DOCUMENT RESUME

ED 114 735 CG 010 195

AUTHOR	Bernard, Michael E.
TITLE	Task Analysis in Instructional Program Development. Theoretical Paper No. 52.
INSTITUTION	Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
REPORT NO	Theore-Pap-52
PUB DATE	May 75
CONTRACT	NE-C-00-3-0065
NOTE	37p.
EDRS PRICE	MF-$0.76 HC-$1.95 Plus Postage
DESCRIPTORS	Cognitive Development; *Concept Formation; Educational Improvement; *Instructional Programs; *Learning; Program Development; *Programed Instruction; Research Needs; *Task Analysis

ABSTRACT

A review of task analysis procedures beginning with the military training and systems development approach and covering the more recent work of Gagne, Klausmeier, Merrill, Resnick, and others is presented along with a plan for effective instruction based on the review of task analysis. Literature dealing with the use of task analysis in programmed instruction designed to teach concepts and principles is summarized. Topics relating to instructional objectives and the organization of subject-matter knowledge, learning hierarchies, hierarchical dependency in cognitive development, and instructional analysis and sequencing are examined from a task analysis perspective. Research recommendations and critique are provided. (Author)

CG

THEORETICAL PAPER NO. 52

task analysis in instructional program development

5

MAY 1975

WISCONSIN RESEARCH
AND DEVELOPMENT
CENTER FOR
COGNITIVE LEARNING

Theoretical Paper No. 52

TASK ANALYSIS IN INSTRUCTIONAL PROGRAM DEVELOPMENT

by Michael Edwin Bernard

Report from the project on Conditions of
School Learning and Instructional Strategies

Herbert J. Klausmeier
Principal Investigator

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

May 1975

Published by the Wisconsin Research and Development Center for Cognitive Learning, supported in part as a research and development center by funds from the National Institute of Education Department of Health, Education, and Welfare. The opinions expressed herein do not necessarily reflect the position or policy of the National Institute of Education and no official endorsement by that agency should be inferred.

Center Contract No. NE-C-00-3-0065

WISCONSIN RESEARCH AND DEVELOPMENT CENTER FOR COGNITIVE LEARNING

MISSION

The mission of the Wisconsin Research and Development Center for Cognitive Learning is to help learners develop as rapidly and effectively as possible their potential as human beings and as contributing members of society. The R&D Center is striving to fulfill this goal by

- conducting research to discover more about how children learn
- developing improved instructional strategies, processes and materials for school administrators, teachers, and children, and
- offering assistance to educators and citizens which will help transfer the outcomes of research and development into practice

PROGRAM

The activities of the Wisconsin R&D Center are organized around one unifying theme, Individually Guided Education.

FUNDING

The Wisconsin R&D Center is supported with funds from the National Institute of Education; the Bureau of Education for the Handicapped, U.S. Office of Education; and the University of Wisconsin.

TABLE OF CONTENTS

		Page
	Abstract	vii
I.	Introduction	1
II.	Task analysis: Antecedents and current status	3
	Military training and systems development	3
	Task analysis and education	5
III.	Task analysis in programmed instructional research	13
	Specification of terminal learning objectives: Structure of knowledge	13
	Behavioral and content analyses	15
	Instructional analysis	21
	Research recommendations	26
	References	27

LIST OF FIGURES

Figure		Page
1	Task analysis: Plan for effective instruction	10

ABSTRACT

A review of task analysis procedures beginning with the military training and systems development approach and covering the more recent work of Gagné, Klausmeier, Merrill, Resnick, and others is presented along with a plan for effective instruction based on the review of task analysis

Literature dealing with the use of task analysis in programmed instruction designed to teach concepts and principles is summarized. Topics relating to instructional objectives and the organization of subject-matter knowledge, learning hierarchies, hierarchical dependency in cognitive development, and instructional analysis and sequencing are examined from a task analysis perspective. Research recommendations and critique are provided.

I

INTRODUCTION

During the past six years, psychologists have increasingly become concerned with investigating the nature of the instructional process (e.g., Glaser & Resnick, 1972). With the advent of instructional psychology as an experimental discipline, the number of studies dealing with the design and validation of optimal learning sequences has dramatically increased.

Many prescriptive theories and models which characterize the process of instruction have been conceived. The following stages are typically present in theories of instructional design: (1) Identification of overall program goals. Decisions concerning the objectives of a curriculum are generally made at an administrative level within an educational system; (2) Specification of terminal learning objectives within a program. The characteristics of the target learning population generally guide the selection of objectives; (3) Analysis of learning objectives to determine prerequisite behaviors and knowledge needed to attain the objectives; (4) Construction of an instructional program based on the previous analysis of learning objectives; and (5) Assessment of learning outcomes.

The major focus of this paper will be on the third and fourth stages of the instructional process. Specifically, this paper examines the interaction of the analysis of learning tasks with the development of programmed instructional sequences designed to facilitate the attainment of learning outcomes. The following definition of an instructional program was used as a basis for the inclusion of theory and research related to the central topic of this paper:

> We define an instructional program as a reproducible sequence of instructional events designed to produce a measureable and consistent effect on the behavior of each and every acceptable student [Markle, 1967, p. 104].

Although many of the studies reviewed here employ autoinstructional media in presenting instructional sequences, the effectiveness of computers and teaching machines as instructional variables will not be examined. These instructional devices are of secondary importance in determining outcomes of learning.

Task-analysis procedures have been used to examine a variety of instructional methods aimed at facilitating the design of optimal learning programs. Several review articles have recently appeared that examine the process of analyzing the properties of complex learning tasks (Glaser & Resnick, 1972), the sequencing of instruction from a hierarchical, task-analysis learning perspective (Briggs, 1967; Gagné, 1970b), and the sequencing of mathematical program development (Heimer, 1969). However, few studies, if any, have centered on the analysis of instructionally oriented, school-related learning tasks. For the most part, this review includes only those studies that employ subject-matter and behavioral analyses of learning tasks as a basis from which sets of related concepts and principles can be taught.

II

TASK ANALYSIS: ANTECEDENTS AND CURRENT STATUS

The need to specify, operationally, the nature of behavioral objectives is widely recognized by psychologists concerned with the development of programmed instruction (e.g., Miller, 1962; Mager, 1962; Gagné, 1965; Mechner, 1967). Dale (1967) indicates that this aspect of instructional design can be traced back to the activity analyses and behavioral specifications elaborated by Bobbitt (1924), Charters and Waples (1929), and Tyler (1932). The different task-analysis procedures that are currently employed in educational research and in program development, however, have primarily been adapted from research on military job training. As a result, a review of conceptions of task analysis will begin with two representative approaches that arose in response to military training needs. Subsequently, strategies for conducting task analyses used in instructional program development in education will be considered.

MILITARY TRAINING AND SYSTEMS DEVELOPMENT

In military-training research, the process of systems design marked the coming of age for attempts to apply psychological principles to complex man-machine interactions (Gagné, 1962a). The advent of a theory of psychotechnology provided the human systems engineer with both a basis for systematically identifying the components of man-machine interactions and for specifying the human or internal conditions of the system. Training programs were developed that were efficient, unambiguous, internally consistent, and reliable (Gagné, 1965).

Miller (1953, 1954, 1962) has indicated that systems design provides a basis for the classification and selection of military personnel for certain jobs as well as for training and evaluation. Task analysis and task description are the two primary components of systems design. Task descriptions state the objectives, accomplishments, or outcomes of behavior. They are complete detailed descriptions (depending on the state of development of a program) of the task requirements of "all the interactions of man with machine and of man with the systems environment [Miller, 1962, p. 187]."

Miller provides the following example of a task description for a typist-keypunch operator: "Must be able to read messages in a variety of handwritings [1962, p. 203]." A more detailed task description of the task activity consists of identifying the following components of the target task (examples are provided by this author):

a. an indicator on which the activity-relevant indication appears [message written on a piece of paper];
b. the indication or cue which calls for a response ['punch out message'];

c. the control object to be activated [keypunch board];
d. the activation or manipulation to be made [keypunching]; and
e. the indication of response adequacy, or feedback [comments by supervisor] [1962, p. 201].

Task analysis is the systematic study of the behavioral requirements of tasks. A task analysis written by Miller for the task activity of a typist-keypunch operator reads:

> The operator must be able to distinguish between those parts of a message in which she can fill in unrecognizable characters from context and those parts of the message in which she cannot depend on context but must go back to the source of the message for interpretation. Both the ability to interpret from message context and deciding when context is not to be trusted require judgment--that is, intelligence of at least average or above. Errors introduced into the system at this point will be difficult to correct in system operation, and can have catastrophic consequences if not detected and corrected [1962, p. 203].

Miller (1954) suggests that the human capabilities that are requisites for performing man-machine task activities can be classified into the following categories: (1) perceiving, (2) recalling procedures, (3) recalling nomenclature, (4) interpreting, (5) making logical inferences, and (6) performing manual operations.

The comprehensive specification and analysis of behavioral outcomes and the identification of fundamental, human learning capabilities serve as the foundation of current educational and instructional programming theory.

The "What, How, Why, and Skills Approach" conceived by Latterner (1964) and Harper, Bull, and Onofrei (1970) has been used extensively at military training and military research and development centers and includes both the task analysis and task description procedures developed by Miller. This approach results in the following determinations: (1) what a person does, (2) how he does it, (3) why he does it, and (4) the skills and knowledge needed to complete a task. Latterner indicates that as a function of this kind of analysis:

> We can establish meaningful objectives; we can correctly delineate the threshold knowledge required in the student; we can accurately determine the behavioral changes we want to effect in the trainee; we can select proper subject matter for programming; we can determine correct sequencing for teaching; we can specify appropriate training or programming techniques, and we can establish real criteria for measurement [p. 168].

From this orientation, task analysis is a complete study of a work process that serves as a basis from which a training program is built.

The following steps are taken once a training objective is selected for analysis. The <u>What</u> phase involves the identification of physical and mental behaviors that are required to accomplish the final objective. Physical behaviors might include transporting, cutting, bending, grinding, putting together, making ready, and setting up. Mental behaviors might include planning, computing, judging, and directing (Harper et al., 1970).

These behaviors or subobjectives are then sequenced according to their difficulty and importance.

The manner in which the behaviors identified in the What phase are learned is accomplished in the How phase of the analysis. Such methods as using machines, tools, measuring instruments, calculators, formulas, and applying judgments or decisions could be included in this phase.

The Why phase provides a justification for the performance of each job. The reason behind each what and how behavior as well as an outline of the overall scope of the task to be completed is described in detail.

The Skill phase includes the identification of the prerequisite or threshold skills that are necessary to accomplish the what and how behaviors. Responsibility, dexterity, problem-solving ability, and endurance to complete a task are examples of skills that a trainee might need to bring to the instructional situation.

As conceived by military systems developers, then, task analysis is a process that identifies the characteristics of tasks in terms of specific attributes and specifies the nature of the prerequisite behaviors that underlie the learning of a task. While a considerable number of different approaches to a task and job analyses have been developed in the military industry (Folley, Farriman, & Jones, 1960; Gustafson, Honsberger, & Michelsen, 1960; Folley, 1964; Corrigan & Kaufman, 1965; U.S. Army Security Agency, 1967), all incorporate at least one of the previously described principles and techniques of task analysis and task development.

TASK ANALYSIS AND EDUCATION

Psychologists, having turned their attention away from conducting laboratory experiments to investigating the nature of the instructional process, have been forced to develop new ways of analyzing tasks and specifying the content of learning (Glaser & Resnick, 1972). This effort has resulted in the parallel development of methods for analyzing the characteristics of learning tasks and inclusive taxonomies that describe nominal categories of human learning. Taxonomies deal typically with internal or inferred processes of learning as well as conditions external to the learner that facilitate the attainment of different learning objectives (e.g., Gagné, 1970a; Klausmeier, Ghatala, & Frayer, 1974).

Numerous approaches to the problem of operationally describing a learning task have been conceived. In fact, in the field of instructional research and development, there is little consensus about what task analysis actually is (see Campbell & Schwenn, 1971). Generally, task analysis is a process that begins after the terminal objectives of an instructional program have been specified. The practical goal and use of task analysis is to facilitate the eventual learning, retention, and transfer of information and behavior. The following assumption, held by many instructional psychologists, underlies the use of task analysis:

> The learning of various kinds of component repertoires requires different kinds of teaching procedures, and an important research task is to identify the learning process and instructional procedures associated with different component repertoires [Glaser, 1965, p. 774].

This section will review major educational-psychological viewpoints that describe ways to analyze the characteristics of subject-matter competence.

The primary emphasis will be on describing the procedures. Somewhat less attention will be given to describing taxonomies of human behavior. While not all writers use the label "task analysis" in describing their procedures, it will be seen that each viewpoint has a great deal in common with the task-analysis procedures developed in the military.

The science of Mathetics, as originated by Gilbert (1962) and extended by Harless (1966), is defined as the "systematic application of reinforcement theory to the analysis and reconstruction of those complex behavior repertoires usually known as 'subject-matter,' 'knowledge,' and 'skill' [Gilbert, 1962, p. 8]." Mathetics is a systematic method for planning and organizing human learning. It has its focus on constructing a road map of instruction which a student should follow in order to master a subject and to organize learning conditions. This will ensure the student's following the designated roads.

The Mathetics process can be represented in four stages. Prescription involves the specification of behaviors or objectives that constitute mastery in some subject-matter domain. In the second stage, Development of the Domain Theory, the most essential elements of the subject matter are identified. The third stage, Characterization, involves analyzing the behavioral characteristics of the essential elements of the subject domain. The essential elements, which are combined into "prescribed repertoires," can be characterized by one of three types of learning: chains, multiple discrimination, and generalizations. The final phase, Exercise Design, incorporates information derived from the Characterization stage into a lesson plan based on an "exercise model." In this model, the learner must attend to a learning stimulus, make a response to the stimulus while under the control of a discriminative stimulus, and be immediately rewarded for an appropriate response.

While the Mathetics method places substantial emphasis on producing effective stimulus-response learning sequences that can adequately be reinforced, an equally important component is the analysis of subject-matter objectives into subordinate behavioral elements. The outcomes of this analysis play a determining role in the construction of programmed lessons.

An extremely popular taxonomy of educational objectives is contained in a volume edited by Bloom (1956). While no procedure for analyzing learning tasks is associated with the Bloom taxonomy, six hierarchical categories of behavioral objectives are identified. The six categories are purported to represent the kinds of human cognitive performances required in different learning situations. The taxonomy has been used extensively to identify behavioral objectives that guide the development of instructional programs and to indicate what behaviors must be learned in order to achieve the objectives.

The six main classes of objectives deal with (1) the recall or recognition of knowledge (e.g., facts, methods, processes); (2) the intellectual skills of comprehension (e.g., translation, interpretation, extrapolation); (3) the application of principles and concepts in novel situations; (4) the analysis of important principles, facts, and hypotheses in a communication; (5) the syntheses of essential elements in a plan of action; and (6) the evaluation of value, accuracy, and consistency using certain criteria.

Gagné (1965) has indicated, however, that the objectives provide "inadequate information about...the important conditions under which behavior will be expected to occur [p. 40]." In addition, Gagné (1965) states that since "the subordinate classes described are distinct from each other only in terms of their specific content rather than in terms of formal characteristics which affect their learning conditions [p. 40]," they cannot be used to derive distinct classes of behavior for which appropriate learning strategies can be specified.

Gagné (1962b) has proposed a method of task analysis that has become a prototype in the field of instructional research and development. Gagné's method derives largely from the work of R. B. Miller. According to Gagné, learning tasks can be broken down into subordinate knowledge (also referred to as capabilities, learning sets, skills, and behaviors) by asking, "What kind of capability would an individual have to possess if he were able to perform the task successfully, were we to give him only instructions [1962b, p. 356]?" This question, which is asked of each newly identified capability, eventually yields a hierarchy of skills related to the final task. It is predicted that the learning of a lower-level capability will produce positive transfer to the next, higher-level capability. Gagné and his associates have shown that in many cases the lower-level capability must be learned before a higher-level capability can be mastered. As will be shown in the discussion of learning hierarchies, Gagné's method provides a way to characterize the underlying structure of subject-matter domains and to decide the manner in which to sequence learning.

Gagné (1968a, 1970a) has generated a cumulative model of learning. A basic assumption of this model is that intellectual development is a function of the progressive learning of ordered sets of capabilities which build upon each other in a hierarchical fashion. Gagné specifies eight hierarchically related capabilities or types of learning that are "distinguishable from each other in terms of the conditions required to bring them about [1970a, p. 33]." The following is an ordering of Gagné's categories of learning: (1) signal learning, (2) stimulus-response learning, (3) chaining, (4) verbal associations, (5) discrimination learning, (6) concept learning, (7) rule learning, and (8) problem solving. These general categories of learning are hypothesized to account for the variety of human behavior observed in an educational setting.

Gagné (1968b) has suggested that the hierarchy can be modified by replacing the category "concept learning" with "classifying" and the category "rule learning" with "rule following." The rationale behind this change is that each type of learning is an intellectual skill rather than knowledge that can be verbalized (concepts, rules). Gagné's method of task analysis centers on what a learner must be able to do in order to achieve a terminal behavioral objective rather than on what the learner can verbally specify or produce.

Resnick (1967) indicates that following the identification of terminal learning objectives, a sequence of subobjectives must be formulated to promote successful attainment of the objectives. This sequence is determined by "identifying prerequisite skills and concepts for each objective; that is, skills and concepts which the child must already command before he can successfully learn the new objective [p. 7]."

The technique of <u>component analysis</u> enables the program developer to identify underlying prerequisite skills and concepts of learning objectives.

> Component analysis begins with any desired instructional objective, behaviorally stated, and asks, in effect, 'To perform this behavior, what prerequisite or component behaviors must the child be able to perform?' Several new behaviors are identified in this way. For

each behavior so identified, the same question is asked, thus generating a hierarchy of objectives based on behavioral prerequisites [Resnick, 1967, p. 7].

Resnick specifies the following three classes of skills that are proposed to represent the range of learned behavior of a child entering primary school: (1) orienting and attending skills, (2) perceptual and motor skills, and (3) conceptual and linguistic skills. Subskills within each of the three classes become terminal objectives. Each objective is analyzed in a backward fashion that yields lower-level subskills. When learned, these lower level subskills facilitate the attainment of the terminal objective. When the investigator identifies a subordinate set of skills, which can be assumed to have previously been learned by the target population, the component analysis is completed. This backward analytic approach provides a basis for the identification of an ordered set of skills for inclusion in an instructional unit as well as for the specification of skills that a learner needs in order to begin a curriculum sequence.

The writings of Klausmeier contain a systematic procedure for the development of instructional programs designed to teach concepts (Klausmeier, Ghatala, & Frayer, 1974; Klausmeier & Goodwin, in press). The procedure consists of the following steps: (1) analysis of the concept-to-be-taught; (2) specification of the level at which the concept is to be attained and of the cognitive operations that underlie the learning of the concept at a particular level; and (3) identification of instructional strategies that facilitate the attainment of the concept at some level of attainment.

Relevant information identified as a result of a concept analysis includes: (1) a definition of the concept; (2) its defining and irrevelant attributes; (3) examples and nonexamples of the concept that can be used in instruction and assessment; (4) the taxonomy in which the concept is a part; (5) principles in which the concept is used; and (6) problem-solving situations that require the concept-to-be-used in arriving at a solution (Klausmeier et al., 1974).

The Conceptual Learning and Development (CLD) Model developed by Klausmeier et al. (1974) can be utilized to identify operations that are prerequisite for the learning of a concept at a specifiable level of mastery. This model outlines the cognitive operations involved in the learning of concepts at four successively higher levels. Each of the levels (concrete, identity, classificatory, and formal) require progressively more complex cognitive operations. The level at which a concept should be taught can be suggested through an assessment of the entering competencies and knowledge of the target population.

Strategies for teaching concepts at each of the four levels have been, or are being, developed by Klausmeier and his associates. These strategies can be applied to the learning of concepts in many different subject-matter areas.

Merrill (1973) indicates five assumptions that can simplify procedures and that have been used for analyzing learning tasks: (1) content and instructional strategies are independent; (2) most educational courses involve two types of content--concepts and operations; (3) concepts and operations can be represented at two levels of abstraction--generalities and instances; (4) most higher level educational courses involve only four levels of behavior--discriminated recall, classification, rule using, and rule finding; and (5) instructional strategies should be directed toward rule using or rule finding (pp. 109-110).

In deciding how to teach an instructional objective, Merrill (1973) indicates, a content specialist with the assistance of an instructional psychologist should perform two separate analyses. First, a content analysis of a learning objective is conducted in order to determine the structure of the content. Most subject-matter content, contends Merrill, consists of a "network of concepts related by a set of operations [p. 119]." Content analysis involves identifying the concepts that compose an instructional unit as well as identifying relationships between the concepts. Second, an instructional analysis is performed to "(a) identify needs and goals as related to the course under consideration, (b) specify a mastery model (description of what the course is preparing the student to do), (c) specify rule using and rule finding situations, and (d) select and sequence the required concepts and operations from the content network [p. 116]."

There appear to be two problems associated with these various task-analysis procedures. The first problem is that the taxonomies of behavior and learning categories, which supposedly provide an organizing framework for analyzing learning tasks, have uncertain heuristic value for the individual concerned with developing instructional programs. That is, when one analyzes a learning objective into subordinate capabilities and prerequisite information, the characteristics of the objective and not an abstract behavioral category determine which subordinate behaviors a learner needs to learn in order to achieve the objective. For example, learning to tie one's shoe can be broken down into a series of sequentially related skills. These skills could be classified in an ad hoc fashion into any one of the taxonomies previously reviewed. Yet, the identity of each skill and the instruction that is needed to effectively teach each skill is, to a great extent, dependent on the nature of shoe-tying behavior.

The second problem concerns the somewhat narrow perspective of task analysis theory and methodology. A primary assumption of this perspective is that learning is an univariate process. Campbell and Schwenn (1971) have argued that learning is a multivariate process and that task-analysis procedures should include analysis of the learning task and the cognitive process that affect the learning process, as well as an investigation of those personality variables of the learner that may interact with the type of task or the mode of acquisition.

In educational research, a variety of methods have been developed to (1) analyze the nature of the content of subject-matter domains; (2) characterize the internal conditions or general behaviors required in learning a variety of tasks; and (3) specify strategies and procedures that will facilitate the acquisition of learning objectives. A plan for effective instruction using task-analysis procedures is presented in Figure 1.

The first step in developing an instructional program is the identification of terminal learning objectives. This activity, which precedes the conducting of a task analysis, requires a thorough knowledge of the subject-matter domain in which the terminal objective is embedded.

The actual task analysis begins after a terminal behavioral objective has been identified. As conceived of in this analysis, five distinct components (see Figure 1) compose a task-analysis procedure.

A content analysis determines the kinds of concepts, principles, and factual information that a student would need to learn in order to attain the terminal objective. A behavioral analysis identifies those skills and behaviors that a student must learn before the terminal objective is attained. These first two analyses provide a basis for evaluating the appropriateness of the terminal objective for a particular student or group of students.

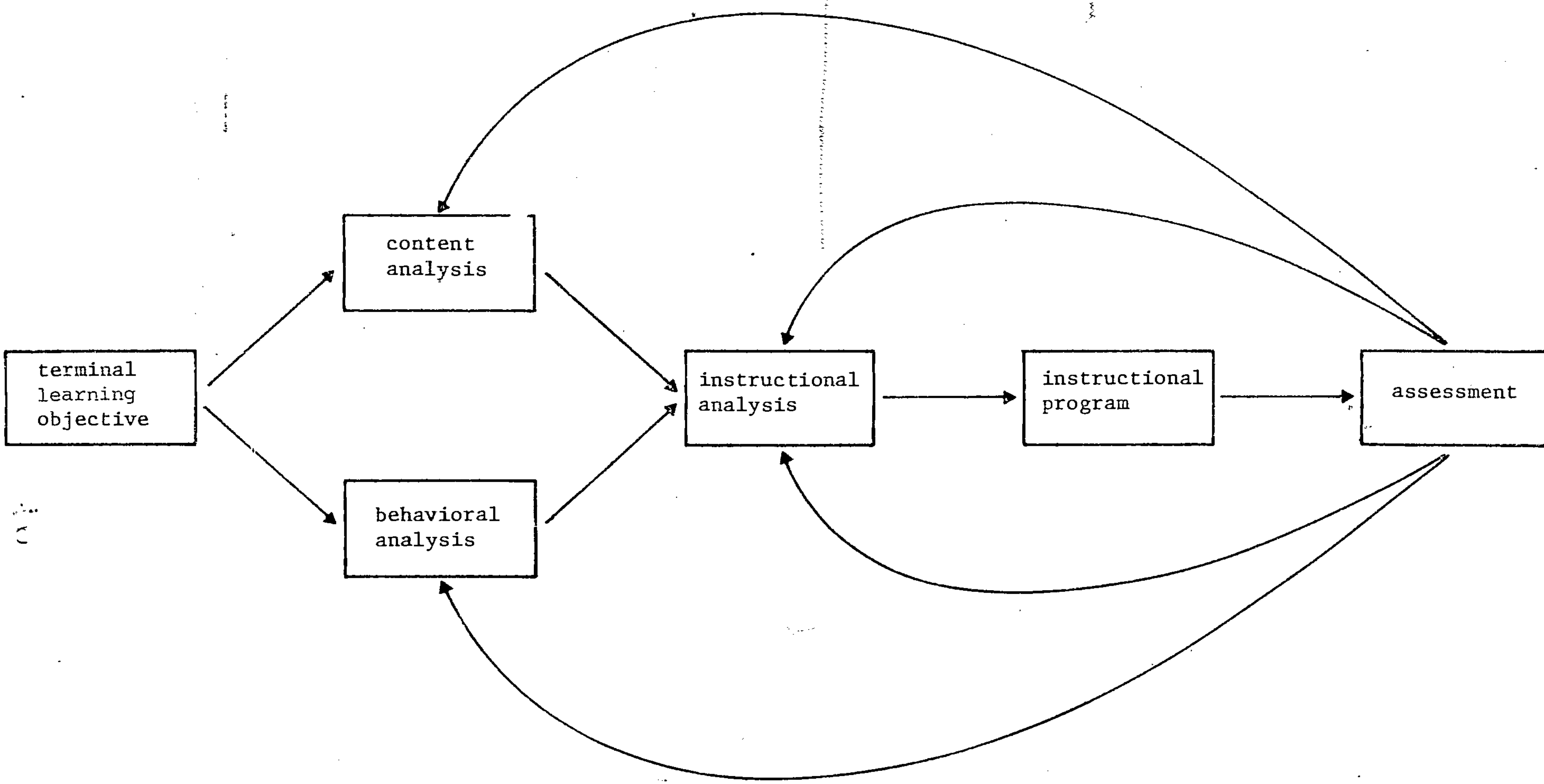

Figure 1. Task Analysis: Plan for Effective Instruction

Given certain content and behavioral subobjectives, an instructional analysis indicates relevant instructional procedures. This analysis integrates the two previous analyses and provides a basis for the optimal sequencing of instruction. The arrows from the content analysis and behavioral-analysis boxes indicate that each analysis may have different instructional implications. In determining instructional outcomes, it has generally been found that the sequence in which content information is presented is not of critical importance, whereas the sequence of instruction directed toward the teaching of skills has been found to be a highly important variable (Glaser & Resnick, 1972).

After the instructional analysis is completed, an instructional program is developed based on the three previous analyses. The program is administered to a target population and an assessment of learning outcomes is conducted. If the program does not produce the intended effect, an examination of performance on the assessment exercise may suggest where errors have been made in any of the three primary analyses.

III

TASK ANALYSIS IN PROGRAMMED INSTRUCTIONAL RESEARCH

As has been demonstrated, task analysis provides information concerning the content and behavioral requirements of learning tasks and identifies the instructional procedures that facilitate the learning process. Primarily, the following review will focus on the ways in which task analysis has been used to develop programmed instructional sequences that are designed to promote the learning of concepts and principles. Each of the three analysis components of the task analysis procedure (see Figure 1) have been used in the development of instructional programs.

The relationship of task analysis to the learning of concepts and principles will be examined from a "behavioral" perspective and from a "content" perspective. The review of concept learning will include studies that conceive of concepts as "ordered information about the properties of one or more things--objects, events, processes--that enables any thing or class of things to be differentiated from, and related to, other things or classes of things [Klausmeier, Ghatala, & Frayer, 1974]." In addition, studies are examined that deal with the learning of behaviors or operations that enable the individual to acquire concepts. The cognitive processes and intellectual skills that underlie the learning of relationships between two or more concepts such as principles will be discussed. As will become apparent, most studies have dealt with the learning and application of complex rules and principles.

In the first section of this review, the relationship of the structure of subject-matter knowledge with the selection of terminal learning objectives is discussed. In the second section, the nature of learning hierarchies is examined. Learning hierarchies have been used as a basis from which instructional programs designed to teach a variety of conceptual behaviors are constructed. The final section of this review deals with the implications of learning hierarchies that effect the sequencing of instruction.

SPECIFICATION OF TERMINAL LEARNING OBJECTIVES: STRUCTURE OF KNOWLEDGE

While in various disciplines such as linguistics, logic, and mathematics, the formal study of the organization of knowledge can aid in the identification of instructional objectives at an advanced level of schooling (Glaser, 1966), increasing numbers of instructional psychologists have recognized that subject-matter structures should be reformulated for students beginning to learn about the nature of a discipline (Glaser & Resnick, 1972). Instructional objectives should reflect the needs and abilities of specific target populations. In particular, developmental, learning experience, and socioemotional variables should dictate the level at which organized information is presented.

Bruner (1964, 1966) is, perhaps, the most well-known proponent of the position that any body of knowledge should be presented in a form that takes into account the characteristics of the learner. In the following paragraph Bruner communicates his views concerning educational objectives:

> A theory of instruction must specify the ways in which a body of knowledge should be structured so that it can be most readily grasped by the learner. 'Optimal structure' refers to a set of propositions from which a larger body of knowledge can be generated, and it is characteristic that the formulation of such structure depends upon the state of advance of a particular field of knowledge....Structure must always be related to the status and gifts of the learner. Viewed in this way, the optimal structure of a body of knowledge is not absolute but relative [1966, p. 4, emphasis added].

In examining the relationship of instructional sequencing to the structure of knowledge, Briggs (1967) suggests the following guidelines when selecting instructional objectives:

> 1. The manner in which existing knowledge in a subject-matter area or 'discipline' was first discovered or acquired need not necessarily have a bearing on the present issue of 'structure of a course.'
>
> 2. How total knowledge is divided up into disciplines is essentially irrelevant to how elements of total knowledge should be taught.
>
> 3. How the knowledge in a discipline is organized as an outline of the field may be extremely different from the structure of knowledge for learning purposes.
>
> 4. For learning purposes, then, 'structure' means none of the above things. It means the description of the dependent and independent relationships among component competencies, arranged so as to imply when sequencing can be random or optional and when sequencing must be carefully planned, on the basis that transfer will be optimal in order to build from simple skills to more complex ones [pp. 7-8].

In this review, the meaning of the term "structure" is used as it applies in Briggs's fourth guideline.

Although "unstructured" and "hierarchical" are the most common kinds of course structures, Briggs (1967) has delineated five basic types of course structures that may have direct implications for the design of programmed instructional sequences:

1. In a flat structure the actual sequence of instruction is unimportant.

2. In a vertical structure there is only one optimal sequence for teaching an object.

3. In a hierarchical structure, represented by a pyramid arrangement of learning objectives, the prerequisite or simpler levels should be taught before the next higher or more complex level.

4. In a mixed structure, such as a course with several learning objectives making up a larger instructional program, the parts can be taught in random order, even though hierarchies may exist in other parts of the program.

5. In the special case of a flat structure requiring spiral sequencing of instruction each set of discrete learning objectives has to be analyzed into several components before being used to solve complex problems [Briggs, 1967, pp. 8-10].

While an analysis of a discipline's structure reveals important information that could provide a basis for identifying and analyzing the objectives of the discipline (Heimer, 1969), such an analysis per se would probably not result in the development of effective instructional programming. Content and behavioral analyses must precede program development. The following discussion deals with the role of content and behavioral analyses in understanding learning hierarchies.

BEHAVIORAL AND CONTENT ANALYSES

Task analysis procedures have been used to identify hierarchies of skills that provide a basis for instruction in different subject-matter areas. A complete description of skills that are requisite for the attainment of a learning objective is called a learning hierarchy.

Although different investigators have seen learning hierarchies in different ways, they are generally defined in terms of asymmetrical transfer relationships between two or more tasks (Resnick, 1972). As indicated earlier, task analysis involves breaking a higher-level task into subordinate tasks. Resnick (1972) indicates that two tasks identified in this manner are considered to be hierarchically related if "(a) one task is easier to learn than the other, and (b) learning the simple task first produces positive transfer in learning the more complex task [p. 1]." For example, learning to recognize letters is easier than learning to read a word. An individual will more readily learn to read if he or she is competent in recognizing letters than if he or she is not.

The majority of the following studies can be classified as exploratory in that they used task-analysis procedures and their primary purpose was to establish the existence of hierarchically structured tasks (learning hierarchies). These are studies in which the experimenter determined a sequence of instruction or assessment in accordance with a hypothesized hierarchical ordering of subordinate learning objectives. Most of the studies reviewed here deal with the acquisition of mathematics and science knowledge since the underlying structures of these domains have been shown to be amenable to task or hierarchical analysis.

The existence of learning hierarchies in mathematics has been verified by a number of investigators. Gagné (1962b) employed a task analysis to identify an inferred hierarchy of nine operations and rules (referred to as learning sets) underlying the task of "finding formulas for the sum of n terms in a number series." He administered a self-instructional program containing test items over each learning set to ninth-grade boys. As predicted, no subject performed successfully on any learning set without having first mastered a lower level. After receiving instruction on those learning sets initially failed, each subject was retested, yielding competencies before and after program administration. Although the self-instructional effect of repeated testing was not controlled, a comparison of the "before" and "after" scores strongly supported the concept of knowledge hierarchies.

Employing a program developed to teach the task of solving linear algebraic equations, Gagné and Paradise (1961) examined the role of the following three factors in determining the efficiency of learning: (1) the number and kinds of learning sets the learner brings to the situation; (2) basic learning abilities relevant to the terminal objective (integration, symbol recognition); and (3) irrelevant learning abilities (general intelligence). A hierarchy of organized learning sets (e.g., identification of an equation; recognizing the equivalence of multiplication and division terms) was constructed using task analysis.

A program developed to teach the prerequisite learning sets and tests of basic abilities (relevant and irrelevant) was administered to 114 seventh-grade students. Gagné and Paradise (1961) found that learning performance was most strongly correlated with attainment of subordinate learning sets. Correlations of theoretically relevant abilities with learning performance were higher than correlations for irrelevant abilities with learning performance. Positive transfer to each learning set from subordinate learning sets ranged from .91 to 1.00. In revealing an underlying structure of mathematical knowledge, the authors indicated that task analysis provides a rational basis for the construction of programmed instructional materials. Gagné and Paradise (1961) also indicated that the learning of hierarchically organized sets of skills "depends not only upon the amount of basic (task-related) ability, but also upon the amount and kind of specifically transferable knowledge that has been acquired [p. 15]."

The work of Gagné, Mayor, Garstens, and Paradise (1962) reveals the importance of understanding an instructional task or objective before designing an instructional exercise. The authors analyzed the content and behavioral requirements of learning a task dealing with the addition of integers. An instructional program designed to teach each of 13 capabilities underlying the terminal objective was administered to 136 seventh-grade mathematics students over a four-day period. Validation of a general theory of the cumulative structure of knowledge received confirmation. Instances of asymmetrical transfer between hierarchically related tasks ranged from 97 percent to 100 percent.

During the year of 1963, another mathematics task was analyzed into a hierarchy of behaviors by Gagné and the staff of the University of Maryland Mathematics Project (1965). A self-instructional program based on a competence hierarchy and aimed at the terminal objective of "specifying sets, intersections of sets, and specifications of sets, using points, lines and curves" was developed. As in each of Gagné's earlier experiments, a program designed to teach the prerequisite capabilities underlying task performance was administered to a group of students who initially demonstrated few of the prerequisite skills. Confirmation of the existence of a learning hierarchy was seen in the close dependence of higher capabilities on the acquisition of those lower in the hierarchy.

In a follow-up to the Gagné et al. (1965) study, Gagné and Bassler (1963) retested the same students nine weeks after the lesson on mathematic sets had been administered. While terminal task performance remained extremely high, performance on the subordinate learning tasks decreased significantly. Apparently, the forgetting of subskills and subconcepts had little effect on the ability to perform the final task.

In deciding how best to sequence instruction in an early childhood curriculum, researchers at the Pittsburgh Learning Research and Development Center have investigated the nature of hierarchies in children's learning.

The following two studies involve the validation of optimal instructional sequences of mathematical behaviors derived from component analyses of learning objectives. Both studies examine the correlation between natural sequences of skills and hypothesized instructional sequences. Both the hierarchical ordering between units of instruction as well as the sequential order within each unit is examined. Wang (1973) summarizes the purpose of these studies as follows:

> We were therefore seeking empirical evidence both for the cumulative dependencies of individual behaviors on one another within a single learning hierarchy and for the interdependence of a set of learning hierarchies comprising the total curriculum structure [p. 55].

Wang, Resnick, and Boozer (1971) examined the performance of 78 kindergarten children on a battery of tasks designed to assess knowledge of three classes of early mathematical behavior: counting, one-to-one correspondence, and numeration. Using a component-analysis procedure, specific hypotheses were established to (1) specify the sequence of behaviors that compose each skill class and (2) distinguish among the classes. These hypothesized developmental sequences were incorporated into a battery of assessment tasks. A scalogram analysis was performed to examine the scalability of subsets of each of the tasks and the scalability of subsets between tasks.

The first analysis examined the ordering of prerequisite skills that composed each of the three classes of mathematical behavior. Results indicated the presence of sequentially related behaviors within each of the tasks. When relationships between classes were examined, the predicted independence of counting and one-to-one correspondence was confirmed. Although these results are only suggestive of the natural sequence of behavior, such information can be used to develop optimal sequences of instruction.

In an extension of the Wang et al. (1971) study, Wang (1973) validated within- and between-unit sequences for similar classes of mathematical behaviors. When the hypothesized ordering of behavior within and across learning hierarchies was compared with the empirical ordering, coefficients of reproducibility ranged from .934 to .993.

Merrill and his associates (1969), using task analysis, sought to establish the nature of fractional concepts. In examining the hierarchical arrangement of concepts related to fractions, Merrill dealt with the learning of the terminal objective "supplying the fractional name given a situation which involves dividing a larger group into parts or dividing an object into pieces [p. 45]." A careful analysis of the type of problem used to assess attainment of the learning objective resulted in a set of hierarchically related behaviors.

According to Merrill and his associates (1969), results of a test constructed to measure student performance on each of the objectives revealed that although students could be led to solve problems using fractional concepts by taking one step at a time, they did not demonstrate real understanding. "It was as if they learned to apply a set of rules in a rather rote way but there was little or no transfer to a problem which was worded differently [p. 47]."

As a consequence of the lack of transfer, a new task analysis was performed. Basic to the reanalysis was the assumption that the naming of fractional parts is not a general ability but is a composite of a learned set of specific abilities. The new, simpler hierarchy of behaviors consisted of a sequence of specific fractions hypothesized to underlie the ability to generalize and to use a set of rules for naming a fraction.

A new assessment test was administered to a large group of second-, third-, and fourth-grade children based on the new hierarchy. The predicted order of acquiring fractional concepts was largely verified. Specifically, students first learned the concept "one half," followed by unit fractions and non-unit fractions. Mastery of unit fractions and numerical representation occurred at about the same time.

Wiegand (1972) explored the teaching of a science task that required logical thinking. A learning hierarchy of subordinate skills was constructed which, when learned, was hypothesized to permit the learner to examine the relationship between "(a) the vertical height of an inclined plane at the starting position of a car and the weight of the car, and (b) the weight of a block at the bottom of an inclined plane and the distance moved by the block after being struck by a moving car [p. 81]."

An instructional program was administered to thirty 12-year-old subjects. The program was designed to teach a sequentially related set of skills required to perform the final task. Twenty-nine of the thirty subjects subsequently passed the final task. In addition, the experiment demonstrated that "successful performance of subordinate tasks was sufficient in itself to produce transfer to the next higher-level task [Weigand, 1972, p. 90]."

Wiegand (1972) also indicated that the inability of sixth graders to initially perform the final task was a function of a lack of prerequisite skills rather than a deficiency in logical thought processes. She summarized her results by specifying that "intellectual development has been brought about by the cumulative effects of the learning of concretely referenced intellectual skills, rather than by the adaptation of structures of intellectual growth [p. 92]."

Okey and Gagné (1970) employed a task analysis to identify subordinate skills underlying an existing chemistry program on solubility product calculations. Fifty-seven tenth-, eleventh-, and twelfth-grade students who received a revised version of a science program designed to teach prerequisite skills underlying the chemistry objective, performed significantly better on a posttest than 49 students who received an initial learning program. While these findings are hardly startling, the improvement made by the revised version group, as a result of changes in the initial program, points to the need for constant validation and revision of instructional programs based on hypothesized sequences of behaviors. Okey and Gagné also found that success on the final task depended on mastery of the complete set of subordinate skills. The attainment of subskills, however, did not have a linear relationship with successful performance on the final task.

Airasian (1970) conducted a study to determine whether two chemistry teachers who were taught to construct learning hierarchies would generate similar content and behavioral objectives from two different book chapters dealing with chemistry topics. On the average, the teachers demonstrated well above 90 percent agreement in (1) specifying the important content introduced in the chapter; (2) the behavioral level at which each content was to be learned; and (3) the relationships between content at different behavioral levels.

Kuhn (1970) presents a hierarchical pattern of behavioral objectives to be used in a program designed to teach Mendelian genetics. Kuhn, after specifying terminal objectives, determined the scientific processes and skills needed to carry them out. These behaviors were then sequenced in order of difficulty. Each successive behavior was hypothesized to subsume and require mastery of the previous behavioral subobjective. Kuhn indicated that optimal learning would be attained when each subordinate step is learned before the next level is attempted. No evidence for the validity of the hierarchy was presented.

A study by Coleman and Gagné (1970) was the only one encountered that employed task analysis procedures in analyzing a social studies task. Skills prerequisite to learning the following task were identified: "Given a detailed list of exported items and their monetary value for two countries, formulate a summary comparison of the exports of the two countries in terms of a limited number of categories which are exhaustive and exclusive [p. 37]."

Ten sixth-grade girls received instruction on 22 subordinate skills. Verbal information, where needed, was provided in instructions and in task directions. When the performance of this group was compared with a matched control group that received a placebo lesson, the following results were obtained: (1) all experimental subjects were able to correctly perform the final task while none of the control subjects were able to do it; (2) on a near-transfer task requiring similar skills using different content, experimental subjects performed significantly better than control subjects; and (3) on a far-transfer task that introduced new content and required more complex behaviors than those needed for the social studies program, experimental subjects again performed significantly better than control subjects. Although almost all of the prerequisite skills in the hierarchy were mastered by subjects previous to passing the final task, no hierarchical pattern of skills was observed. Coleman and Gagné (1970) suggest that the demonstrated effectiveness of instruction on ordered and unordered prerequisite capabilities is extremely relevant for the design of social-studies instructional programs.

Kingsley and Hall (1967) used a task-analysis procedure to identify a set of hierarchically-related behaviors hypothesized as necessary for successful conservation of weight and length. A large percentage of kindergarten subjects who learned the subordinate behaviors in the hypothesized order were able to demonstrate length and weight conservation. In addition, the trained kindergarten subjects performed significantly better than nontrained kindergarten subjects on a substance conservation task. Kingsley and Hall suggested that this finding was due to the similarity of behaviors underlying the three kinds of conservation. Only a small proportion of the trained kindergarten subjects resisted extinction of the learned behaviors.

LeFrancois (1968) developed a number of learning tasks designed to accelerate the age at which conservation of substance is normally acquired. The learning tasks were developed to teach nine hierarchically related capabilities that were hypothesized to represent the normal sequence of acquiring substance conservation. The hierarchy ranged from higher-level tasks dealing with combinativity and identity, to tasks that facilitated visual discrimination of height and weight.

In order to determine the validity of the hierarchy, the nine ordered learning tasks were administered to 20 subjects ranging in age from four years six months to six years. The validity of the ordering of the capabilities was confirmed (coefficient of reproducibility = .90+). Several of the capabilities that either failed to discriminate among subjects or that did not appear to belong to the ordinal arrangement of the hierarchy were eliminated. When the learning tasks were readministered, all 25 experimental (newly drawn) subjects demonstrated substance conservation.

Rothenberg and Orost (1969) generated a logical sequence of component concepts that teach young children to conserve the concept of number. A training program based on a logical sequence of skills was given to a group of kindergarten children. In a series of three training experiments, these children demonstrated considerable growth in their ability to conserve when compared with nontrained, control-group children.

Resnick, Siegel, and Kresh (1971) trained 27 kindergarten children on two different double classification matrix tasks to determine whether the tasks were hierarchically related. An analysis of the behavioral components of each task revealed that while there was considerable overlap of the behaviors required to learn each task, the task in which subjects had to infer the nature of row and column cells in a partially completed matrix required additional behaviors that were not prerequisites for a task in which row and column attributes were explicitly defined.

Twenty-seven kindergarten children who initially failed each matrix task were administered learning programs based on the behavioral analysis of each task. Subjects who received the simpler task first, followed by the complex one, learned both tasks in fewer trials than subjects who received the tasks in the reverse order. Additionally, those subjects in the reverse-order group who succeeded in mastering the complex task, also showed evidence of having already mastered the simpler task. Both findings provided evidence that the tasks were hierarchically related.

Caruso and Resnick (1971) validated empirically hypothesized sequence of three double classification tasks. As in the Resnick et al. (1971) study, the behavioral components needed to learn each of the three classification tasks were identified using a component-analysis procedure. The ordering of the tasks was determined on the basis of the kinds of inferring behaviors required to perform each task. Subjects who were taught in the optimal order learned the most complex task more quickly than subjects who were trained on the same three tasks in reverse sequence. In addition, no subject mastered a higher-level task without having previously learned the lower-level task. A substantial amount of positive transfer to a double classification task that required similar behaviors was demonstrated by subjects who successfully learned the most complex task in the hierarchy.

Mouw and Hecht (1973) found that the concept of class inclusion could successfully be taught to third- and fourth-grade students. An experimental group was taught the ability to organize elements (i.e., class inclusion). Two hierarchically ordered tasks taught subjects the prerequisite skills and concepts underlying class-inclusion behavior. When compared with matched control subjects who received a placebo lesson, experimental subjects demonstrated mastery of the class-inclusion concept. The authors suggest that abstract concepts thought traditionally to be acquired as a function of developmental readiness can, in fact, be taught.

As Gagné (1970b) has stated, it is clear that research "has shown that 'minimal requisite' sequences of rules can be identified (in the sense that a rule such as factoring the parts of a fraction must be known before addition of fractions can be learned) and also that hierarchies expressing such sequences can be verified [p. 2]." Several problems related to task analysis and learning hierarchies will be briefly discussed.

As is probably apparent, no systematic procedure has been established for analyzing the characteristics of learning tasks. Besides the basic question developed by Gagné (1962b), no algorithm for producing learning hierarchies is apparent. Rather, task-analysis procedures seem to be characterized by a trial-and-error, "if it works it must be valid" approach.

GPO 809-043-4

A majority of the studies reviewed have analyzed the behaviors or skills that contribute to learning a task. Little attention has been given to the analysis of content or information objectives. This tendency seems to have resulted from investigators relying on Gagné's (1968b) article in which he indicates that learning hierarchies are composed of intellectual skills rather than knowledge that can be verbalized. The work of Ausubel (1963) and Klausmeier, Ghatala, and Frayer (1974) suggests that the identification and sequencing of content (concepts) is an extremely important learning variable.

A lack of concern for demonstrating the relationship between logical structures of knowledge and the organization of a body of knowledge for instructional purposes appears to be a related problem. To this writer's knowledge, no theory of instruction has been developed that attempts to integrate abstract bodies of knowledge with learning structures derived from task-analysis research.

In particular, the work of Gagné has not disclosed the relationship of general categories of learning to the construction and validation of learning hierarchies. As indicated earlier, identification of subordinate behaviors is generally tied to a specific subject-matter context. General classes of learning or behavior do not appear to aid in specifying the attributes of behaviors to be learned.

Several researchers with developmental psychology backgrounds have questioned whether the learning of discrete sets of experimenter-generated tasks promotes "fundamental" understanding and transfer (e.g., Merrill et al., 1969; Almy, 1972). It remains to be demonstrated whether subjects who learn to classify or conserve as a result of expository instruction can spontaneously and appropriately perform on a variety of tasks requiring similar behaviors. Do subjects learn to apply rules in a "rote" way? Does an individual's maturational status restrict the efficiency with which concepts and skills are learned and used?

Finally, the studies reviewed here do not validate principles or procedures derived from an instructional analysis of learning objectives. For example, the relationship of the hierarchical structure of a task to the hierarchical presentation of a task remains unclear. This issue and others dealing with the nature and sequence of instruction will be discussed in the next section of this paper.

INSTRUCTIONAL ANALYSIS

The previous section on learning hierarchies revealed that task analysis can determine the "what" of teaching. The work of Gagné and others has shown that some things should be learned before others. The need to carefully sequence the "what" of learning has been universally recognized (e.g., Skinner, 1968). At this point, a distinction must be made between hypothesized learning sequences and the development of instructional sequences. Gagné (1968b) has stated, "I am not sure that a learning hierarchy is supposed to represent a presentation sequence for instruction in an entirely uncomplicated way [p. 3]." Niedermeyer (1968) discusses the relevance of frame sequence in programmed instruction: "Once the programmer has determined precisely what a group of learners has to be able to do in order to perform the terminal tasks, and after he has written instructional frames for all of these tasks, it may or may not be relevant how he sequences the instruction [p. 315]." Additionally, variables such as learning structure, nature and amount of program review, frame and program length, prerequisite knowledge of the learner, age and general intelligence, have been shown to determine whether learning can be facilitated through a logical sequencing of tasks.

Investigations of the sequencing of instruction have ranged from studies in which the learner has complete control over the sequencing to studies in which sequence is determined solely by the experimenter. Briggs (1967) has enumerated the following nine categories in which experiments dealing with instructional sequencing can be grouped: (1) maximum learner control; (2) learner-controlled content and sequencing; (3) learner selection of materials and procedures; (4) adjunct autoinstruction--mixed experimenter and learner control; (5) experimenter-determined sequencing of instruction in accordance with hierarchies of competence; (6) experimenter-determined sequencing of frames in programmed instruction; (7) learner-determined branching in auto-instruction; (8) experimenter-prepared advance organizers; and (9) sequence preplanned by the experimenter to test hypotheses about effective characteristics of learning programs (pp. 23-24).

The studies reviewed here are ones where the sequence of instruction has been derived from either a content analysis or a behavioral analysis of a terminal objective. Those studies in which the experimenter did not deliberately attempt to analyze the structure of the terminal task before sequencing instructional frames have not been included. In many of the studies, the experimenter has determined the precise sequence of instruction. The studies can be subsumed in the fifth, seventh, eighth, and ninth categories of Briggs's taxonomy of instructional sequences.

These studies emphasize the use of instructional analysis to determine an optimal sequence of instruction rather than emphasizing the use of behavioral and content analyses in examining the structure of subject-matter. Five studies are also included that examine the effectiveness of instructional sequencing in relation to the manner in which a program is reviewed and practiced.

Wodtke, Brown, Sands, and Fredericks (1967) proposed that the effects of scrambling a sequence of instruction depend upon characteristics of the subject matter being taught and individual differences among learners. They contended that if subject matter contains a sequential hierarchy of concepts (i.e., learning hierarchy) then a scrambled sequence of instruction would inhibit learning. If, however, a subject matter consists of a set of unrelated facts, then the sequence of instruction would probably not be an important variable. It was also predicted that a scrambled sequence of instruction would be most detrimental to the learning of low-ability students.

A hierarchy of concepts and skills in mathematics and a set of relatively unrelated facts dealing with the anatomy of the ear were selected as subject-matter domains that had contrasting structures. Scrambled and ordered sequences of each subject matter were administered to college students stratified on scholastic aptitude.

As hypothesized, the effects of the scrambled sequence were not significant for the anatomy program. However, while an increase in the number of errors and time was demonstrated for the group that received the scrambled mathematics program, no differences were observed on a posttest between the groups that received the scrambled sequence and the groups that received the logically ordered sequence. Tentative evidence for a treatment by aptitude interaction was found.

Using a task-analysis procedure, Eustace (1969) constructed a learning program leading to the understanding of the concept "noun." The validity of the ordering of seven sequentially related levels of understanding was verified in a pilot study. Two hundred and thirty-eight second- and third-grade students were given the levels of the program in varying degrees of ordered sequence. The prediction that the group receiving the logically ordered sequence of the learning program would demonstrate greater learning than groups receiving successively lesser degrees of order was confirmed.

Niedermeyer, Brown, and Sulzen (1969) compared three sequence versions (logical-, scrambled-, and reverse-frame order) of a guided discovery program on number series. The program was based on a hierarchy of competencies underlying the task "finding a formula for the sum of n terms in a number series" developed by Gagné and Brown (1961). No differences in posttest performance were found among the groups that received the three different sequence versions. The group that received the logically ordered sequence did, however, make fewer program errors, performed better on a test of the concepts taught in the program and on a transfer test that required students to "start a general equation that would give the sum of the series of any term, n," for five new number series.

Brown (1970) examined the effects of sequence on the learning of the same number series program used by Niedermeyer et al. (1969) for high-ability high school students. The group that received a logical sequence of frames took significantly less time to complete the program, made fewer errors on a test of program mastery, and made fewer errors on a test of complex problem-solving skills than a group that received a scrambled sequence. No differences were observed on "on-route" program subtasks.

Spencer and Briggs (1972) conducted two studies to determine whether a programmed lesson in algebra would be more effective if the program frames were presented in a sequence suggested by a hierarchical analysis of the terminal objective than if the frames were presented in a random order. No performance differences among groups that received three sequence versions (forward order, reverse order, random order) were found in the first study.

The second study replicated the first study but used older students from a more "advantaged" background. The forward version of the test resulted in a higher performance for the older and more advantaged children than the performance of the younger children in the first study. Surprisingly, the performance of the younger less-advantaged children who received the random sequence was higher on a retention test than all other groups.

Kane, McDaniel, and Phillips (1972) conducted an experiment to develop and evaluate procedure for the validation of learning hierarchies from test data. Employing task analysis, a learning hierarchy was constructed for "computational skills of rational number addition involving like denominators [p. 14]." A test based on a logical sequencing of the subskills was administered to a large group of children to assess mastery at each level in the hierarchy.

The efficacy of five statistical procedures was evaluated by "actually sequencing learning materials according to the hierarchies generated by each method and determining the effect of sequence upon achievement, transfer, retention, and time to complete program [Kane et al., p. 35]." In addition, the effectiveness of textbook and random ordering of subobjectives was examined.

Learning programs based on seven different sequence orderings were administered to 142 fourth-grade students. Of primary interest was the comparison of the logical-sequence group (derived using task analysis) and the random-sequence group with all the statistically derived sequence groups.

No significant differences were found when the mean achievement score of the logical-sequence group was compared with the other sequence groups. When the random-sequence group was compared with all other groups, no significant differences were obtained. Also, no significant differences were found when the logical- and random-sequence groups were compared individually with all other groups on a transfer posttest dealing with the subtraction of rational numbers. However, on an alternate form of the achievement test administered two weeks after the learning program was administered, the logical-sequence group performed significantly better than all other groups. No other comparisons were found to be significant.

Merrill (1965) hypothesized that the learning and retention of a hierarchical task should be facilitated if each successive component of the task is mastered before proceeding to the next. Sixty-two college-aged subjects who were randomly assigned to three treatment groups and one control group were given a programmed instructional lesson on an imaginary science topic. Group 1 received both feedback and review on five lessons and quizzes. Group 2 received feedback and review on quizzes only. Group 3 received no feedback on either quizzes or lessons. Group 4 (control) did not receive any program materials but rather received an extensive summary of the major topics taught in the instructional program.

The nature and sequence of the instructional program was derived from a hierarchical analysis of the science topic. All groups received feedback and review on a terminal mastery test and were tested again, three weeks later, without feedback or review. The results did not confirm Merrill's (1965) central hypothesis. No differences among the treatment groups were observed on the terminal mastery test. More importantly, the control group performed as well as the treatment groups on the retention test.

Merrill and Stolurow (1966) found that learning was facilitated when students were given a summary statement of a hierarchically related set of principles that were taught in an instructional program prior to testing. Specific review of detailed step-by-step instructions for applying principles following incorrect responses also increased the number of subsequent correct responses when compared with a general restatement of the principles. Verbal and quantitative aptitude did not significantly effect the speed or performance with which the program was completed.

In extending the work of Merrill (1965), Merrill, Barton, and Wood (1970) found that specific review in which a subject is given a step-by-step solution to an incorrect response did not increase the number of overall errors made in the program. The major advantage of specific review was to decrease the total time needed to complete the learning program.

Merrill (1970) examined the relative merits of specific review and repeated presentation (rereading) in the learning of hierarchically sequenced programmed instructional materials. He found that neither the amount of specific review nor the number of times information was presented following an incorrect response decreased the number of errors committed in the program. The failure of the specific-review procedure to enhance learning contradicted the findings of the Merrill and Stolurow (1966) study. A group that received specific review until a criterion performance was achieved completed the program more quickly than a group that received repeated presentation of material until a specified criterion was reached.

Using an instructional program derived from a task analysis of a mathematics topic, Gibson (1970) examined the effects of three learning variables on the achievement, retention, and transfer of principles. The specific hypotheses tested in the study are as follows:

1. A greater number of practice examples following initial learning will increase retention more than a lesser number of examples.

2. A broad variety of practice examples will facilitate transfer to related tasks more than a narrow variety.

3. A broad variety of practice examples will facilitate retention more than a narrow variety.

4. Many examples of a broad variety will facilitate both retention and transfer more than many examples of narrow variety, few examples of narrow variety, or few examples of broad variety [p. 5].

Another purpose of the study was to determine whether I.Q. would interact with the "number of repetitions of examples" and "variety of examples" variables in influencing learning performance.

The "number of repetitions of examples" (many and few) variable provided for the repeated application of learning sets. The inclusion of this variable was meant to assess the effect of overlearning on retention and transfer. The "variety of examples" variable was defined as "the amount of diversity of context, form, and wording among examples which involved application of the subordinate principle during the practice period [Gibson, 1970, p. 7]."

Ninety third- and fourth-grade children ranked according to grade and I.Q. were randomly assigned in groups of five to one of five conditions: (1) broad variety, many examples; (2) broad variety, few examples; (3) narrow variety, many examples; (4) narrow variety, few examples; and (5) control group, no practice examples.

Gibson's (1970) study has been outlined in some length to demonstrate how task analysis can be used to examine the relationship between learning variables and programmed instructional sequences. The variables of number and variety of examples did not, however, significantly affect the learning, transfer, and retention of principles. Intelligence was found to be a contributing factor on the retention and transfer tests. Gibson attributed the lack of significant findings to the placement of practice examples. In her study, examples were placed after, rather than before or during, the original learning of subsets.

Several generalizations can be drawn from the results of the studies reviewed here. In the process of attaining a hierarchically related set of behaviors, it appears that what is learned is more crucial than the sequence in which it is learned. The equivalent performances of groups that received a logically ordered sequence and a scrambled sequence on immediate achievement posttests suggest that individuals actively integrate and organize information that is presented in a scrambled order.

The sequencing of instructional programs does seem to affect the transferability of subordinate sets of concepts and skills. Less efficient learning of subordinate capabilities appears to take place if a hierarchically structured learning task is presented in a randomly ordered sequence. Although a learner can overcome, to some extent, the effects of sequence through organizational strategies, a learner will not be able to use the behaviors that underlie a final task performance in novel situations. While not specifically examined in any of the studies, it would appear that the forgetting of subordinate knowledge learned in a scrambled order may occur at a faster rate than forgetting information learned in a natural order.

The retention of information or skills may be inhibited if instructional units are presented in scrambled order. Ausubel (1963) has hypothesized that mastery of previous parts in a hierarchical task facilitates the learning and retention of subsequent parts. It seems reasonable that while small amounts of illogically ordered information can be retained for short periods of time, a well-organized presentation of material enables the individual to integrate that which is to be learned with what already has been learned.

When compared with a scrambled presentation of a hierarchically structured task, a hierarchically sequenced presentation has been shown to decrease the overall time of instruction. That is, the mastery of prerequisite skills and concepts may make it easier to learn each succeeding part.

Merrill and his collaborators have found that learning is facilitated when a learner is presented with a summary of relevant information that is contained in a hierarchically sequenced learning program. This finding is substantiated by the work of Ausubel and his co-researchers (Ausubel, 1960; Ausubel & Fitzgerald, 1962; Ausubel, Robbins, & Blake, 1957; Ausubel, Stager, & Gaite, 1968) who have found that relevant introductory and summary materials presented at a high level of inclusiveness promote the learning and retention of new ideas.

RESEARCH RECOMMENDATIONS

There seems to be little question that task analysis has been and can be used effectively in the construction of programmed instructional sequences designed to teach a wide variety of concepts, principles, skills, and rules. Several avenues of further research suggested by this review and suggested by Briggs (1967) may be summarized as follows:

1. Research dealing with the nature of hierarchical structures and instructional sequencing needs to be extended to cover larger interrelated blocks of instruction.

2. Investigation of the relationship of component concepts and principles to instruction in areas other than math and science.

3. Task analysis of learning objectives should permit the construction of written non-autoinstructional programs. Such materials could be compared with more traditionally presented instructional programs.

4. Investigation of the interaction of learner characteristics with task and instruction variables.

REFERENCES

Airasian, P. W. The use of hierarchies in the analysis and planning of chemistry instruction. Science Education, 1970, 54, 91-95.

Almy, M. Discussion. In L. B. Resnick (Ed.), Hierarchies in children's learning. Pittsburgh: Learning Research and Development Center, 1972, 109-114.

Ausubel, D. P. The use of advance organizers in the learning and retention of meaningful verbal material. Journal of Educational Psychology, 1960, 51, 267-272.

Ausubel, D. P. The psychology of meaningful verbal learning. New York: Grune & Stratton, 1963.

Ausubel, D. P., Robins, L. C., & Blake, E. Retroactive inhibition and facilitation in the learning of school materials. Journal of Educational Psychology, 1957, 48, 334-343.

Ausubel, D. P., & Fitzgerald, D. Organizer, general background and antecedent learning variables in sequential verbal learning. Journal of Educational Psychology, 1962, 53, 243-249.

Ausubel, D. P., Stager, M., & Gaite, A. J. H. Retroactive facilitation in meaningful verbal learning. Journal of Educational Psychology, 1968, 59, 250-255.

Bloom, B. S. (Ed.) Taxonomy of educational objectives. New York: Longmans, Green, 1956.

Bobbitt, F. How to make a curriculum. Boston: Houghton Mifflin, 1924.

Briggs, L. J. Sequencing of instruction in relation to hierarchies of competence. American Institutes for Research, Palo Alto, California. U.S. Office of Education, 1967.

Brown, J. L. Effects of logical and scrambled sequences in mathematical materials on learning with programmed instruction materials. Journal of Educational Psychology, 1970, 61, 41-45.

Bruner, J. S. Some theorems on instruction illustrated with reference to mathematics. In E. R. Hilgard & H. G. Richey (Eds.), Theories of learning and instruction. The Sixty-third Yearbook of the National Society for the Study of Education. Chicago: The University of Chicago Press, 1964, 306-335.

Bruner, J. S. Toward a theory of instruction. New York: W. W. Norton & Company, 1966.

Campbell, D. S., & Schwenn, T. M. Beyond the remedial loop: Toward the integration of task and learner analysis for a process approach to instructional development. Paper presented at the Association for Educational Communications and Technology Annual Convention, Philadelphia, Pennsylvania, March 21-26, 1971.

Caruso, J. L., & Resnick, L. B. Task sequence and overtraining in children's learning and transfer of double classification skills. Publication No. 8. Pittsburgh: Learning Research and Development Center, 1971.

Charters, W. W., & Waples, D. The commonwealth teacher study. Chicago: The University of Chicago Press, 1929.

Coleman, L. T., & Gagné, R. M. Transfer of learning in a social studies task of comparing-contrasting. In R. M. Gagné (Ed.), Basic studies of learning hierarchies in school subjects. Final report. University of California, Berkeley. U.S. Office of Education, Bureau of Research, 1970. Pp. 34-47.

Corrigan, R. E., & Kaufman, R. A. Why system engineering. Palo Alto, California: Fearon, 1965.

Dale, S. M. The nature of instruction. In P. C. Lange (Ed.), Programed instruction. The Sixty-sixth Yearbook of the National Society for the Study of Education. Chicago: The University of Chicago Press, Pp. 28-56.

Eustace, B. W. Learning a complex concept at differing hierarchical levels. Journal of Educational Psychology, 1969, 60, 449-452.

Folley, J. D., Jr. Guidelines for task analysis. Technical Report NAVTRADEVCEN 1218-2, Port Washington, New York, U.S. Naval Training Device Center, 1964.

Folley, J. D., Jr., Farriman, J. B., & Jones, E. M. A survey of the literature on prediction of air force personnel requirements. WADD TR 60-493. Wright-Patterson AFB, Ohio, Wright Air Development Center, 1960.

Gagné, R. M. (Ed.) Psychological principles in system development. New York: Holt, Rinehart & Winston, Inc., 1962. (a)

Gagné, R. M. The acquisition of knowledge. Psychological Review, 1962, 69, 355-365. (b)

Gagné, R. M. The analysis of instructional objectives for the design of instruction. In R. Glaser (Ed.), Teaching machines and programed learning II: Data and directions. Washington: National Education Association of the United States, 1965. Pp. 21-65.

Gagné, R. M. Contributions of learning to human development. Psychological Review, 1968, 75, 177-191. (a)

Gagné, R. M. Learning hierarchies. Educational Psychologist, 1968, 6, 1-6. (b)

Gagné, R. M. The conditions of learning. (2nd ed.) New York: Holt, Rinehart & Winston, 1970. (a)

Gagné, R. M. Basic studies of learning hierarchies in school subjects. Final report. University of California, Berkeley. U.S. Office of Education, Bureau of Research, 1970. (b)

Gagné, R. M., & Bassler, O. C. Study of retention of some topics of elementary non-metric geometry. Journal of Educational Psychology, 1963, 54, 123-131.

Gagné, R. M., & Brown, L. T. Some factors in the programming of conceptual learning. Journal of Experimental Psychology, 1961, 62, 313-321.

Gagné, R. M., Mayor, J. R., Garstens, H. L., & Paradise, N. E. Factors in acquiring knowledge of a mathematical task. Psychological Monographs, 1962, 76, (7, Whole No. 518).

Gagné, R. M., & Paradise, N. E. Abilities and learning sets in knowledge acquisition. Psychological Monographs, 1961, 75, (14, Whole No. 518).

Gagné, R. M., & Staff, University of Maryland Math Project. Some factors in learning non-metric geometry. Monographs of the Society for Research in Child Development, 1965, 30, 42-49.

GPO 809-043-3

Gibson, J. R. Transfer effects of practice variety in principle learning. In R. M. Gagné (Ed.), Basic studies of learning hierarchies in school subjects. Final report. University of California, Berkeley. U.S. Office of Education, Bureau of Research, 1970.

Gilbert, T. F. Mathetics: The technology of education. The Journal of Mathetics, 1962, 1, 7-73.

Glaser, R. Toward a behavioral science base for instructional design. In R. Glaser (Ed.), Teaching machines and programmed learning II: Data and directions. Washington: National Education Association of the United States, 1965. Pp. 771-809.

Glaser, R. The design of instruction. In J. I. Goodlad (Ed.), The changing American school. The Sixty-fifth Yearbook of the National Society for the Study of Education. Chicago: The University of Chicago Press, 1966. Pp. 215-242.

Glaser, R., & Resnick, L. B. Instructional psychology. In P. H. Mussen and M. R. Rosenzweig (Eds.), Annual Review of Psychology, 1972, 23. Pp. 207-276.

Gustafson, H. W., Honsberger, W. D., & Michelsen, S. Determination of task analysis content. In WADD TR 60-593, Uses of task analysis in deriving training and training equipment requirements. Wright-Patterson AFB, Ohio: Wright Air Development Center, 1960.

Harless, J. H. Mathetics: The ugly duckling learns to fly. Paper presented at the 4th annual National Society for Programmed Instruction Convention, St. Louis, Missouri, April, 1966.

Harper, W., Bull, K., & Onofrei, D. J. The oscar system analysis: Programmed instruction. Great Lakes, Illinois: Service School Command, Naval Training Center, 1970.

Heimer, R. T. Conditions of learning in mathematics: Sequence theory development. Review of Educational Research, 1969, 39, 493-508.

Kane, R. B., McDaniel, E. D., & Phillips, E. R. Analyzing learning hierarchies relative to transfer relationships within arithmetic. Final Report. Purdue Research Foundation, Lafayette, Indiana. U.S. Office of Education, Bureau of Research, 1972.

Kingsley, R. C., & Hall, V. C. Training conservation through the use of learning sets. Child Development, 1967, 38, 1111-1126.

Klausmeier, H. J., Ghatala, E. S., & Frayer, D. A. Conceptual learning and development: A cognitive view. New York: Academic Press, 1974.

Klausmeier, H. J., & Goodwin, W. Learning and human abilities. (4th ed.) New York: Harper & Row, in press.

Kuhn, D. J. Behavioral objectives in the life sciences: A useful instrument in curriculum development. Science Education, 1970, 54, 123-126.

Latterner, C. G. Task analysis--Bane or blessing? In G. D. Ofiesh and W. C. Meierhenry (Eds.), Trends in programmed instruction. Washington: Department of Audiovisual Instruction, National Education Association, 1964.

LeFrancois, G. R. A treatment hierarchy for the acceleration of conservation of substance. Canadian Journal of Psychology/Revue Canadienne De Psychologie, 1968, 22, 277-284.

Mager, R. M. Preparing instructional objectives. Belmont, California: Fearon Publishers, 1962.

Markle, S. M. Empirical testing of programs. In P. C. Lange (Ed.), Programmed instruction. The Sixty-sixth Yearbook of the National Society for the Study of Education. Chicago: The University of Chicago Press, 1967. Pp. 104-140.

Mechner, F. Behavioral analysis and instructional sequencing. In P. C. Lange (Ed.), Programmed instruction. The Sixty-sixth Yearbook of the National Society for the Study of Education. Chicago: The University of Chicago Press, 1967. Pp. 81-103.

Merrill, M. D. Correction and review on successive parts in learning a hierarchical task. Journal of Educational Psychology, 1965, 56, 225-234.

Merrill, M. D. Specific review versus repeated presentation in a programmed imaginary science. Journal of Educational Psychology, 1970, 61, 392-399.

Merrill, M. D., & Stolurow, L. M. Hierarchical preview vs. problem oriented review in learning an imaginary science. American Educational Research Journal, 1966, 4, 251-261.

Merrill, M. D., Barton, K., & Wood, L. E. Specific review in learning a hierarchical imaginary science. Journal of Educational Psychology, 1970, 61, 102-109.

Merrill, M. D. Content and instructional analysis for cognitive transfer tasks. AV Communications Review, 1973, 21, 109-126.

Merrill, M. D., et al. Feedback and remedial instruction in learning tasks. Final report. Brigham Young University, Provo, Utah. U.S. Office of Education, Bureau of Research, 1969.

Miller, R. B. A method for man-machine task analysis. Technical Report 53-137. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1953.

Miller, R. B. Some working concepts of systems analysis. Pittsburgh: American Institutes for Research, 1954.

Miller, R. B. Task description and analysis. In R. M. Gagné (Ed.) Psychological principles in system development. New York: Holt, Rinehart & Winston, 1962.

Mouw, J. T., & Hecht, J. T. Transfer of the "concept" of class inclusion. Journal of Educational Psychology, 1973, 64, 57-62.

Niedermeyer, F. C. The relevance of frame sequence in programmed instruction: An addition to the dialogue. AV Communication Review, 1968, 16, 301-317.

Niedermeyer, F., Brown, J., & Sulzen, B. Learning and varying sequences of ninth-grade mathematics materials. The Journal of Experimental Education, 1969, 37, 61-66.

Okey, J. R., & Gagné, R. M. Revision of a science topic using evidence of performance on subordinate skills. Journal of Research in Science Teaching, 1970, 7, 321-325.

Resnick, L. B. Design of an early learning curriculum. Working Paper No. 16. Pittsburgh: Learning Research and Development Center, 1967.

Resnick, L. B. Issues in the study of learning hierarchies. In L. B. Resnick (Ed.), Hierarchies in children's learning. Pittsburgh: Learning Research and Development Center, 1972. Pp. 1-20.

Resnick, L. B., Siegel, A. W., & Kresh, E. Transfer and sequence in learning double classification skills. Journal of Experimental Child Psychology, 1971, 11, 139-149.

Romberg, T. A., Harvey, J. G., & McLeod, D. B. The task analysis for Developing Mathematical Processes, Arithmetic, Book 1: Comparing and equalizing objects and sets. Working Paper No. 48. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1970.

Rothenberg, B. R., & Orost, J. H. The training of conservation of number in young children. Child Development, 1969, 40, 707-726.

Skinner, B. F. The technology of teaching. New York: Appleton-Century-Crofts, 1968.

Spencer, R. Y., & Briggs, L. J. Application of a learning hierarchy to sequence an instructional program, and comparison of this program with reverse and random sequences. Final Report. Florida State University, Tallahassee. U.S. Office of Education, National Center for Educational Research and Development, 1972.

Tyler, R. W. The construction of examinations in botany and zoology. In R. W. Tyler (Ed.), Service studies in higher education. Ohio State University Studies, Bureau of Educational Research Monographs, No. 15, 1932.

U.S. Army Security Agency, The development of instructional systems. Fort Devens, Massachusetts: Department of the Army, Headquarters United States Army Security Agency, Training Center and School, 1967.

Wang, M. C. Psychometric studies in the validation of an early learning curriculum. Child Development, 1973, 44, 54-60.

Wang, M. C., Resnick, L. B., & Boozer, R. The sequence of development of some early mathematics behaviors. Child Development, 1971, 42, 1767-1778.

Wiegand, V. K. A study of subordinate skills in science problem solving. In L. B. Resnick (Ed.), Hierarchies in children's learning. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1972.

Wodtke, K. H., Brown, B. R., Sands, H. R., & Fredericks, P. Scrambled versus ordered sequencing in computer assisted instruction. Final report. Pennsylvania State University, University Park. U.S. Office of Education, Bureau of Research, 1967.

GPO 809-043-2

National Evaluation Committee

Francis S. Chase, Committee Chairman
Emeritus Professor, Department of Education
University of Chicago

Helen Bain
Past President
National Education Association

Lyle E. Bourne, Jr.
Institute for the Study of Intellectual Behavior
University of Colorado

Sue Buel
Dissemination and Installation Services
Northwest Regional Educational Laboratory

Roald Campbell
Emeritus Professor, Department of Educational Administration
The Ohio State University

George E. Dickson
College of Education
University of Toledo

L. R. Goulet
Departments of Educational Psychology and Psychology
University of Illinois—Champaign-Urbana

Chester W. Harris
Department of Education
University of California—Santa Barbara

W. G. Katzenmeyer
Department of Education
Duke University

Hugh J. Scott
Department of Education
Howard University

Barbara Thompson
Superintendent of Public Instruction
State of Wisconsin

Joanna Williams
Department of Psychology and Education
Teachers' College, Columbia University

Executive Committee

Richard A. Rossmiller, Committee Chairman
Director
R & D Center

William R. Bush
Deputy Director
R & D Center

M. Vere DeVault
Professor of Curriculum and Instruction
School of Education

Dale D. Johnson
Assistant Dean
School of Education

Karlyn Kamm
Developmental Specialist
R & D Center

Herbert J. Klausmeier
Principal Investigator
R & D Center

Joel R. Levin
Principal Investigator
R & D Center

James M. Moser
Senior Research Scientist
R & D Center

Len VanEss
Associate Vice Chancellor
University of Wisconsin—Madison

Faculty of Principal Investigators

Vernon L. Allen
Professor
Psychology

B. Dean Bowles
Professor
Educational Administration

Marvin J. Fruth
Professor
Educational Administration

John G. Harvey
Associate Professor
Mathematics

Frank H. Hooper
Professor
Child and Family Studies

Herbert J. Klausmeier
V. A. C. Henmon Professor
Educational Psychology

Gisela Labouvie-Vief
Assistant Professor
Educational Psychology

Joel R. Levin
Professor
Educational Psychology

L. Joseph Lins
Professor
Institutional Studies

James Lipham
Professor
Educational Administration

Wayne Otto
Professor
Curriculum and Instruction

Robert Petzold
Professor
Curriculum and Instruction

Thomas A. Romberg
Professor
Curriculum and Instruction

Richard A. Rossmiller
Professor
Educational Administration

Dennis W. Spuck
Assistant Professor
Educational Administration

Richard L. Venezky
Professor
Computer Sciences

Larry M. Wilder
Assistant Professor
Child and Family Studies