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THIS LECTURE, PRESENTED NOVEMBER 16, 1965, AT THE UNIVERSITY OF WASHINGTON, WAS THE SEVENTH IN A SERIES ENTITLED 'EDUCATION IN AMERICA--THE CONTINUING CHALLENGES.' THREE AREAS WERE DISCUSSED WHICH RELATE TO THE FORCES EXPECTED TO INFLUENCE EDUCATIONAL SYSTEMS--(1) THE INDIVIDUALIZATION OF INSTRUCTION, (2) COMPUTER-ASSISTED INSTRUCTION, AND (3) PSYCHOLOGICALLY BASED INSTRUCTIONAL DESIGN. (JC)

THE NEW PEDAGOGY

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Learning Research and Development Center
University of Pittsburgh

November, 1965

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If one sets his sights on the shape of pedagogy and instruction in the schools of tomorrow, and tomorrow is not the distant future, what can be said about the forces that will influence educational systems? In my talk this evening I will venture some opinions about my expectations. I will suggest three areas for your consideration: (1) the individualization of instruction; (2) computer-assisted instruction; and (3) psychologically-based instructional design. Many of you might have corrections and additions to contribute which I hope will come up in discussion.

Individualization of Instruction

By the individualization of instruction I mean the adaptation of instructional procedures to the requirements of the individual learner. The theme of individualizing instruction is a very old one in education, and much lip-service is paid to the psychological fact of individual differences in abilities and styles of learning. Educators however continue

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[1]This lecture, presented November 16, 1965, at the University of Washington, is the seventh in a series entitled Education in America: The Continuing Challenges.

to struggle with the problems of meeting each child's educational needs; in the elementary school, serious attempts are made at grouping within the classroom, and recently the ungraded elementary school has attracted considerable attention as an opportunity to provide for a greater degree of individualized instruction. Efforts like ungraded elementary schools will undoubtedly continue and will be important as attempts to tailor education to the individual child. However, other solutions are clearly needed if we are to approach anything like our ideals for individualization of instruction.

Very early in this century the work of Washburne and Parkhurst was concerned with "an individual system in education." With respect to this, in 1926 Dean William S. Gray and his associates concluded that "sufficient evidence has been adduced, not in Winnetka alone, but in other schools and under differing conditions as well, to make it difficult to justify complacent adherence to traditional methods." Over the years political expediency and technical difficulties seem to have resulted in something of a compromise between individualized instruction and traditional practices. As Cremin points out: ". . . most frequently this took the form of dividing the students in each grade into sections of slow, average, and rapid learners on the basis of group intelligence tests. This practice is fraught with difficulty, since the aptitudes and achievement of any given child may vary considerably from subject to subject."

The problem of adapting to individual differences in education has been analyzed by Cronbach in terms of several patterns; these patterns which I shall describe are probably not mutually exclusive and range from historical, to present, to future possibilities.

Pattern one assumes fixed educational goals in a fixed educational treatment. Individual differences are taken into account chiefly by dropping students along the way. Tests are used to decide which students should go faster and be imbued with higher-educational aspirations. The social theory involved is that every child should "go as far as his abilities warrant." However, in this case, a weeding-out process, reached earlier or later by various individuals, is assumed.

A variant of the pattern I have just described, which can be called "adaptation within a pre-determined program," is to permit an individual to stay in school until he masters, or at least learns to a specified criterion, certain essential and common educational outcomes. This procedure has never been followed in any pure form since it would extend the education of some youngsters until they are oldsters. It is practiced, however, in the old policy of keeping the child in the first grade until he can read his primer, and in the more recent non-graded primary unit which some children complete in two years and some in four.

This first pattern of adaptation has two variants then: one in which the duration of instruction is altered for an individual by sequential selection and weeding-out, and the other in which the duration of instruction is altered by training to a fixed criterion. In both of these patterns the educational goal for each student is essentially the same and the instructional treatments provided to the student are fixed.

A second pattern of adaptation to individual differences is to determine for each student his prospective future role and provide for him an appropriate curriculum. We see this system in operation when students are channeled into academic courses, vocational courses, or homemaking courses;

or in the decision to give the vocationally oriented students one kind of mathematics and the academically oriented another kind. There is an obvious danger in setting differentiated goals, e.g., differentiating mathematics so that it is the exclusive possession of a selected class while other classes are drilled on formulas useful to shopkeepers. (Today the theme in mathematics teaching, and in other subjects, is to give every pupil an understanding of the same basic discipline, even though some students go farther, deeper, and broader.) Adaptation to the individual by this second major pattern of "matching goals to the individual" is also operating when a student selects his major field of study in high school or college. Adapting to individual differences by this second pattern assumes that an educational system has provision for optional educational objectives, but within each option the instructional treatment is relatively fixed.

A third pattern of adaptation to individual differences attempts to teach different students by different instructional procedures; within each of these instructional treatments there is a minimum fixed sequence of educational goals which must be mastered. This pattern of adaptation can be implemented in a variety of ways: at one extreme a school can provide a fixed instructional sequence and students are pulled off the track for remedial work, and then, when the damage is repaired he is put back into the general track. At the other extreme, an instructional program can provide detailed diagnosis of the student's competencies -- his learning habits, achievements and skills -- on the basis of which a unique prescription is made for a course of instruction specifically tailored to that student. In this latter procedure, some students might learn on their own by discovery, some learn by more structured methods, some learn by reading, some by listening, etc.

Between these two extremes, toward the direction of the latter, lies the kind of adaptation to individual differences that will probably occur in the near future. The quality of the system which is developed depends upon the answer to many research and practical implementation questions. How well can individual student needs be diagnosed? How well can teachers write instructional prescriptions based on student information? What is the character of the information required? Research indicates that in the presence of inadequate information, it may be best for teachers to follow an average treatment for everybody and not attempt to differentiate on the basis of unreliable information; but with reliable information and techniques for making an instructional decision, effective student differentiation is possible. The entire question of the interaction between the characteristics of the student at a particular point in his learning and the methods of instruction is raised. An additional problem is practical determination of the costs and operating techniques that will make the differentiation of instruction suitable to the practical school administrator and to the training of the teacher.

The differentiation of instructional techniques on the basis of individual-differences variables is an ideal which will demand detailed analysis that intertwines the methods of experimental psychology and psychometrics. Proof will have to be forthcoming that the selection and devising of instructional methods does indeed interact with student differences so that their achievement in seeking a given educational goal is significantly greater than if an average best method were employed.

There are two principal problems in researching and developing systems for implementing individualized learning: (1) the psychological study of the interaction between individual difference variables and learning treatments, and (2) experimentation in school systems with strategies for adapting to individual differences. This latter includes the development of appropriate administrative procedures, teacher training, and especially the development of appropriate instructional materials (including computerized classrooms) and testing instruments.

The best way to get on with the first problem, i.e., study of the interaction between individual differences and learning patterns is to do controlled experiments which involve the analysis of student histories of response to subject matter as a basis for assigning future instructional procedures.

The second problem involves innovations by school administrators in the effort to produce a school environment which is highly responsive to the differences among students. What would such an individualized system look like? Each student would be placed at his achievement level on a learning continuum, and his instruction would proceed from that point. Student performance would be carefully tracked and monitored so that information would be provided about his style of learning, his rate of learning, and his subject-matter mastery. Information would be provided about the necessity for more detailed instruction and about attained proficiencies which require little additional teaching. With the provision of detailed information about student learning progress, the teacher would provide instructional decisions in the form of prescriptions for the student's subsequent learning steps. This would be accomplished in a school organization permitting individualized learning to proceed in the absence of conventional class boundaries. The teacher would no longer see the student as a component of the class but an individual on a continuum of achievement. Materials would be provided to maximize the student's self-instructional capability and to provide the teacher with a rich resource of materials for differentiation among students.

Automatic data-processing methods would be necessitated by the large amount of information obtained for each student and required for effective instructional decisions by the teacher. Instructional decision-making in the writing of lesson prescriptions would become an increasingly important role of the teacher. He would not assign lessons grossly to a group, but would be flexible on the basis of the differential information provided to him.

In building such a procedure, specific technical problems are abundant. For example, how does one evaluate the effectiveness of individually prescribed instruction? How does one grade and evaluate students in such a learning situation? What are the technical problems not only of student evaluation but of test construction, materials development, and teacher training, for such a system? Furthermore, what are the questions to be asked of the data obtained from detailed tracking of the student in individualized learning which can provide a rich resource for studying long-term subject-matter learning?

Computer-Assisted Instruction

The second area influencing a new pedagogy is the use of the computer for instruction; and when I say "for instruction," I preclude the very important influence of large-scale batch data-processing which consists of record-keeping in a school, a school system, or on state-wide basis, and also such things as school scheduling, data-bank functions, budgeting and accounting, inventory control, prediction of enrollment, school summary statistics, and so on. In contrast, I refer to the fact that during the past ten years there has been considerable growth of interest in programmed instruction and teaching machines, and that also during this time, there has been a rapid development of computer technology. To date, for the most part, there has been only sporadic interplay between the teaching machine and computer developments, but concern is accelerating along these lines. This will be especially true in the light of individualized instruction, since it appears that it will be highly impractical to provide the amount of instructional material, the number of teachers and assistants, the close monitoring of student performance, and the data-processing required for adapting to individual differences without calling on computer capabilities. Two aspects of computer-assisted instruction are of interest: 1) the console or station where the student interacts with the subject mater and 2) the analysis of student performance for wise instructional decision-making.

With appropriately designed student stations, a computer-on-line station can provide a rich environment for the student. New ways can be provided for him to interact with and manipulate subject material as he works with it; for example, by means of a cathode-ray tube which looks very much like a small television screen, alpha-numeric characters can be generated directly by the computer; the student can control these with a standard typewriter keyboard. He can also use a device such as a light pen to move objects on the screen. Through appropriate audio and video storage devices, the computer can control fast-access to sound messages and pictures. A young child might manipulate a number line on a cathode-ray tube; he might trace letter patterns to learn handwriting The typewriter can accept only the correct spelling of a word and prompt him as he makes errors. A high school student might learn about the algebraic representation of an equation by manipulating different parameters on a keyboard, which change the slope and intercepts of a curve displayed on the cathode-ray tube. A college student in a qualitative analysis course in chemistry might analyze various materials in a simulated laboratory by indicating his reagents on a keyboard and getting a picture of the solution or precipitate that might be obtained in the actual laboratory.

What I have just said is the general propaganda by those [illegible] interested in this field, and it is realistically being at[illegible] in [illegible] own laboratory and in others, but there is even more [illegible]ating and hard work involved in the second aspect, that is -- the specific problem of instructional decision-making. As the student learns, the system must prescribe the next instructional step on the basis of information about the student's immediate and more long-term history. An instructional strategy is built up on the basis of the student's performance.

Consider the following: we have a subject matter broken down into sub-objectives that the educator decides to teach the student; for each sub-objective a test has been constructed to assess the behavior defined by that objective. We also have designed a set of alternative instructional steps which the educator has provided for teaching each sub-objective. We have then [illegible] teaching materials which we need to prescribe and present to the student in some order. This order is determined by the instructional decisions made by the teacher, by the rules we build into the computer, or by a combination of teacher and computer rules. The interesting question involved is how the teacher makes instructional decisions on the basis of student performance and whether he can be assisted by building some of his rules into the computer. (This is somewhat analagous to saying that we build certain rules into a test in order to score it, and the teacher or counselor then uses this test to make decisions about the student.)

Of course, when such decisions are made, we have in mind certain criteria which we are trying to optimize. Many things can be considered as important criteria, to name a few: a high score on an achievement test, the largest increase between a pretest and a posttest, the time taken to reach a certain percent correct, performance on a retention test given some months after learning, performance on a test of novel instances of the concept being learned, and the ability and willingness of the student to learn similar concepts on his own and in his own way.

The important question for research is how the history of student performance is to be taken account of and what criteria of performance are to be emphasized. The variables involved are several: first, the extra-instructional history of the student; these are long-range existing individual differences, such as aptitudes and learning styles; second, the more immediate instructional history, or those measures obtained in the course of instruction which summarize learning status at any point in time; and third, decisions about the next learning step. Efforts to examine instructional decision-making rules will involve intensive research concerned with the empirical determination of the interaction between long-term history effects, measures over the more immediate course of learning, the teaching characteristics of a lesson, and the stated criteria for learned performance.

I have spent a little time elaborating what I consider to be an especially interesting problem to be faced in the development of computer-assisted instruction. There are others, such as the development of computer languages which make it easy for the designers of a curriculum to put their course in a computer system without being forced to become minor expert computer programmers. Such problems obviously require study and development, but the solutions certainly appear to be not impossible.

Two more items should be mentioned in reference to computer-assisted instruction, and then I can move on. First is the point that a significant use of computer-assisted instruction is in the design and development of instructional materials. It is reasonable to assume that in the future, a mathematics or reading curriculum will be developed and validated on the basis of feedback data obtained about how well certain aspects of the course teach certain objectives. If certain parts of a teaching sequence do not teach well, then data can be obtained on student learning to indicate how these teaching sequences are to be revised. A computer-assisted instructional system can provide a means for rather immediate and detailed analysis of learning records for curriculum revision.

The second item is that in addition to the tutorial and drill-and-practice aspects of a computer instruction system, it is further possible to envision a student station which is essentially an interrogative information-retrieval unit. Here we would like to have a capability which enables the student to freely construct general questions to which he can get reasonable information. The student might like to ask "What were the reasons for the depression in the early nineteen-thirties?" or "Why did Booth kill Lincoln?" Such systems which can provide to the student information in complex matters are certainly, at the present time, difficult to consider feasible; but it does seem possible, through a thorough analysis of the types of questions which might be asked, that progress can be made toward the recognition of a question by a computer program. The central problem seems to be not that of providing the answer, or of storing the information appropriate for the answer, but rather that of recognizing precisely what question is being asked.

Finally, in mentioning computer-based instruction I have done a direct disservice if I have conjured up any images of 1984 and cold, metallic automation. On the contrary, I suspect that efficient use of these tools will permit more time to be devoted to humanitarianism -- time which we seem to be in danger of decreasing.

Instructional Design

I turn now to a third aspect of pedagogy of the future, perhaps somewhat more difficult to say succinctly. It concerns the emergence of a unique speciality called educational technology or instructional design. To elaborate further: The use of modern science in the interest of society has become an important obligation of our times. This is true no less in education than it is in medicine and engineering. As increasing knowledge is accumulated in psychology and the behavioral sciences in general, a foundation will be provided for a growing scientific and technological base for instructional practice. The translation of scientific knowledge into practice requires extensive applied research and technological development. However, at this point in time, an entity to carry out the function of instructional design and development hardly exists. If a person (or organization) carried out such a function, how would he begin to work, and in what sort of conceptual framework would he carry out his job? I would like to guess at and discuss such a framework and describe some of the concepts that an "instructional designer" might use in thinking about his work. The tasks he must perform involve the interplay between theory, research, and application. I shall mention not application as such, but some aspects of the necessary research and development which can eventually lead to innovation and redesign in instructional practice.

The forces encouraging research and development basic to instructional practice are the following: (1) The increasing recognition among psychologists that their work has been too remote from the many problems of classroom learning. This recognition has been spurred on by the basic research that led to programmed learning in the form of programmed texts and teaching machines; (2) the increasing sophistication of the teaching profession which is forcing the behavioral scientist to provide it with knowledge relevant to the educational process; and (3) the increasing national sponsorship of centers and laboratories dedicated to mutually supporting relationships between behavioral science and educational practice.

Out of these trends will grow the "instructional designer." If such a person working in a research and development setting did exist, then it can be assumed that he would operate in the following manner. First this psychologist-instructional designer would analyze the subject-matter domain he is considering -- reading, mathematics, or what have you. He would think of a domain in terms of the performance competencies which comprise it. He would analyze representative instances of subject-matter competence in terms of the nature of the material the student has to attend to and the kinds of responses the student makes to this material, e.g., memorizing, concept learning, or problem solving; he would further analyze the structure of the subject-matter domain, perhaps in terms of its conceptual hierarchies. Second, our instructional designer would turn his attention to the characteristics of the students to be taught. He would need to determine the extent to which the students have already acquired some of the things to be learned and the extent to which they have certain predispositions which might facilitate or interfere with new learning.

These first two steps conceivably provide some information to the educational designer about the target performance to be obtained and the existing pre-instructional behavior of the learner. The designer must now proceed to get from one state to the other. This sets up his third task. This task consists of guiding or allowing the student to go from the preinstructional behavioral state to a state of subject-matter competence. This requires the construction of teaching procedures and materials that are to be employed in the educational process. As part of this process, he must take account of motivational effects and the ability of humans to generalize and extrapolate by providing conditions which will result in the maintenance and extension of the competence being taught. Finally, the educational designer must make provision for assessing and evaluating the nature of the competence and kind of knowledge achieved by the learner in relation to some performance criteria that have been established.

To many present-day educational practicioners this description of the process of instructional design may sound harshly technological, and indeed, perhaps some elegance has been lost in analysis. But presumably, once basic techniques are constructed, the teacher can use the tools of his profession with understanding, artistry, and sensitivity.

The design components that I have just described are: (1) analyzing the characteristics of subject-matter competence, (2) diagnosing preinstructional behavior, (3) carrying out the instructional process, and (4) measuring learning outcomes. I should like to briefly comment further on each of these.

Analyzing Subject-Matter Competence. First, analyzing subject-matter competence or what is it that is to be learned. When the psychologist turns his attention from analysis of standardized arbitrary tasks used in the laboratory to analysis of the behavior generally taught in school, he runs head-on into the problem of what is coming to be called task analysis. This is a relatively new phenomenon for the psychologist, because in the laboratory he has decided upon and constructed an experimental task pertinent to his particular purposes. He is not in a position to do this in the educational situation. In the laboratory, by preselecting his task to fit a problem, he has in a sense analyzed its stimulus and response characteristics. With real-life subject matter, he is faced with the problem of identifying the properties of subject-matter stimuli and their associated responses.

The properties of a subject matter which have been identified by some sort of an analysis of tasks, determine the dimensions along which the student is taught to generalize and transfer his knowledge. Presumably, the ability to transfer is a function of experience with a variety of examples and different subject-matter instances. For some dimensions of subject matter, there is little ambiguity about teaching for generalization and transfer or about what constitutes a variation of instances of a basic concept. However, as a subject matter becomes more complex, definition of a range of examples becomes more difficult and problems arise concerning whether training in various instances does indeed carry over to new situations.

The influence of the analysis of subject-matter dimensions can be seen clearly when one considers the teaching of very simple concepts. For example, in teaching a child color concepts, such as red and blue, he must learn to make the same responses to all members falling within a stimulus class and to make different responses to members of different classes. That is, the child discriminates between colors but learns to generalize to objects which differ in properties other than color -- red squares, red circles, etc. Once the appropriate dimensions of the task have been analyzed, they are handled systematically in the teaching procedure, and dimensions not relevant to the concept being taught are varied randomly so that the student learns to generalize among objects having in common no characteristic other than their color. As a result, the child learns the concepts of redness and blueness. This is the simple case however, and the instructional proce s becomes complicated w en the subject-matter properties to be generalized and discriminated are very subtle. For example, the concepts of early or late Mozart. A major problem with teaching such subtle and complex concepts is analysis and definition of subject-matter properties. Such analysis becomes increasingly problemmatical when there is disagreement among experts and where there are semantic imprecisions. Sometimes the distinction between classes is not clear to the learner because he does not have the necessary preliminary training required. At other times the confusion is subject-matter imprecision itself.

Analysis of subject-matter domain is the first step in the sequence of steps required for instructional design, and without it, the succeeding components will be inadequate.

Diagnosing Pre-Instructional Behavior. Once the subject matter and the content of the related behavioral objectives have been analyzed, the instructional designer turns his attention to the characteristics of the learner. This raises all the problems involved in diagnosing preinstructional behavior. At least four classes of preinstructional variables are determinants of the nature of instruction -- and I exclude here personality-type variables. (1) The extent to which the student has already learned the behavior to be acquired in instruction. It is not uncommon to find, if one gives the final test in a course as a pretest, that a portion of the students display the behavior they are to be taught. (2) The extent to which the student has acquired the prerequisites for learning the knowledge to be acquired, for example, knowing how to add before learning to multiply. Again a pretest often shows the absence of the behavior that is necessary for a student to begin new instruction. (3) The extent to which styles of learning or learning sets facilitate or interfere with new learning under certain instructional conditions. (4) A final consideration is given to aptitude-like variables which consist of the ability to make the discriminations necessary to profit from instruction. For example, aptitude in spatial visualization may be necessary in learning solid geometry or engineering drawing. These kinds of entering competencies which vary among individuals obviously influence what is learned and what can be taught.

In the instructional process, just as the analysis of subject-matter competence determines the target behavior to be attained, so does preinstructional behavior define the beginning point for guiding behavior through teaching. The array of variables and concepts involved in the preinstructional measurement of aptitudes, readinesses, and diagnostic measures of achievement must be systematized for increased understanding of how they interact with learning and for use in instructional design. In the analysis of readiness, for example, measurement of the fact that readiness factors differ with age and with individuals must be supplemented by analysis of the conditions influencing these differences and of the contribution of these differences to learning. When is a child "normally" capable of distinguishing a b from a d so that it is useful to teach him to learn to read? Prevailing norms necessarily presume prevailing learning conditions and not new learning environments. If designing instructional environments for early ages is considered, it is conceivable that the "curriculum" will not be formal subject matters like mathematics or reading, but instruction in behaviors which look more like basic aptitude-like skills.

In tackling the problems involved in considering preinstructional repertoires, the important jobs are first to investigate the relationships between individual difference variables and learning variables -- How shall individual differences be conceptualized in learning theories? -- and second, and more practically, to construct teaching systems for the accommodation of education to individual differences.

Carrying Out the Instructional Process. In the framework I am presenting, once the terminal objectives and intermediate subobjectives have been described, and once the preinstructional state of the student is described, the instructional process can be carried out. If entering behavior is considered state A, and a subsequent performance objective is state B, then the instructional process is designed to arrange the student's environment to get him, or if you prefer, have him get himself, from state A to state B.

For ease of thinking about the instructional process designed to produce subject-matter learning, I shall postulate that at least three kinds of processes seem to be involved. One, setting up new forms of student response, such as new speaking patterns or a new skill like handwriting. Second, setting up new kinds of subject-matter stimulus control, such as attaching already learned speech sounds to particular visual symbols. And third, maintaining the behavior of the student. This third category is less involved with behavior change and more concerned with increasing the student's likelihood to behave, and in this sense falls under the general label of motivation. I shall comment briefly on these three categories:

A very evident characteristic which leads to subject-matter mastery is the increasing precision of a student's behavior. In learning complex behavior, the student's initial performance is variable and crude and rarely meets the criteria of subject-matter competence. Effective instructional procedure tolerates these initially crude responses and gradually takes the student toward mastery. In accomplishing this, the instructional process involves the establishment of successively more rigorous standards for the learner's performance. This increasing competence is established by gradually contracting the permissible margin of error, and gradually decreasing the tolerance for exactness. An example of this is teaching precise timing and tempo to the music student. The student's beginning performance will be quite variable, and performance criteria should be initially gross and changed at a rate which assures continuing progress toward mastery. Over the sequence of instruction, the range of student performance will align itself with the particular range of acceptable performance defined as subject-matter competence which the student reaches or exceeds. Inappropriate constriction of performance criteria can be a hallmark of ineffective instruction leading to frustration for the student.

An equally, if not more significant process in subject-matter learning than the one just described is the process of setting up the stimulus control of performance. For example, in second language learning, it is easy to think about the transfer from an initial repertoire to a target repertoire. In teaching translation, the response "flower" is transferred from the English word flower to the German word "die Blume." In learning a concept, the responses apple, peach, and pear are transferred from the specific objects to the word fruit. The pertinent instructional process involved here is restructuring the student's entering repertoire so that certain responses are transferred to the control of new subject-matter material. The transfer of stimulus control is a major process involved in teaching students to make responses to more precise subject-matter discriminations, and also in teaching them to use previously learned skills in response to new subject-matter dimensions.

The two processes just described assume only that the behavior of an expert in a given subject matter is characterized by the facility by which it is called out by particular subject-matter contexts. However, a further characteristic of an expert's behavior is that it is apparently self-sustaining. The expert may continue to work for relatively long periods of time without seeming external support and without the various supports that are needed by the novice. Not only then is the expert's behavior controlled by the subject matter, but with increasing competence it can be characterized as self-sustaining. Research on the learning and teaching of self-sustaining behavior is an interesting problem related, perhaps, to exploration and curiosity.

Conditions Influencing Instruction. Within the kind of categories I have just described, the task of the experimentalist thinking about instructional design is to examine the conditions which influence these processes. Let me list three aspects especially interesting for research and development in instruction. They are: (1) the sequencing of instruction — for example, on what basis are the stages of teaching reading to sequenced?; (2) stimulus and response factors -- by what means of audio and visual displays do we best enrich the environment of the learner?; and (3) response contingencies -- how do we handle schedules of reinforcement, error correction, and other sources of instructional feedback? Systematic knowledge in answer to such questions is required for specific subject matters.

Measuring Learning Outcomes. Finally I come to my fourth component of instructional design -- the measurement of learning outcomes. It is clear that an effective technology of instruction relies heavily upon the detailed measurement of subject-matter competence at the beginning, in the course of, and at the end of the educational process. The increasing emphasis on instructional design in recent years has raised questions concerning the nature and properties of measures of student achievement and the assessment of subject-matter competence as it may be defined by subject-matter scholars.

Achievement measurement can be defined as the assessment of criterion behavior involving the determination of the characteristics of student performance with respect to specified standards. However, the scores obtained from an achievement test can provide primarily two kinds of information. One is the degree to which the student has attained criterion performance, for example, whether he can satisfactorily prepare an experimental report or can solve certain kinds of word problems in arithmetic. The second type of information that an achievement test score provides is the relative ordering of individuals with respect to their test performance, for example, whether Student A can solve his problems more quickly than Student B.

The principal difference between these two kinds of information lies in the standard used as a reference. The standard against which a student's performance is compared in order to obtain the first kind of information is increasing subject-matter competence along a continuum of achievement. The student's score with respect to specific tasks provides explicit information as to what he can or cannot do and indicates the correspondence between what the student does and the achievement criteria at that point in his learning. Measures cast in terms of such criterion standards provide information as to the degree of competence obtained by a particular student which is independent of reference to the performance of others.

On the other hand, achievement measures convey the second sort of information about the capability of a student compared with the capability of other students. In instances where a student's relative standing is the primary purpose of measurement, reference need not be made to criterion behavior or achievement standards. Educational achievement examinations, for example, are administered frequently for the purpose of ordering students in a class or school, rather than for assessing their attainment of specified curriculum objectives. When such norm-referenced measures are used, a particular student's achievement is evaluated in terms of a comparison between his performance and the performance of other members of the group. Such measures need provide little or no information about the degree of proficiency exhibited by the tested behaviors in terms of what the individual can do. They tell that one student is more or less proficient than another, but do not tell how proficient either of them is with respect to the subject-matter tasks involved. In large part, achievement measures currently employed in education are norm-referenced, and work needs to be done which will contribute to the development of criterion-referenced tests in order to assess the outcomes of learning. Criterion-referenced measures can provide information about both degree of competence and relative standing. Such tests are the kind most helpful for the purpose of curriculum evaluation and curriculum design.

In conclusion, I have attempted to give some of the research approach and perspective that is likely to be introduced into the design of instructional procedures in the future, as behavioral science and educational practice begin to be related in a mutually helpful way. I hypothesize that in the future four main areas of the educational process will be influenced: (1) Instructional goals will be analyzed in terms of both subject-matter content and categories of student behavior that suggest strategies of teaching. (2) The diagnosis of the learner's strengths and weaknesses prior to instruction for appropriate guidance will become a more definitive process so that it can aid in the design of a curriculum specially suited for the student involved. (3) The techniques and materials employed by the teacher will undergo significant change. And (4) the ways in which the outcomes of education are assessed, both for student evaluation and curriculum improvement, will receive more attention.

As these changes occur, it is likely that they will result in certain changes in school operation. First, the role of the teacher will be restructured. It seems likely that the teacher will be able to become more concerned with individual student guidance and individual progress in addition to his role as a group mentor. Second, the educators' goal of the individualization of student progress based upon student background, aptitude, and achievement will come closer to realization by school reorganization and the adoption of new practices. Third, instructional materials and devices supplied by industry will come under close scrutiny as to their instructional effectiveness (just as tests come under close scrutiny with respect to reports on their reliability and validity). Fourth, mastery of subject-matter competence will be easier to attain for a larger number of people in our schools, and tests which measure progress toward mastery will become important aids for the quality control of educational excellence. These developments, necessarily based on a developing body of pedagogical principles, should advance teaching toward the status of a profession nurtured by underlying behavioral sciences which are becoming increasingly relevant to the educational process.