learnable than basic sciences to the elementary school child.

Overemphasis on Analytical, Quantitative, and Experimental Aspects of Science. One of the characteristic features of the curriculum reform movement is an overcorrection of the unnecessarily low level of sophistication at which many high school subjects have been and are still taught. In the sciences, this tendency is marked by a virtual repudiation of the descriptive, naturalistic, and applied approach and an overemphasis on the analytical, experimental, and quantitative aspects of science. The implied rationale of this policy is Bruner's untenable assertation that any concept can be taught to any person irrespective of his level of subject-matter sophistication. By any reasonable criterion, introductory high school biology should continue to remain predominantly naturalistic and descriptive in approach. It should concentrate on those broad ideas that constitute part of general education rather than on a detailed and technical analysis of the physical and chemical basis of biological phenomena. It is much more important for the beginning student in science to learn how to observe events in nature systematically and precisely than to learn how to manipulate an experimental variable and control other relevant variables in a laboratory situation. Retention of the naturalistic school biology is thus consistent with the fact that tenth-grade biology is the terminal course in science for many students. It is also more consistent with the tenth-grader's existing background of experience, interest and intellectual readiness. This proposed emphasis is also in no way inappropriate for those students who will subsequently take high school physics and chemistry. These latter students will be much better prepared, after taking such introductory courses, for a second course in biology, in the twenfth grade or in college, that takes a more quantitative and experimental-analytical approach, introduces more esoterical topics, and considers the biochemical and biophysical aspects of biological knowledge.

The "Process" Approach to the Teaching of Science. Many current writers in the field of science education express the view that the principal objective of science instruction is the acquisition of general inquiry skills, of appropraite attitudes about science, and of training in the "heuristics of discovery." In my opinion, however, any science curriculum worthy of the name must be concerned with the systematic presentation of an organized body of knowledge as an explicit end in itself. Some advocates of the "process" method favor independent pupil discovery that is somewhat reminiscent of the faculty psychology approach to improving overall critical thinking ability through instruction in the general principles of logic. The principal difficulty with this approach, as the faculty psychologists discovered, is that critical thinking ability can be enhanced only within the context of a specific discipline. Grand strategies of discovery, like scientific method, do not seem to be transferrable across disciplinary lines. The only kinds of transfer that have been empirically demonstrated in problem-solving situations are the transfer of specific skills, the transfer of general principles, and the transfer of general approach or orientation to a specific class of problems. From the standpoint of elementary school children, one wonders whether principles of inquiry pitched at a general level of abstraction could be meaningful enough to be used successfully in problem-solving. The rapid rate of obsolescence in science is often offered as a rationale for the heuristics of discovery approach to science teaching. Actually, the rate of obsolescence is greatly exaggerated. Although the specifics change rapidly, basic principles tend to manifest impressive lengevity. Obsolescence is a fact of life that must always be kept in mind; but this does not render futile the assimilation of the current content of knowledge or counsel exclusive attention to the process whereby knowledge is acquired. It merely presupposes a readiness to revise those aspects of one's knowledge that gradually become outdated.

Developmental Issues

How instruction in science is individualized depends in large measure on the characteristics of cognitive functioning at different stages in intellectual growth.

Are There Stages of Intellectual Development? Developmental stages imply nothing more than identifiable sequential phases in an orderly progression of development that are quantitatively discriminable from adjacent phases and generally characteristic of most members of a broad age range. It is unreasonable to insist that a given stage must always occur at the same age in every culture. Similarly, within a given culture for all individuals a particular stage cannot be expected to occur at the same age. A certain amount of overlapping among age groups in inevitable. One also cannot expect consistency and generality of stage behavior within an individual from one week or month to another. Since transitions to new stages do not occur instanteously, but over a period of time, fluctuations between stages are common until the newly emerging stage is consolidated. It is hardly surprising that transitions from one stage to another do not occur simultaneously in all subject-matter areas or subareas. Abstract thinking, for example, generally emerges earlier in science than in social studies. It is erroneous to believe that stages of intellectual development are exclusively the products of "internal ripening," and hence that they primarily reflect the influence of indigenous factors. In fact, as the educational system proves, we can confidently look forward to the earlier mean emergence of the various stages of cognitive development.

The Concrete Operational Stage of Intellectual Development. During the operational stage, the child is capable of acquiring secondary abstractions and the relations between them. He differs from the abstract operational individual in using concrete empirical props in acquiring secondary abstractions and in understanding and manipulation of relations between them. Once secondary concepts are acquired, the concrete operational child is no longer dependent on props in understanding and using their meanings. Understanding relationships between secondary abstractions, however, is quite another matter. In this kind of learning task he is dependent upon recently prior or concurrent concrete-empirical props consisting of a particular examplar for each of the abstractions in the relationship when such props are not available, he finds abstract propositions unrelatable to cognitive structure and hence devoid of meaning. Thus, where complex propositions are involved, he is largely restricted to an intuitive level of cognitive functioning, a level that falls short of the clarity, precision, explicitness, and generality associated with the more advanced abstract stage of intellectual development. During the elementary school years, therefore, abstract verbal propositions that are presented on a purely expository basis are too remotely removed from concrete-empirical evidence to be relatable to cognitive structure. This does not mean, however, that autonomous discovery is required before such propositions can be meaningfully learned; as long as concrete-empirical props are made an integral part of the learning situation, the propositions are eminently learnable. Concrete-empirical props need not necessarily be nonverbal or tangible (e.g., objects, pictures). After a child masters both the concept and its name, concept names are just as meaningful to him as the concepts themselves or the perceptible physical objects or events to which they refer. I would take issue, therefore, with Lipson's view that direct or nonrepresentational experience is essential for science learning in the elementary school. What about the assertion by Lipson that the use of direct experience in the teaching of scientific concepts enabled elementary school children to learn the concepts in question as well or better than college students and to retain them over a year with little forgetting? In the first place, these results can hardly be attributed to direct experience per se inasmuch as other important variables affecting the potential meaningfulness of the textbook materials were not equated in the two groups. Second, no data are available regarding the learning outcomes that would have been obtained if direct experience were emphasized to lesser degree, i.e., if an expository approach, using verbal concrete-empirical props for the most part, were employed. Finally, there is definitive evidence that when the conditions of meaningful verbal learning are optimized, scientific concepts taught by verbal exposition can be retained over impressively extended periods of time. It is also important to realize that just because the concrete-operational child uses concrete-empirical props in understanding and thinking about relationships between abstractions, this stage of intellectual development is not really concrete in the sense that objects or concrete images of objects are rationally manipulated in meaningful reception or discovery learning. The concreteness of this stage inheres in the fact that secondary abstractions and relationships between them can be understood and meaningfully manipulated only with the aid of currently or recently prior concrete-empirical props. It appears that Piaget overstates his case and gives children too little credit, when he does not differentiate between primary and secondary abstractions in asserting that only in the final stage can children understand and manipulate relationships between abstraction; as far as relationships between primary abstractions are concerned, this capacity is evident without props in the concrete operational and even in the preoperational stage.

Educational Implications of the Concrete, Intuitive Level of Cognitive Functioning. The elementary school child is completely dependent upon current or recently prior concrete-empirical props in understanding or meaningfully manipulating rational propositions consisting of secondary abstractions. Hence, general laws and methodological canons of science have little meaning and intellectual appeal to him. As far as elementary school children are concerned, therefore, one cannot hope to reduce science to "first principles" and basic abstract laws. At the very best one can strive for a semiabstract intuitive grasp of these laws on a descriptive or semianalytical level that is somewhat tied to a particularized experience. The developmental characteristics of the elementary school child's cognitive functioning do not require, however, that we restrict the pedagogic use of these years to teaching the fundamental intellectual skills. His cognitive equipment is certainly adequate for acquiring an intuitive grasp of many concepts in the basic disciplines. The psychological argument for teaching science in the elementary school is extremely convincing. First, it is well known that young children spontaneously acquire many animistic and subjectivistic conceptions about the physical and biological universe. These notions tend to persist and compete with more mature conceptions, especially when not counteracted by early scientific training. Second, without early and satisfactory instruction in science, it is difficult for children both to assimilate positive interest in and attitudes toward the scientific enterprise, and to avoid being negatively conditioned to scientific subject matter. Third, since elementary school pupils can easily acquire an intuitive grasp of many scientific concepts, failure to provide suitable opportunities for them to do so wastes available readiness for such learning and in junior and senior high school that could be used for more advanced instruction in science. Thus, the concept of a "spiral curriculum" is eminently sound, provided that an attempt is not made to teach at an intuitive level "reduced" versions of anything or everything that is presented later at a more abstract level. The suggestion that the sciences be studied in the order of their phenomenological complexity, i.e., that one start with the "basic concepts of physics and chemistry before tackling the complex phenomena of biology and geology," although logically sound, is psychologically unfeasible. More important pedagogically than the logical structure of knowledge is the pupil's intellectual readiness to handle different kinds of subject matter; and from the standpoint of relevant experience and readiness, the phenomenologically "simple" laws of physics are far more abstract and difficult than the phenomenologically "complex" laws of biology and geology which are so much closer to everyday experience. The teacher's task of translating ideas into language that is compatible with the elementary school child's capacities is difficult indeed. First, in teaching others, his natural tendency is to adopt the same level of discourse he himself uses in learning new ideas. Second, once he has acquired difficult concepts, he tends to regard them as self-evident. Third, after he has mastered a particular discipline, he tends to think only in terms of the logical relationships between component ideas. Lastly, because of his more sophisticated and highly differentiated cognitive structure, he is very aware of the various subtleties and qualifications connected with even simple ideas, and often fails to realize that the introduction of such complications only confuses his pupils. Although the preschool child is restricted to relatively non-abstract concepts in the learning of most propositions, it is not necessary that all rational learning during this period take place on a nonverbal, problem-solving, or completely autonomous self-discovery basis in order to be meaningful. Neither does the elementary school child's dependence on concrete-empirical props for the understanding of more anstract propositions require that all, or even most, teaching be conducted on an inductive, problem-solving and nonverbal basis. Verbally expressed relationships between abstract ideas can be adequately comprehended when presented didactically as long as concrete-empirical props (verbal or nonverbal) are available.

Various developmental factors counsel a choice of breadth over depth in the content of elementary school science curriculum. First, from a logistical standpoint, the young child is not prepared for depth of subject-matter coverage. Second, the relationship between breadth and depth must also take into account the progressive differentiation of intelligence, interests, and personality structure with increasing age. Breadth, of course, inevitably implies a certain amount of superficiality. Whether it is desirable or undesirable can be judged only in relation to the student's intellectual readiness for depth. It should also be pointed out that superficiality itself is always a relative state of affairs. It need not be synonymous with triviality or with slip-shod, unsystematic or out-of-date teaching. Good teaching implies precise presentation of significant, organized, lucid, and valid content at any level of breadth. The probing in depth of isolated areas, apart from the systematic presentation of subject-matter, merely as a means of enhancing inquiry skills, it is indefensible at any age level, and particularly in the elementary school. It is a type of activity suitable for the scholar and research scientist - after he has acquired substantive and methodological sophistication in his field.

Abstract Operational Stage of Intellectual Development. Beginning in the junior high school period, the pupil becomes increasingly less dependent upon the availability of concrete-empirical props. Inhelder and Piaget present considerable evidence indicating that "formal" operations appear slightly before the onset of adolescence. Eventually, after sufficient gradual change in this direction, the intellectually mature individual can use indirect, second-order logical operations for structuring the data. He can transcend the previously achieved level of intuitive thought and formulate general laws relating general variables. The distinctive feature of formal operations is not that the older child is able to deal internally with ideas about ideas. The younger child can also do these things. It is rather the adolescent's ability verbally to manipulate relationships between ideas in the absence of recently prior or concurrently available concrete-empirical props that is the distinctive attribute to formal operations. After adolescence, ideas about ideas achieve a truly general status that is freed from any dependence whatsoever on particular instances and concrete experience. Beginning in the junior high school period, students can acquire most new concepts and learn most new propositions by directly grasping higher order relationships between abstractions. Expository instruction thus becomes more feasible. At this stage of development, it is unnecessary routinely to introduce concrete-empirical props or time-consuming discovery techniques in order to make possible or to enhance intuitive understanding of abstract propositions.

General and Specific Aspects of the Transition. It is apparent that the transition from concrete to abstract cognitive functioning takes place specifically in each subject-matter area. It is still possible to designate an individual's overall developmental status as concrete or abstract on the basis of an estimate of his characteristics or predominant mode of cognitive functioning. This distinction between specific and general aspects is important for two reasons; first, the individual necessarily continues to undergo the same transition from concrete to abstract cognitive functioning in each new subject-matter area he encounters even after he reaches the abstract stage of development on an overall basis. Second, once he attains this latter general stage, however, the transition in unfamiliar new subject-matter fields takes place more readily. For example, a cognitively mature adult who has never studied astronomy is not completely in the same developmental position as an eleven-year-old when both begin an introductory course in astronomy. In other words, growth in cognitive development always proceeds at two levels concomitantly - specific and general. As a result of experience in studying a given discipline, pupils not only learn particular ideas that facilitate the later learning of other particular ideas, but also acquire greater capacity meaningfully to process more abstract material of any nature in that particular discipline and in other disciplines as well.

Educational Implications of the Transition from Concrete to Abstract Cognitive Functioning. The developmental shift in learning mode during early adolescent years has far-reaching implications for teaching methods and curricular practices in the secondary school. On developmental grounds, the student is ready at the secondary school level for a new type of verbal expository teaching that uses particular examples primarily for illustrative purposes. Concrete-empirical props and discovery methods should, however, be employed during during the early stages of instruction. Continued use of discovery techniques to improve problem-solving skills or to foster appreciation of scientific method is also thoroughly defensible. While it is reasonable for teachers to use examples and analogies occasionally, it is quite another thing to think that they must use them routinely as necessary props for transmitting all abstract meanings. Unfortunately, the progressive movement of education fostered widespread acceptance of the proposition that all verbal concepts are necessarily nothing more than rotely memorized verbalisms unless they reflect prior concrete experience. This belief led to the summary rejection of verbal exposition and discovery practices as the teaching of "type problems," the wholly mechanical manipulation of mathematical symbols, and the performance of cookbook laboratory experiments. Toward the latter portion of the junior high school period, a markedly different kind of developmental situation begins to emerge to the breadth-depth issue. Many students at this stage are ready to sink their teeth into more serious and solid academic fare, but unfortunately, suitable instructional programs are all too rarely available. Instructional programs such as the PSSC and the BSCS represent merely crude beginnings toward a psychologically and educationally defensible science curriculum for secondary school pupils. The secondary school student is prepared to master a much greater volume of subject-matter knowledge and to cope with greater depth as well as with greater breadth. If, however, he is required to discover most principles autonomously, to obtain most subject-matter content from primary sources, and to design his own experiments, he has time to acquire only methodological sophistication; in terms of substantive depth, he simply moves from a previously superficial coverage of broad areas to a comparably superficial coverage of more circumscribed areas. The real aim of secondary school and undergraduate education is to produce students who are knowledgeable both in breadth and depth of subject matter.

Specificity or Generality of Intuitive Learnings

Conceptual Schemes versus Specific Disciplines. Bruner and Inhelder proposed that the elementary school science curriculum should be based on an intuitive level, characterized by extreme generality and separation from the actual content of the various disciplines. Young children should learn certain universal and recurrent principles of science, e.g., "categorization and its uses, the unit of measure and its development, the indirectness of information in science and the need for operational definition," etc. It is questionable, however, whether general, content-free logical operations and principles of science have any applicability to the understanding of ideas in a particular science. Scientific method and theory are not readily transferable across different disciplines. Besides, general principles of scientific inquiry cannot be learned on a purely abstract and general basis at grade school age. The child could best understand them on an intuitive basis, but it is precisely because of the generality and nonintuitive properties that such general principles are valuable. Although the context, organization, objectives, and methods of the elementary school curriculum must obviously be adapted to the cognitive capacities of pupils, the curriculum must still systematically come to grips with the actual substantive content and specific methodology of each of the various disciplines.

The "Conceptual Schemes" Approach to Science Teaching. A notion propogated by an NSTA curriculum committee is that one set of conceptual schemes can integrate the substantive content of all of the scientific disciplines. In my opinion, no such set of conceptual schemes applicable to all of the scientific fields exists. Even if such a set of principles, comprehensive enough to embrace all sciences would be formulated, its utility would obviously be dependent on its being understood and applied at the high level of generality implicit in any such formation. On developmental grounds, however, elementary school pupils could, at the very most, hope to understand these themes at an intuitive level if at all; even high school students would typically lack sufficient sophistication to understand principles at the philosohical level required. Yet the NSTA Position Paper curriculum programs at all age levels. Such an assumption relies heavily on Bruner's conception that any subject can be taught meaningfully to students at any grade level. The Conceptual Schemes approach is philosophically, psychologically, and pedagogically sound provided that it is modified so that a separate set of conceptual schemes is made available for each particular discipline.

Learning by Discovery. In the early, unsophisticated stages of learning any abstract subject matter, the discovery method is extremely helpful. It is indispensible for testing the meaningfulness of knowledge and for teaching scientific method and effective problem-solving skills. Occasional use of inductive discovery techniques for teaching subject-matter content is defensible when pupils are in the concrete-operational stage of cognitive development. When the learning task is difficult and unfamiliar, autonomous discovery probably enhances intuitive meaningfulness by intensifying and personalizing both the concreteness of experience and the actual operations of abstracting and generalizing from empirical data. In lesser degree, this rationale also applies to adolescents and adults who are relatively unsophisticated in the basic concepts and terminology of a given discipline. As a primary method of transmitting subject-matter content, discovery methods are much too time-consuming and inefficient. In spite of conclusive empirical evidence, there are probably valid reasons for occasional learning by discovery. Probably the greater effort, motivation, excitement, and vividness associated with independent discovery leads to somewhat greater learning and retention. The question, however, is whether learning by discovery enhances learning sufficiently for learners who are capable without it, to warrent the vastly increased expenditure of time it requires, and whether, in view of this time-cost consideration, the discovery method is a feasible technique for transmitting the substantive content of an intellectual discipline to cognitively mature students.

Pedagogic Considerations. Two strands of the progressive education movement - emphasis on the child's direct experience and spontaneous interests, and insistence on autonomously achieved insight free of all directive manipulation of the learning environment - set the stage for the subsequent deification of problem-solving, laboratory work, and naive emulation of the scientific method. It was felt that if students worked enough problems and were kept busy pouring reagents into a sufficient number of test tubes, they would somehow spontaneously discover in a meaningful way all of the important concepts and generalizations they needed. In accordance with this new emphasis, students ceased memorizing formulas and memorized instead type problems. They learned how to work exemplars of all the kinds of problems they were responsible for. All was well provided that the teacher presented only recognizable exemplars of the various types. As the terms "laboratory" and "scientific method" became sacrosanct in American high schools and universities, students were coerced into mimicking the externally conspicuous but inherently trivial aspects of scientific method. Partly as a result of the superstitious faith in educators in the magical efficacy of problem-solving and laboratory mehtods, we have produced in the past four decades, millions of high school and college graduates who never had the foggiest notion of the meaning of a variable, of a function, of an exponent, of calculus, of molecular structure, or of electricity, but who have done all of the prescribed laboratory work. One basic lesson that some modern proponents of the discovery method have drawn from this educational disaster is that problem solving per se does not guarrantee meaningful discovery. The types of learning outcomes that emerge are largely a function of the structure, the organization, and the spirit of the problem-solving experiences one provides. However, an equally important lesson which these same proponents of the discovery method refuse to draw is that, because of the educational logistics involved, even the best program of problem-solving experience is no substitute for a minimally necessary amount of appropriate didactic exposition.

Discovery Methods in Acquiring Subject-Matter Content. Some discovery enthusiasts such as Bruner and Suchman grudgingly admit that there is not sufficient time for pupils to discover everything they need to know in the various disciplines, and hence concede that there is also room for good expository teaching in the schools. In practice, however, this concession amounts to little because they then claim that the acquisition of actual knowledge is less important than the acquisition of the ability to discover knowledge autonomously. Discovery methods are often based on a naive premise that autonomous problem-solving necessarily proceeds on the basis of inductive reasoning from empirical data. Actually, even young children usually start with some preconceptions or spontaneous models derived from their own experience or from the prevailing folklore. Another disadvantage in the discovery approach is caused by children's subjectivism and by their exaggerated tendency to jump to conclusions, to overgeneralize on the basis of limited experience, and to consider only one aspect of a problem at a time. It is unrealistic to expect that subject-matter content can be acquired incidentally as a by-product of the discovery experience. How many students have the ability to discover everything they need to know? In my opinion, the principal reliand should be placed on the expository approach for learning the content of a discipline, and "arranged" discovery should be reserved primarily for the learning process of science.

Discovery Learning and Structure. Learning by discovery leads to more orderly organization of knowledge only insofar as the learning situation is highly structured by the teacher or the textbook. Pure discovery techniques could lead only to utter chaos in the classroom. In the UICSM (University of Illinois Committee on School Mathematics) program, students are given a prearranged sequence of suitable exemplars, and from these they "spontaneously self-discover" the appropriate generalization. This type of discovery is obviously a far cry from the kind of discovery that takes place in research laboratories. I do not quarrel with the UICSM method of inducing discovery, but only with Bruner's interpretation that the integrative effects of learning by discovery are attributable to the act of discovery per se rather than to the structure and organization of curriculums such as UICSM or PSSC. Discovery methods often tend to ignore the particular substantive content of a discipline as long as it can be used to further the inquiry process. In Suchman's Inquiry Training, for example, there is no attempt to present systematically the content of a scientific discipline.

Readiness: Postponement and Premature Learning. There is little disagreement about the fact that cognitive readiness always crucially influences the efficiency of the learning process, and often determines whether a given intellectual skill or type of school material is learnable at all at a particular age of development. The pedagogic problem in readiness is to manipulate the learning situation that one takes optimal advantage of existing cognitive capacities and modes of assimilating ideas and information. Knowledge of the time table of intellectual development makes possible for the first time the scientific grade placement of subject matter. Intellectual training should not be postponed merely on the theory that an older child can invariably learn anything more efficiently than a younger child. Adequate readiness rather than age per se is the relevant criterion. By using an intuitive approach, it is possible successfully to teach elementary school children many ideas in science and mathematics that were previously thought much too difficult. The crucial issues are whether such early learning is reasonably economical in terms of the time and effort involved, and whether it helps children developmentally in terms of theri total educational careers.

Optimal Readiness and the "Critical Periods" Hypothesis. It has been argued by several groups that there are optimal (i.e., critical) periods of readiness for all kinds of cognitive acquisitions, and that children who fail to learn the age-appropriate skills at the appropriate time are forever handicapped in acquiring them later. Actually this hypothesis has been validated only for infant individuals in infra-human species. It has never been empirically demonstrated that optimal readiness exists at particular age periods for specified kinds of intellectual activities. The problem appears to be not that the degree of maturity disappears or declines in some mysterious fashion, but rather that it fails to grow at a normal rate because it is not appropriately exercised. When this happens, the individual in comparison with equally endowed peers incurs a deficit in cognitive capacity.

Can Any Subject Be Taught Intuitively at Any Age Level? Bruner believes that the answer to this question is "Yes." It is quite possible that prior intuitive understanding of certain concepts and principles during childhood cna facilitate their learning when they are taught at a more formal, abstract level during adolescence - even if the child's readiness for the earlier learnings is not adequate. However, confirmatory empirical evidence is still available. Furthermore, one must consider the greater risk of failure and the excessive time and effort cost involved in premature instances of intuitive learning. In general it is preferable to restrict the intuitively oriented content of the elementary school curriculum to materials for which the child exhibits adequate developmental readiness. In addition, the case is undoubtedly overstated to claim that any subject can be taught to children in the preoperational stage, or in the stage of concrete logical operations. Even assuming that all abstract concepts could be restructured on an intuitive basis, it would still be unreasonable to expect that they could all be made comprehensible to children at any grade level.

Can Children Learn Anything More Efficiently than Adults? David Page asserts that children can learn almost anything faster than adults if it can be given to them in terms they can understand. In my opinion, this proposition is generally untrue, although perhaps valid in a very limited sense. In the first place, older individuals, particularly miseducated, must often unlearn what they have been previously taught. Second, older individuals are more apt to haveemotional blocks with respect to particular subject-matter areas. Third, their intellectual abilities tend to be more highly differentiated. Finally, there is a marked flexibility as children move up the academic ladder. Generally speaking, however, adolescents and adults have a tremendous advantage in learning any new subject matter. In their initial contact with a new discipline, they are unable to move through the concrete-intuitive phase of intellectual functioning very rapidly and are soon able to dispense entirely with this aspect. Research findings suggest that genuinlly abstract and verbal learning is more efficient and yields a more precise and transferrable form of knowledge than its concrete-intuitive counterpart.

Accelerating Stages of Intellectual Development. If stages of development have any true meaning, acceleration of intellectual development must necessarily be limited. Piaget, in my opinion, unwarrentedly excludes the role of training and education in bringing about transition from one stage of intellectual development to another. There is evidence to indicate that schooling and urban living, per se, accelerate the acquisition of conservation and of combinational reasoning. Generally speaking, simple drill or training does not suffice to bring about acceleration of developmental stages, as many investigators have demonstrated. There is evidence, however, that the use of various verbal didactic procedures, in conjunction with concrete-empirical props, can accelerate certain developmental stages. Thus, it appears that after a certain degree of consolidation of the preoperational stage occurs, one can anticipate, and thereby accelerate, the attainment of the next high stage.

Developmental Aspects of Concept Acquisition. The preoperational child's dependence on concrete-empirical experience typically limits him to the acquisition of those primary concepts whose reference consists of perceptible and familiar objects and events (e. g., dog, house). The concrete-operational child's acquisition of concepts proceeds at a much higher level of abstraction and yields correspondingly more abstract concept meanings. He is able to cope with secondary concepts whose meanings he learns without actually coming into contact with the concrete-empirical experience from which they are derived. The highest level of abstraction in concept acquisition is reached during the stage of abstract logical operations.

Increased Abstraction and Precision. One of the most signifigant developmental trends in concept acquisition consists of a gradual shift from a precategorical to a categorical basis of classifying experience, or from a relatively concrete to a truly abstract basis of categorizing and designating generic meanings. At first, concrete images are employed to represent a general class of perceptible objects. With increasing age, various dimensional properties (e. g., size, form, color) become conceptualized and attain independent status in their own right and can be applied to any relevant object or situation. Conceptual development involves a continuous series of reorganizations in which existing concepts are modified as they interact with new perceptions, ideational processes, affective states, and value systems. Older children are less disposed to regard conceptual opposites (e. g., ugliness and beauty) as reified entities than as opposite ends of a conceptual continuum. They not only generate concepts of much greater scope and inclusiveness, but also develop subconcepts within concepts. Before subconcepts can truly be differentiated from a more inclusive concept, the latter itself must first be acquired by a conceptualizing process in which concrete (precategorical) criterial attributes are progressively replaced by attributes that are more abstract or categorical in nature.

More Concept Assimilation and Less Concept Formation. Beginning with the child's entrance into school, an increasing proportion of his concepts are acquired by definition or use in context. This concept assimilation characterizes the acquistion of secondary concepts. Once a child can meaningfully relate ot his cognitive structure the criterial attributes of a new concept without first relating them to multiple particular instances that exemplify it, he can acquire concepts much more efficiently. He would find it relatively more difficult to discover by himself (to acquire by concept formation) the more abstract and complex concepts he attains relatively easily through concept assimilation. After discovering the body of simple, everyday concepts that are available to them when they enter school, most individuals discover very few concepts by themselves thereafter. During the elementary school years, the ability to assimilate concepts depends on (a) gradual acquisition of an adequate working body of higher-order abstractions; (b) gradual acquisition of "transactional" terms; and (c) gradual acquisition of the cognitive capacity itself. Within the limits imposed by developmental readiness, systematic verbal instruction in abstract concepts at the elementary school level, combined with the appropriate use of concrete-empirical props, is pedagogically feasible and can greatly accelerate the acquisition of higher-order concepts.

Increased Awareness of Conceptualizing Operations. Awareness of the cognitive operations involved in concept acquisition does not develop until the child approaches adolescence and has been exposed to considerable systematic instruction in scientific concepts than in others because it is frequently the subject of direct exercise, with the teacher requiring the pupil to give reasons for his ideas.

Group Factors in Learning

Interaction Among Pupils. Do pupils learn more effectively when they work individually or in groups? There is no single answer to this question since it all depends on the nature of the task; on the size and nature of the group; and on whether our criterion of superiority is a group product or the individual products of the component group members. In performing simple tasks requiring little thinking, group activity seems to serve as a stimulus similar to the effect of a pace-setter. In novel and problem-solving tasks where obtaining a correct solution is facilitated by generating a multiplicity of alternative hypotheses, group effort often appears to be superior to individual effort. Closer analysis, however, reveals that this superiority is mostly attributable to the pooling of ideas. The group effort merely increases the possibliity of having at least one person who can arrive independently at the correct solution. If the learning product of each group member is used as the criterion of success, the less able members of the group usually accomplish more than they could individually. In effect, they enjoy the benefit of pupil-tutors. Certain tasks, however, such as the drafting of a report, can be performed more dfficiently by an individual than by a group. Finally, individualized instruction is much more efficient for learning the established content of a discipline than the traditional recitation or lecture-discussion approach. Discussion, on the other hand, is the most effective method of promoting intellectual growth with respect to the more controversial aspects of subject matter.

Teaching Style. The confusing debate about this subject is completely unresolved and promises to yield few clear implications for teaching practice. What works well for one teacher may be completely ineffective for another. This does not mean, of course, that all techniques of teaching are equally effective, or that pedagogic technique is not teachable. Teaching styles should vary, not only because of the variable personality of teachers, but because of the variability in pupil needs and characteristics. Appropriate teaching style is always relative to the particular educational objective that is being striven for at a given moment, e.g., the efficient transmission of established knowledge, the generation or modification of attitudes, the improvement of provlem-solving abilities, or the exploration and refinement of alternative viewpoints in controversial areas of knowledge.

Lecture versus Discussion. Most of the studies concerned with this problem report little difference between the two methods in terms of student mastery of subject matter; where differences do occur, they are usually in favor of the lecture method. It cannot be too strongly emphasized that discussion techniques cannot be expected to enhance learning outcomes unless students possess the necessary background information prerequisite for intelligent discussion.

Preconceptions and the Individualization of Instruction. Anyone who has attempted to teach science to children, or to adults for that matter, is painfully aware of the potent role of preconceptions in inhibiting the learning and retention of scientific concepts and principles. My students and I are currently investigating some of the reasons for the tenacity of preconceptions that are related to cognitive style. It seems plausible to me that individualized pedagogical organizers, specially tailored to the particular preconceptions of a particular learner, will greatly facilitate meaningful learning and retention. Unless proposed organizers take explicit account of existing preconceptions, it seems likely that these preconceptions will both inhibit related new learning of more valid scientific concepts, and eventually assimilate the proposed new ideas designed to replace them. Thus a seemingly important precondition for constructing individualized organizers for instructional units in science is to ascertain what the more common preconceptions of learners are by means of appropriate tests, and then to match suitable tailored organizers with pupils exhibiting corresponding preconceptions. If I had to reduce all of educational psychology to just a single principle, I would say this: "Find out what the learner already knows and teach him accordingly."

COMMENTS ON THE CONTENT OF THE SCIENCE PROGRAM

Richard M. Harbeck

U. S. Office of Education

To me, individually prescribed instruction is that instruction that is based on the meeting of performance objectives that have been selected on the basis of knowledge of what the individual brings to a learning situation, on what is judged to be his best rate of learning, and in the light of what would seem to be the best objectives that that particular student should meet. Then, on the basis of these objectives, there would be the selection and the sequencing of the various strategies or tactics for causing the learning to take place that seems to be best adapted to that particular student's needs. In the selecting and sequencing of these particular objectives, it should be done in such a way that the student is fully aware of the logical trend that ties these things together.

I have tried to take a look at what has been going on in the past few years in the development of science programs. There have been tremendous efforts and resources invested. I question the amount of some of these, not on the basis that they weren't needed but rather on the basis that if too much of an investment is made in something, the amount of the investment itself can stand in the way of certain kinds of needed change. It may be that the amount of investment in science programs over the last twenty years may represent a kind of Pyrrhic victory, especially when viewed in the light of what might hopefully be coming along in educational change. There are forces today that require that we be very, very direct in addressing ourselves to what is the best way of maintaining and improving a quality educational program. What happens when the resources made available for the improvement of education begin to increase to the point that they absorb the total national income? In other words, we've got to do something to increase the efficiency of the educational processes.

Science education must take place within whatever kind of educational organization we happen to have at the moment. If that context changes, then necessarily we must adapt or change our science education program. In talking about the content of science programs in general, I think that it is of value to take a look at the kinds of objectives that seem to be quite commonly used. These are usually stated in ways similar to those used in the other major areas of study. Words and phrases such as "appreciate," "understand the role of," and "realize" seem to predominate such statements. Some programs which seem designed for future scientists and engineers are specified in words such as "encourage," "develop skills," "challenge." Only a few science programs have gone beyond such general statements and represent attempts to subject the objectives to the kind of analysis essential for a program of individual progress. The objectives of most programs seem to reflect acceptance of such assumptions as these:

> All pupils enrolled in a given course need the same content and kind of instruction; all pupils enrolled in a course must learn at about the same rate; science learning takes place best in an open-ended laboratory situation; the established disciplines of science provide the best basis for curriculum and course organization; teachers well trained in the specialized science disciplines can be made available to teach the science course; it is possible to achieve to a reasonable degree the stated curriculum objectives within a traditionally organized educational program; it is possible to make objective measures of achievement of general objectives using normative and other traditional tests.

In listing these assumptions, I am not necessarily saying that they are wrong, but only that they are the basis for most existing programs. Their most outstanding characteristic is their lack of specificity. Ideally, if there are reasonable objectives, these should be the basis for the selection of the course content. From a practical point of view, the content in most of these courses seems to have as the basis for its selection, its relative importance to the science disciplines rather than to the learning needs of the students. Because of the general nature of most objectives, rationales can easily be found for the inclusion of almost any subject-matter topics. Of course, most science programs exhibit a selection and sequencing of content to assure some kind of logical development. Attempts have also been made in most programs to select content which will offer a real challenge to pupils and, hopefully, whet their intellectual appetites. Elementary school and junior high school programs frequently try to tie content elements together with the great ideas of science. This, perhaps, is in contrast to older general science courses which attempted to cover large amounts of factual information with little interrelatedness. Content certainly cannot be considered apart from achievement testing. It is best to assume that most teachers will still tend to emphasize those content elements that they know will be included in state or national tests.

The content of most of the major science programs has been organized to fit into the traditional educational structure. Elementary school programs are divided into content sequences identified with each of the grade levels. Junior high school programs tend to be organized around major discipline lines but are still associated with the departmentalized and graded school. Senior high school science programs were designed from the beginning with the assumption that specific sciences should be taught at their traditional levels. Some of the newest programs do reflect attempts to make them adaptable to some of the requirements for individualized instruction. At least one major elementary program has been primarily organized around such objectives arranged in hierarchical series. However, the surface organization of the science programs today does not differ substantially from that of twenty or thirty years ago.

I do want to point out that existing science programs are neither all black nor all white. There are key experiments or developmental activities underway which may lead the way for the educational context which seems to be developing. Most present programs, however, fail adequately to identify what it is that pupils should be able to do as a consequence of participating in them. For this reason, it is seldom to make more than subjective evaluations of the effectiveness and efficiency of the instructional materials and techniques.

To summarize, for the most part what has been developed in science education programs over the last ten or twenty years does not appear to depart organizationally from science programs prior to that period. There has not been enough attention given to the establishment or analysis of objectives and to the performance terms so that there could be developed adequate means of evaluating and assessing alternative ways of achieving these objectives.

SCIENTIFIC METHOD

Michael Scriven

University of California, Berkeley

I don't think science is very different from other subjects in its need for individualized instruction, particularly because the sciences are cumulative with respect to cognitive content and cognitive skills. I think it's obvious that individualized instruction is in some sense an ideal, and the main problem is how to do it without moving to the Oxford tutorial system. It seems to me that Swartz's paper, "A School for Human Children, is an ingenious argument for greater utilization of teacher time. There will probably be a predictable hang-up over the self-perceived status loss involved in a teacher becoming a guide rather than a resource person. To get that system going, we might need more psychotherapy and fewer summer institutes.

What should the goals of science learning be? Much lip service is paid to the idea of teaching scientific method rather than scientific content, an idea which leads to the conclusion just mentioned, that the best science teacher will be a guide rather than an authority.

I would like to talk now about one particular way of trying to handle one particular goal which is commonly dismissed as having been disproved five or six times. All claims, it seems to me, about the best routes to the criterion of scientific behavior and the proper age correlations for each stage of the route are so speculative as to belie all connection with the subject of science to which they allegedly refer. Consider the two following claims: (1) Some kids at a certain age and with a certain educational background can't handle certain types of concepts - obviously true; (2) We can now do something about this in terms of sequencing subject matter - that, it seems to me, is not true. The important question is not readiness for a particular set of pupils, at any particular year, but what could they have been doing and what would be the best out of the range of possibilities open? I think that this is one of the areas where we are going to have to abandon the hope of finding large generalizations. I think we're going to have to operate more in terms of finding out what is possible first, and then argue about whether we should do one or another of possible sequences.

Where do we get the ultimate goals of science education? My view is that in the ultimate selection of goals, we must first look at our obligation to society. This, however, does not mean that what we ought to be doing is increasing the amount of engineering education. Pure research into pure math, to take the extreme case, has always been worth at least what we paid for it. There is no need for the mathematicians to consider the pay-off for society, but society should observe that there is such a pay-off. It is, however, considerably more doubtful whether most research in psychology or in education has been sufficiently concerned with social return. In my view, research more directly aimed at helping society answer questions that were important to it would have paid off more at the theoretical level than the kind of anecdotal or rat-based kind of thing that has been going on in most of those areas. I spend a lot of my time refereeing research papers, and a great many of them are simply examples of the failure of science education. They consist of attempts to show that Newton is almost here for the social scientist, and that by supporting research on fish, some basic laws of learning will be produced. Parallels from discoveries in classical physics have no bearing on the highly complex fields of sociology and psychology. To find out things in these fields, you should know statistics and a whole lot of other things that nobody in physics knows or has to know. Science education, then, must certainly not fail to impart the background needed to operate the engines of technology and its gadgets to the prospective mechanic and housewife as well as to the prospective researcher. There seems no reason why everyday examples cannot be used to illustrate fundamental principles with both motivational and practical payoff, and it is a feature of some new curricula that they do this quite extensively.

How should we decide to divide the school year between science and nonscience courses and among the various sciences? I think that a good case can be made for a core curriculum occupying 50 to 75 percent of the student's time in the early grades (two through seven) with a core curriculum consisting of something to do with reasoning skills - alias critical thinking, alias scientific method in earlier and probably in later incarnations. Such a solution would bypass the need for an explicit division of study time into science and nonscience. The material to be used in the reasoning course would come from the sciences and from literature, from history, from philosophy and from medicine. There would be natural involvement of laboratory and field work, of projects, reading and lecturing. Somewhere near the present seventh grade, the separate identity of the subjects would be developed along with their special techniques. A part of the curriculum would still be reserved for the integrated, problem-solving training.

The real problem of the two-culture representation is that the humanities are often inhumane and the sciences, unscientific. We are all much too specialized to make use in our own fields of elementary techniques from others. To counteract this in schools, we need to emphasize, not only method rather than mass detail, but also the rational method rather than a mass of methodologies, each appropriate to a particular area. Philosophers of science have not contributed to this area. They keep trying to identify the true nexus of all scientific method and it's on a level of abstraction which is not teachable. But the other extreme of fiddling around with lab instruments is equally bad.

Is there a common core of scientific method that can be taught independent of extensive training in particular sciences? Our reply to this is to mention that there was no single, novel element in either Newton's or Einstein's grand syntheses. These paradigms of problem-solvers were just providing the right combination of ideas already in existence and that is all we can hope to do in education, whether on the mechanical or the content side. My view is that a large teachable area comprising both skills and knowledge can be identified between the two extremes that I've just mentioned. It's ancestry involves common sense, logic, operations research, probability and elementary statistics, cybernetics, experimental design, literary criticism, information and decision theory, the history of science and particular aspects of psychology, sociology, economics, and anthropology.

Let me mention a couple of things that I stuck into this scientific method program and then say one word about a slightly more general point of view. First of all, I used a programmed text for this which illustrates the topic coverage I am advocating. There are generally two objections to such texts - first, that they are too verbal, and second, that they present the subject in too granulated a form. There are, indeed, lots of bad programmed texts, but there are also some good ones. The good ones allow the overall structure to be seen. Usually programmed materials have pitted one particular program against a standard good textbook. If you are going to make such a comparison, certainly only the best in each field should be used. Good programs are very hard to write, but it can be done. My particular one, which got mangled in the editorial process, was written for eleventh graders and has been tested successfully with low background tenth graders. In picking materials I used topics where the kids will have no idea what the officially approved answer is. Some of the materials are psychical research, from magic, and even from astrology. Some elementary material on probability is included because we have got to get across to the kids the idea of chance expectation, and the fact that scientific information only begins at the point where you are doing better than chance, not at the point where you are getting right answers. Lots of trivial theories will give you right answers.

I want to stress that I do not think that the way you teach science is by teaching only this little core thing. Science involves teaching people the practice of science - instrumental work, laboratory experimentation, problem-solving, acquisition of knowledge, development of standards of objectivity, and so on. I don't think that you even need try to teach all of those to every kid, but one part of science that is important is the abstraction train. From my own experience, it does not seem that this is necessary for every kid to have laboratory experience. Part of the point of science education is to squeeze them away from the tangible to the theoretical. It isn't just that when they get to be fairly sophisticated the abstract concept will stand as a concrete objection for them. It is that it _must_, if they are going to be able to do any theoretical thinking in the more formalized sciences. An example of this is the close relationship between theoretical physics and mathematics. Problem-solving here is entirely formal without recourse to the lab.

Let me try to get some of this across by saying something about computers. If you try to get a computer to be an efficient storer of data, then you will find that it must have capacities which we describe in human beings as comprehension and understanding. That's a surprising result and indicates how hard it is for us to draw this line between merely teaching knowledge and teaching understanding. The criteria for efficient data storage are these: (1) high capacity, (2) fast read-out and recovery, (3) some filter on the input to avoid redundancy and inconsistency. Now it turns out that the human brain cannot handle the data that goes into it within one hour from its sensory input unless it takes the most stringent steps toward internal modeling, toward oversimplification, and toward the development of concepts. These simplifications, maps, codes and mnemonic devices are precisely what we have to give a child in order that he will be able to say that he understands the subject. The key criterion of understanding is novel output, and the automatic sequence of the use of analogical models is the capacity to produce novel output. The crudest approach to science education, namely stuffing them with facts, automatically necessitates that you give them what it takes to produce understanding. It appears that in science education, sometimes those things which appear to be most antipathetical are, as a matter of fact, reconcilable.

INDIVIDUALLY PRESCRIBED INSTRUCTION IN SCI :E

THE OAKLEAF PROJECT

Warren Shepler and Jacqueline Cohen

University of Pittsburgh

Dr. Shepler. In 1964 the Learning Research and Development Center at the University of Pittsburgh established a cooperative working relationship with the Baldwin-Whitehall School System. During the three-year interval, 1964 to the present, the IPI (Individually Prescribed Instruction) model has been implemented in the areas of reading, mathematics and science at the Oakleaf ELementary School. The project was based on the following assumptions:

1. One obvious way in which pupils differ is in the amount of time and practice that it takes to master given instructional objectives.

2. One important aspect of providing for individual differences is to arrange conditions so that each student can work through the sequence of instructional units at his own pace and with the amount of practice he needs.

3. If a school has the proper types of study materials, elementary school pupils working in a tutorial environment which emphasizes self-learning can learn with a minimum amount of direct teacher instruction.

4. In working through a sequence of instructional units, no pupil should be permitted to start work on a new unit until he has acquired a specified minimum degree of mastery of the material in the units identified as prerequisite to it.

5. If pupils are to be permitted and encouraged to proceed at individual rates, it is important for both the individual pupil and the teacher that the program provide for frequent evaluations of pupil progress, which can provide a basis for the development of individual instruction prescriptions.

6. Professionally trained teachers are employing themselves most productively when they are permitting such tasks as instructing individual pupils or small groups, diagnosing pupil needs, and planning instructional programs, rather than carrying out such clerical duties as keeping records, scoring tests, and so forth. The efficiency and economy of a school program can be increased by employing clerical help to relieve teachers of many nonteaching duties.

7. Each pupil can assume more responsibility for planning and carrying out his own program of study than is permitted in most classrooms.

8. Learning can be enhanced, both for the tutor and the one being tutored, if pupils are permitted to help one another in certain ways.

Dr. Bolvin, Director of the IPI project, has added some other assumptions that he and the staff feel are important.

1. A sequence of ordering of objectives can be made in each of the curriculum areas.

2. Learning, to be meaningful, must be placed to some degree in the hands of the learner.

3. Active responses are better than passive responses for most learning.

4. Student errors when used for diagnostic purposes are not punishing.

5. In the elementary years of school all children can move through the same objectives in the tool subjects.

6. Entering behaviors can be measured and suitable instructional materials can be prescribed for each child.

7. Permitting the child to work at the boundary between what he knows and what he needs to know next is itself a motivating strategy.

8. If individualization is to be accomplished, then children must be provided the materials that permit self-learning.

9. Children can learn effectively with much less teacher verbal instruction.

10. Children can learn from other children.

11. Not all teachers can work effectively with all students.

The IPI science program was developed around the rationale found in two science programs: the AAAS (American Association for the Advancement of Science) program and the SCIS (Science Curriculum Improvement Study) program. We have attempted to provide pupils with an opportunity for having stimulating laboratory experience based on the hierarchy of scientific processes and concepts to be found in these two programs. In the primary grades we have focused on the process goals, while at the intermediate level we are assessing the possibility of developing a structure which will deliberately integrate the process goals with the content hierarchy. Our first task was to develop specific instructional objectives stated in behavioral terms that would teach the condepts and processes. These goals are stated in terms of such action verbs as "the pupil discriminates, sorts, names, identifies," and so forth, instead of such words as "the student understands, knows," and so forth.

Dr. C. M. Lindvall, The Associate Director of the Learning Research and Development Center, has specified the characteristics of these objectives as follows:

1. Each objective should tell exactly what a pupil should be able to do to exhibit his mastery of a given content and skill. It should typically be something that an average student can master in a relatively short time, such as one class period.

2. Objectives should be grouped in meaningful streams of content.

3. Within each stream or area the objective should be sequenced in an order such that each one builds on those that preceded and is prerequisite to those that follow.

4. Within the sequence of objectives in each area the objectives should be grouped in meaningful sequences or units. Such units can provide breakpoints, so that when a student finishes a unit in one area he may either go on to the next unit or switch to a unit in another area.

What we are finding in our continual assessment and diagnosis of our objectives is that often we are wrong. We have found that some of the programs did not work when we tried to put them in their particular structure. What we thought was an appropriate order ten years ago may not be an appropriate order today.

Mrs. Cohen described the operation of the program. One of the most important elements of a program of individualized instruction, whether in science or in any other curriculum area, is diagnosis. A placement test is administered to each student before he begins instruction in the science program. This test enables the teacher to identify the general areas of the curriculum in which the student lacks competency, and those in which he exhibits mastery. It does not test for mastery of each objective in the curriculum. The placement test is scored in terms of individual "test units" (each unit is a small cluster of related objectives, which is a subset of all of the objectives found within a unit of study). By examining the individual placement scores for each unit test, the teacher can determine which test unit the student has placed out of, and which test unit requires more extensive diagnosis to determine his exact instructional needs. To pinpoint the exact needs in a unit where a student has not exhibited mastery he takes a pretest prior to receiving any instruction in that unit. This pretest covers specific sequences of behavioral objectives. It covers each objective in the test unit and is scored with individual totals for each objective. Although the placement tests are administered to groups of children, the pretests are given to individuals. A student works independently on one of these and then takes as much time as he feels is necessary. The last element of diagnosis is the posttest. This test also consists of items related to each objective in the unit. The posttest and pretest are identical in format, and both are administered to the students individually (to non readers by means of a tape).

If the student demonstrates mastery on the posttest, he then begins the next unit sequence as prescribed by his teacher. If he fails to exhibit mastery on the posttest, he may be prescribed the same lesson again or assigned whatever related worksheets and supplementary materials are available. We plan to have more alternate lessons available in the future.

Information gained from these diagnostic techniques is used in prescription writing, which is the daily process of designating a task for the student to complete. In a typical example, placement test scores indicated that Mary K. fell below the mastery level at test unit 3. She was therefore prescribed pretest 3. On the basis of her scores the teacher then prescribed lessons K-6, K-7, and K-8. On Mary's first attempt in lesson K-6 she did very well, but her performance in lessons K-7 and K-8 was unsatisfactory. Lessons K-7 and K-8 were thus prescribed again, but this time she was directed to work with two other students who would serve as peer-tutors. After Mary K. successfully completes the prescribed lessons, the teacher will prescribe posttest 3 to assess mastery.

At the present time the instructional sequence consists of a series of highly structured lessons. These lessons are designed to teach a very specific behavioral objective through laboratory experiences. They are primarily self-instructional packages that require little, if any, interaction with the teacher. Each lesson package consists of assorted materials (i.e., manipulative devices, single-concept films, tape cartridges, and lesson booklets). Throughout the lesson the student is required to respond directly to various taped questions directly related to the lesson. He marks his answer in the lesson booklet so that his responses can be monitored at some later time.

All the students work independently on the lessons and they may take as much time as they like. While working with a given lesson package, the student is free to observe a pheromenon as many times as he likes. If he wishes, he can devote all of his science period to free exploration with the materials. There is no direct student-teacher interaction required during the lesson, and the teacher is essentially free to serve as a tutor.

Dr. Shepler. One of the critical elements of this method is pupil self-evaluation. Each student has a folder which contains work pages for the day's tasks and also the prescription sheets for the student's current work. The student himself knows in which areas he has performed poorly and how he has subsequently recovered. Presently some of the fourth-grade students are participating in a very sophisticated form of pupil self-evaluation. They are examining the diagnostic information and writing their own prescriptions. Although the teacher does not interfere, he continually evaluates the student's prescriptions and may offer suggestions at times.

A certain amount of efficient classroom organization is necessary with this method. All of the science paper work is taken care of by teacher's aides, who are neighborhood women working full or part time. The aides score and record the test mark, make sure that the student's folder is up-to-date, and periodically check the materials kits. At the present time, the first and second grades at Oakleaf have twenty-five minute science periods twice a week. The third and fourth grades have three twenty-five minute science periods a week, one of which is a discussion period. Each student works at his own carrel in the science classroom. Each carrel is equipped with a small cartridge-loading tape recorder and a set of earphones.

At the beginning of each science period the students go to the material shelves in small groups to get the materials kit prescribed for the day's work. These kits are prepackaged and self-contained so that the students merely have to pick out their appropriate box.

We have had many criticisms from the casual observer about the amount of testing we are doing. Dr. Glenn Heather has made some assessments recently of how children feel about our whole testing procedure. In his preliminary studies he finds that the children in the IPI program are much more receptive to testing than the children in non-IPI schools. Apparently the children find this testing approach a motivation to learn and do not experience test anxiety in a way that they would in a normal school. This business of pupil self-assessment and self-awareness is a very critical aspect of individualization of instruction.

Dr. Thier. These tests specify the activity that the child has just gone through. Do you do any testing regarding the child's understanding of the relationship between various pieces and his ability to apply some of this knowledge to new situations?

Dr. Shepler. We are not as sophisticated as we would like to be. However, integration of knowledge is also an individualized experience. I don't think that anybody knows how to tell just when this happens to an individual.

Mrs. Sherburne. How do you keep your system flexible enough with all these set objectives?

Dr. Shepler. There is an ongoing research and development program. We gather a great deal more data in this particular program than normally in a school system. By studying the relationship between pretest, posttest and lessons, we are able to analyze whether they are effective measuring instruments for children. When we find an inconsistency we never blame the child; we immediately go back to the materials in the program to see where we have erred.

Dr. Lipson. I'd like to comment on Herb Thier's point about teaching the ability to solve new problems. Every pretest is often a challenge to use the student's integrated past knowledge.

Dr. Shepler. We consider what we have done so far pretty much the development of the core of the program. Our next attempt to further individualize instruction is to prepare materials so that the child can move away from the core when he is ready. From the structured core, the student should move toward guided learnings where he has many opportunities to make selections in terms of process and approach. Then his next step should be toward much more independent, individualized learning where he can attack a long-range problem in science for an extended period of time. Not all children are ready for these steps at the same time, and we'll have to develop some real good diagnostic techniques to try to find out when the child is ready.

Presently there are several types of data being collected by LRDC to aid in the assessment of the IPI science program. The wide variation of student scores on the placement test clearly indicates the need for individualized instruction. We continue to evaluate all of the many tests to determine whether (1) the program is an effective means of individualizing instruction, and (2) whether the instructional materials and tests are effective teaching sequences. Although standard tests, such as the Stanford Achievement Tests, are administered to all Oakleaf pupils, consequences concerning the effectiveness of our program will not be clear for some time. Only the first, second, and third graders have been actively engaged in the total program so far. An attitude inventory administered to the students indicates that they like science best of all the subjects they study.

At the present time, we have a total of forty-seven lessons in the kindergarten-first grade series. The next series for first and second graders, has a total of 114 objectives. We estimate that the K-3 program would contain approximately 500 objectives. Hopefully by September of 1968 we shall have completed this primary program, and by September, 1970 we should have completed the entire K-6. Our basic goal in future curriculum development is to integrate the three planes of learning: process goals, content goals and permeating concepts. These last will be drawn from the three major areas of science: physics, chemistry and biology. In our learning model we view each objective as being one segment in a cube, having the dimensions of process, content and concepts. As a student progresses up the core continuum, he should begin to branch out in a deliberately planned and structured manner. From "directed learning" he would move to "guided learning." The last and highest order of student experience would be that of independent study. To implement such a program would require a very rich environment.

THE INTERMEDIATE SCIENCE CURRICULUM STUDY

A Program of Individualized Science Instruction

For Grades Seven Through Nine

Ernest Burkman

Florida State University

The ISCS group has set three goals for itself. First, we aim to develop a general rationale and a set of specific objectives for instruction in science in grades 7 through 9. Second, we are designing full-year sets of individually prescribed instructional materials directed toward the objectives emerging from the rationale study. Finally, we are studying the impact of these materials on a large and presumably representative national sample of junior high school students and teachers working in standard classrooms. We do this in a school setting where most junior high science instruction covers many relatively unrelated topics in a rather arbitrary sequence. Very little experience and virtually no data have been accumulated as to how students at this age level form associations or concepts in any area of science. Since science teaching at this level has tended to be verbal rather than laboratory or environment centered, there is very little direct classroom experience to draw upon. With this in mind, we decided to remain flexible in the early stages of effort. We have assumed that careful specification of objectives, sequence, etc., could be done better and more efficiently after a period of trial and error with respect to the impact of various learning sequences, and with the process of individualizing instruction.

The project began full-scale operation in June of 1966. The primary product of the first writing conference was a core sequence and several separately bound "excursions." The initial outline for the core sequence was organized around the twin themes of "operational definition and measurement," and "energy, its forms and characteristics." Basic to the design of the materials was the assumption that all students should be able to move through the activities in the materials with little direction beyond that provided there. The teacher was to serve as a stimulator of thought and as a classroom organizer and manager. These materials were tested during the 1966-67 school year in 37 schools by 50 teachers with 4,000 students. Other than periodic informal center meetings the teachers received no direct orientation in classroom procedures (a teacher's manual was provided). The trial schools were selected to include a wide range of geographic and cultural conditions. Very few of the schools or teachers had been involved with any of the recent efforts to develop science curriculum materials. Since the first year's field test was aimed at answering fairly broad questions, the project depended heavily upon subjective data.

On the whole, the 1966-67 teachers not only adjusted well to their new role, but most actually preferred it to what they has been doing previously. Some teachers chose to keep their students together for a time before allowing them to proceed at their own rate, but many had sufficient confidence to use the self-pacing approach from the beginning. Teacher feedback indicated that student motivation was extremely positive. Overall interest was reported to be high for both boys and girls throughout the year except where there were severe reading problems.

It was recognized from the outset that the achievement test data in the trial schools could never provide the fine-grain information needed to make judgments about adequacy of sequence. To get this kind of information, a second trial of materials was conducted - this one using computer-assisted instruction equipment. As the materials became available for classroom use, they were programmed for presentation by the Florida State University 1440 CAI system. The semiprogrammed nature of the classroom materials made programming less difficult than it would have been with conventional textbooks. During the 1966-1967 school year, sixteen Tallahassee, Florida junior high school students of varying abilities took the computer-controlled course in lieu of regular classroom work. After each session the proctors made comprehensive subjective notes as to what problems each individual student had encountered and what help was given. The major problem pointed up by the CAI trial was that invalid assumptions had been made regarding the quantitative skills of seventh graders. Students' facility in carrying out arithmetic operations with decimals had been overestimated as had their ability to handle multi-variable quantities (such as speed and momentum). In addition, dealing with certain abstractions such as the distinction between mass and weight proved difficult for many students.

As a result of the 1966-1967 field and CAI test it was decided to retain the basic instructional approach but to revise both text and format drastically. This was done during the summer of 1967, and in addition an eighth-grade sequence was drafted that built upon the content and process notions included in the seventh grade. The twin themes for the eighth-grade program were "the structure of matter" and "model building." In the seventh-grade revision, the relationship between the core sequence and the excursion had been altered. Performance tests have been included at several points in the core and these determine which students should do certain excursions. Many new excursions were developed, and the volume of the excursion material is now approximately equal to the core. Particular attention was given to developing remedial excursions dealing with quantitative skills.

The overall flow of content in the projected three-year sequence is from physics toward chemistry toward biological science and from the fundamental to the applied.

In September of this year, roughly 12,000 students began field testing the new materials. The eighth-grade sample is composed, for the most part, of students who used seventh-grade materials in 1966-1967. The revised seventh-grade materials are once again being tested via computer-assisted instruction but on a new and improved IBM 1500 system. Thus far, the 1967-1968 tryout teacher feedback has been highly enthusiastic about both the seventh- and eighth-grade courses. Student motivation is reported to be very high in both programs and reading difficulties appear to be much less severe than last year. Teachers new to the program this year appear to be adjusting to their new role more readily than did their counterparts last year. The reaction of the computer-assisted instruction students is quite interesting. Motivation remained high for all of them throughout the entire 1966-1967 school year. All chose to remain in the CAI group throughout the year even though they were free to return to their regular classrooms at any time. This year motivation has, if anything, been higher than last.

This coming spring the project will begin a careful behavioral study of the seventh-grade course. We will begin by attempting to state in behavioral terms what is called for at each step of the present sequence. We plan very little revision for the seventh-grade program until the summer of 1969. By then, the behavioral study should have yielded specific revision guidelines. During the summer of 1968, the eighth-grade course will be revised into a form not unlike the present seventh-grade materials. The first draft of the ninth-grade materials will also be developed. The project is scheduled for completion in August of 1971.

The size and comprehensiveness of the ISCS sample, the nature of the materials being developed, and the large bank of easily retrievable data being collected offer unique opportunities for much-needed longitudinal research. Some studies have already begun, but much of the time of the project's staff and graduate students has been invested in developing materials and organizing the information collecting and retrieval system.

In commenting on the formal paper that I have submitted, let me point out that the two characteristic features of individualization about which we are most concerned are self-pacing (where the student goes at his own rate) and multiple pathways. We have two basic activities going on. One is a short-range activity and the other is long-range. We'd like to see something happen in individualization in schools right away - this year if we can. There are some dangers here obviously. A whole area of research is necessary to find out to what degree school administrators, teachers and students will accept a different mode of instruction. We also have to consider such things as cost and other practical details, but at the same time it would be nice to have solutions on a long-haul basis, and the main thing we need before we can get these is data.

In determining the content of our program we had to make arbitrary decisions and then see what happens in practice. We do not trust many of the theories made in exclusion of subject matter or of the kids. So many dictums of education that seemed very possible to me last year no longer seem possible since I've been trying to put pen on paper and tinker with wires and make equipment and materials that the kids will react to. Curriculum-making, like politics, is the art of the possible and you have to go through a developmental aspect along with a research aspect.

In the seventh-grade material the core book describes a series of activities. This keeps kids going through the tedium much less painfully than if you don't have the gadgets in front of them. Wherever we think there might be a problem, for instance where we first asked the kids to multiply two decimals together, we provide a branch point leading them to the excursion book. If the student is able to perform that part of the excursion, he is directed to proceed back to the core. If he doesn't have that competency then he is programmed off into a side loop. About two-thirds of the excursions are not keyed in that manner. Instead, the excursion is mentioned in the core book with words that suggest, "If you'd like to try this, go ahead."

We designed special equipment available in an equipment kit to go with the course. The complete apparatus costs about $700 for five sections, which is reasonably cheap.

So far, we are depending on printed presentation and equipment handling to carry the course. Without question, we are going to have to go to other media as we go along. We know of certain points where we want to make loop films, and we may have to audio-program the whole thing for some very slow readers.

THE COMPUTER AS AN AID TO INDIVIDUALIZED INSTRUCTION

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A computer may be used as an aid for individualization of instruction or, as I should prefer to say, for individualization of a learning program through any of several techniques. These can be used in any of the three concepts of individualization. The first of these concerns the master tutor concept with complete customization of learner projects. The second is optimal adjustment to the individual learner's proficiency profile, and the third is the learner-directed approach. The simplest goal of individualization is purely quantitative; that the student for a given time and effort should learn as much as possible judged by customary achievement measures. A second goal is more qualitative; that the student should have a better understanding and retention of the things he has learned through his work. Beyond these there are further less tangible goals, but many think, potentially more important; that emphasis on meaning and purpose in the learning activity and on formulation and achievement of goals may give the student a broad perspective of the interrelationships of things he knows and insight into how he develops mastery of a new area, so that he will develop general ability to laarn, a problem-solving set toward his work, and habituation to a self-direction and initiative.

Individualization does not imply the gross inefficiency of putting the student entirely on his own, either in designing or in carrying out his learning program. It is clear that for a fixed student-teacher ratio the teacher will find that in the case of individualized activity it is more demanding to follow what is happening and to recognize the need for teacher intervention in it, then in the case of group activity. Thus, a key technical goal in realizing individualization of instruction is to find efficient means of collecting and processing behavioral data and using it to achieve effective supervision of student activity with a minimum of teacher time. It might seem that the problem of supervision is thus an economic one, but even with this factor set aside I think that a more fundamental limitation would be discovered, namely that too few teachers have the combination of talents needed to make an individualized program fully successful. Some technical means would need to be found so that the average supervising teacher is not required to be exceptionally capable.

Perhaps the first use of the compter in individualized science instruction is as an object of instruction itself. My colleague, Dr. Kenneth Iverson of IBM, has demonstrated for years that even students well below high school level can learn to program computers well, and develop enhanced depth and breadth of mathematical understanding from having done so. Used in this mode, a computer should be considered as a kind of mathematical laboratory. Availability of the computer may permit the student to experiment directly with simulation models of processes or systems that would otherwise be completely inaccessible to him. A computer can also present and supervise extremely rich programs of instruction involving simultaneous use of flexible displays, logical control, rapid calculation power, and so forth. In addition to the above essentially conversational modes of use, the computer can also effectively be used as a direct tool of administration to carry out the elaborate record-keeping functions and routine tests and prescription functions that are central to an individualized school.

In an individualized school these several uses of the computer are complementary rather than mutually exclusive, each facilitates taking advantage of the other. As more work is done in the area of computer assisted instruction, it seems more and more likely the computer techniques will be of decisive importance for making possible individualized instruction on a broad basis in the schools.

STATEMENT OF THE ROLE OF STANDARDIZED TESTS

IN SCIENCE EDUCATION

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Beginning with the introduction of the Army Alpha Test of Intelligence in World War I, standardized or norms-based tests were introduced into U.S. schools at a slow but steady pace. Then, following World War II and the wide-scale use of intelligence and aptitude tests, standardized or norms-based tests rapidly assumed a prominent, and in many cases, a dominant role in U.S. education.

Buros' Sixth Mental Measurements Yearbook published in 1965, lists 1,219 tests, of which 795 were deemed of sufficient interest nationwide that they were critically reviewed. Consider, then the present state of affairs -- like it or not, a sizable portion of U.S. secondary schools today teach "to the test" -- either the various aptitude and achievement tests of the College Entrance Examination Board, the New York State Regents' Examination, or the American College Testing Program. Additionally, an even larger number of elementary and secondary schools teach "to the test" in efforts to prove to their constituencies that the quality of their education is "at or above the national average." In such cases, "the test" is usually a nationally standardized instrument such as the Stanford or Metropolitan Achievement Tests, the Iowa Tests of Basic Skills, the Iowa Tests of Educational Development, the California Achievement Tests, and others.

Large city school systems in particular are acutely aware of their national standing and view with alarm their falling progressively further below the national averages as more and more of their pupils come from culturally different backgrounds that virtually guarantee low performance on these essentially culturally loaded assessment instruments.

By "teaching to the test," I mean that consciously or unconsciously, teachers tend to teach those kinds of learning tasks called for on these various standardized achievement tests. Consequently, there is heavy emphasis on teaching fundamental operations in mathematics; reading for detail and main ideas; vocabulary; diagramming sentences; and rules and laws (sometimes prettied up as concepts and generalizations) in science. Now it so happens that many of these learning tasks are perfectly legitimate and do in fact, in the opinion of many curriculum developers, represent the "need to know" objectives of learning and teaching at the elementary and secondary school levels. At the same time, there exists little or no hard data that supports the inclusion of certain of these tasks in a priority list of learning objectives for the late 1960s and beyond. Clearly, a sizable group of educators and academicians currently believes that the processes of science and social inquiry deserve at least equal time with the rules and laws of science and sociology.

Further, the most insidious side-effect of norms-based or standardized tests seems to me to be the emphasis on the norm -- the emphasis on the performance on a particular test of a mythical, typical child in a mythical, typical class in a mythical, typical school.

The key question that test instruments should be addressing is: "What is the learner now able to do that is measurable or observable?" This requires the development of criterion items that are performance tasks arranged in a validated hierarchy of learner behaviors. Probably the soundest approach to the development of such items is the building of voluminous item pools as suggested and implemented some ten years ago by Benjamin S. Bloom and his associates, and more recently advocated by Michael Scriven in Perspectives of Curriculum Evaluation. A more economically feasible approach may be the development of criterion items that have been adjudged to be representative of a class of generalizable tasks, as exemplified in the Process Measures of Science -- A Process Approach, developed by AAAS.

In any event, it is my earnest hope that in the foreseeable future, schools and colleges will be mainly concerned with what their entering students and their graduates can do and not with their grade-point averages, their Carnegie units, or their SAT scores.

THE APPLICATION OF THE CONTINUOUS PROGRESS CONCEPT TO THE NATURAL SCIENCES IN HIGHER EDUCATION

J. William Moore

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For the past two years, Bucknell University has been experimenting with a continuous progress concept of course development in several departments including biology and physics. Although the notion of continuous progress is not new in education, it has remained relatively untried in four-year institutions of higher education. This may be because of an assumption that college students are more homogeneous than those in elementary and secondary schools; and second, the reward system for university faculty members does not encourage innovation in teaching practice. Bucknell's interest in trying such a program stems from the university insistence that both teaching and research can be subjects for scholarly approach.

The guidelines involving objectives for both instructional program and procedures are:

1. The university has a responsibility to develop an instructional program which systematically increases the students' capability for self-directed inquiry.

2. The university has a responsibility to develop an instructional program which maximizes the probability that the skills, concepts, principles, and the more creative dimensions will be mastered by the student.

3. The university has a responsibility to provide an opportunity for the student to observe great exemplars of scholarship.

4. The university believes that teaching occurs only when the student acquires a previously determined set of behaviors

more effectively and/or efficiently as the result of the involvement of a teacher.

5. The great variation of individual student characteristics demands an instructional program which will allow for these differences while permitting the individual to attain those educational objectives deemed important by the university.

6. In order to constantly improve the instructional process, the university's instructional improvement program must be based on a sound program of research and evaluation.

As a result of these guidelines, the Continuous Progress Program was initiated in the fall of 1965. In September of 1965, the Department of Biology became the first science department to become involved in the program. Beginning with the academic year 1967-68, the Physics Department has also been included.

The procedures for program development and implementation for both science departments are essentially the same. In both cases, the departments spent the first year in the development of the instructional program with one staff member in each department being released full time to assume responsibility for this activity. To assist each department, the dean of the College of Arts and Sciences and one member of the Department of Education worked with the respective departmental faculty members. Implementation of the continuous progress program was scheduled to begin with the second academic year of the program. During this actual trial, special attention was given to program evaluation.

A segment of each discipline, equivalent to three course units in the traditional program, was selected for programming. In biology, the courses were: Animal Anatomy I, Animal Anatomy II, and Experimental Morphology; in physics, the courses were General Physics I, General Physics II, and Introduction to Atomic or Nuclear Physics. In the discussion of course objectives, particular attention was given to the objectives of the laboratory. In the case of biology, the decision was made to maintain the existing traditional objectives of the laboratory. Physics has chosen to question the objectives of the traditional laboratory program and they have attempted to redefine the laboratory's function in terms of unique experiences which it can provide.

During the process of specifying course objectives, direction was given to the departmental staff members by the Department of Education project coordinator in the preparation of course objectives in behavioral terms. The development of an adequate evaluation program for student achievement proved to be the most formidable task. First, department staff members frequently assume that their tests are reliable and valid. In the new format, however, the professor is forced to evaluate carefully the reliability and validity of his testing procedure, as well as his instructional procedure. Second, many students fail to achieve mastery on the first or even the second examination of a unit, and consequently numerous equivalent forms of the respective test had to be developed. Finally, it was necessary to develop a system of test scoring which would provide the students with results as quickly as possible and information about what to do if his performance had been unsatisfactory. A 1620 computer is being used for test development, test scoring, and test analysis in the non-laboratory parts of the courses. Four alternate forms of each test item were placed in the computer. This procedure makes it possible for the computer to develop numerous equivalent forms of a test for each unit with only minimal effort on the part of the staff member. The computer was also used to score the student responses to multiple-choice items and to direct students to additional instructional sequences of material which they might study in preparation for a second or third examination on the unit. Finally, the computer provided an item analysis as a basis for revising the instructional sequence.

Following the development of evaluation procedures, the staff next turned their attention to the instructional procedures to be used by the student. Because of the magnitude of this aspect of development and because there were limited funds and time, currently available instructional materials were used wherever possible. New materials created by the staff were developed in a highly intuitive fashion. The three criteria used in selection of appropriate materials were: First, the effectiveness of one form over another; second, the cost of a particular mode; and third, the amount of teacher time required for presentation in a particular mode. During the 1968-69 academic year, a series of "coordinated seminars" will be held as a means of providing the student an opportunity to relate the individual concepts and principles he has learned and to observe and hopefully identify with a scholar in a discipline.

At the first meeting of the biology program, students were given instructions about this new mode of learning. They were told that they were expected to reach a predetermined achievement level equivalent to an A or B in the traditional grading system. Failing to achieve this level of mastery, they would be required to complete additional programs and then be retested. Only when a student had achieved mastery on a given unit would he be permitted to advance to the next unit of work. Thus, some students might complete more than one course during the semester while others might require all or part of two semesters to complete one course. The only limits placed on these individually determined rates of progress was the requirement that every student complete at least four of the seven units of the first course by the end of the first semester, and that no student be permitted to spend more than two semesters in completing the entire course. The students were then given a statement of the objectives of the course, copies of the instructional materials and procedures for the first unit, and were told that when they felt they were ready to complete a unit test, they should petition the professor to take it. On the second day after taking the test, they should check with the professor to determine how successful they were and to set up a conference with him during which time they would either be given additional instructional material on the first unit or a list of objectives and educational materials for the next unit. While in some cases it would be necessary for them to work directly with the professor in the actual achievements of these concepts, in the majority of the cases, the instructional procedures would be of a self-instructional nature. It may be of some interest to note one difference between the Bucknell Continuous Progress Program and similar programs in the elementary and secondary schools. Specifically, the Bucknell Program permits the students to work on instructional sequences at a time suitable to them rather than during regularly scheduled periods.

To determine the effectiveness of this Continuous Progress Program in biology, students who had applied for admission to the introductory anatomy course were randomly assigned to two groups. The experimental group (N=35) participated in the Continuous Progress Program as described above, while the control group (N=35) participated in a traditionally structured lecture-laboratory course. Both groups had the same educational objectives, utilized the same evaluation devices, and were taught by the same professor. Finally, all students in both groups were tested on each unit, posttested at the end of the first course, and administered a questionnaire to assess their attitudes. An analysis of the data concerning the achievements and attitudes of the experimental and control groups showed the differences between the groups to be statistically significant at the .001 level. Comparisons of performance of the two groups on the final test administered at the end of the course yielded results consistent with the results of comparisons of errors on the unit test. The mean numbers of errors on the posttest for the control group was 67.40 with a standard deviation of 17.04, while the corresponding mean number of errors made by the experimental group was 58.97, with a standard deviation of 14.82. Again, there were reliable differences between the two groups with the statistical differences reaching the .001 level of significance. Because of the significance of student attitudes concerning the instructional process, statistical comparisons were made of student responses to items describing concepts central to the Continuous Progress Program. On the basis of a chi-square analysis of each item, it appears that the experimental group responded more favorably to the Continuous Progress Program than did the control group. In general, students responded most favorably to the different mode. An effort was made to make some observations concerning the faculty's attitude toward the program. An analysis of the responses of those members who were directly involved in the program indicates strong, favorable support. To date, fourteen of the twenty-eight departments at Bucknell have made formal requests to cooperate with the Department of Education in the initiation of Continuous Progress Programs.

Some of the more apparent questions raised in this development are these:

1. How can more efficient means be developed for coping with the overwhelming task of providing the necessary instructional and evaluation materials?

2. How does one define the teaching load in the Continuous Progress Program?

3. What are the ramifications of such a program for the four-year university? Will it be a three-year program for some students and five for others?

4. How can the university obtain the funds to support the development and research aspects of the program?

It can be concluded that the Continuous Progress approach to instruction does have the potential for solving some of the more perplexing instructional problems for the individual learner than the traditional program. It seems clear, also, both from an intellectual and operational point of view, that the Continuous Progress Program will always be a more complex approach to instruction. However, in dealing with the instructional problems of the learner, it is critical that educators resist the temptation to reduce the complexities of those problems by regressing to the traditional approach to instruction, thus, tending to ignore the more important instructional problem of the individual learner.

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