A Functional Analysis of Task Analysis Procedures For Instuctional Design

Patricia Kennedy, *Associate Professor*

Timm Esque, *Graduate Student*

Jerry Novak, *Graduate Student*

Department of Educational Technology
Arizona State University
Tempe, AZ 85287

Abstract. Representative examples of task analysis procedures were examined for common components, methods, and terminology. Resulting generic components were categorized into two phases of task analysis: task description and instructional analysis. Task description included the components of task inventory, ordering, and refinement. Instructional analysis was comprised of the specification of needs, goals, objectives, learning hierarchy, learning taxonomy, training considerations, and product development specifications. Identification of these components permitted the formulation of a generalized model of task analysis. The model contained a consensus of procedures comprising educational and industrial task analysis applications.

Task analysis is a procedure for identifying different kinds of performances which are the outcomes of learning and sequencing structural units in the design of training or instruction. The roots of the concept of task analysis can be traced to contributions made by two researchers: Robert Miller (1953a, 1953b) in connection with military training research, and Robert Gagne (1965) who related task analysis to the design of instruction. While serving as a generic term covering various types of "front end" analysis, task analysis contributes to research from both a theoretical and practical base (Dick, 1981).

As a bridge among theories of knowledge, instruction, and learning, task analysis serves three roles: as a prescription of the prerequisites and conditions under which optimal performance may occur or even what optimal performance is (a theory of instruction); as a description of the behaviors and processes through which performance may be efficiently achieved (a theory of learning); and as a means by which basic questions concerning the relevance and utility of performance may be explored (a theory of knowledge) (Davies, 1973).

To many, the accepted procedure of task analysis involves specifying a task's terminal components and subsequently ordering its instructionally useful, prerequisite subtasks (Gibbons, 1977). This procedure differs somewhat with Gagne's pioneering work in using task analysis to design instruction optimally for learning (Gagne, 1965, 1974). Gagne recommends that the learning task must be broken down into behavior capabilities that are not themselves the task, but are contributors to the performance of the task. The contributors are classified into types for identifying different optimal conditions for their learning. In practice, however, there are many ways of determining the hierarchical or linear relationship among the constituent elements and identifying the learning processes associated with each (Gibbons, 1975). Despite a long history of successful applications of task analysis, users lack agreement regarding terminology and methodology (Duncan, 1972). In fact, Duncan calls task analysis an art. Identification of the common components of task analysis procedures would be the first step in standardizing terminology and methodology.

In this paper, selected task analysis procedures are analyzed and contrasted after the isolation of key concepts and common procedural components. The identification of "common denominators" across the representative task analysis procedures permits the determination of the structural relationship between procedural components and formulation of a generalized model of task analysis with standardized terminology.

Methods

Procedure

An exhaustive review was conducted of all articles dealing with theory or application of task analysis published between 1979 and 1982 in National Technical Information Service, Psychological Abstracts, and ERIC. With additional articles identified in bibliographies, 415 articles in the public domain were reviewed. Proprietary models were not included.

Of the 415 articles, about two-thirds were immediately discarded. They were not useful for our purpose, because their abstracts did not contain a reference to discernible procedures for conducting a task analysis. Many of these were project-specific technical reports. Of the remaining 149 abstracts, availability of the articles was limited to 52. These articles were helpful for generating references to older articles describing task analysis procedures. The topics of the available references was varied widely, spanning learning theory (Wildman & Burton, 1981; Fleishman, 1978), developmental theory (Spada, 1978; Seigler, 1980; Swinton, 1977), diagnostic prescriptive special education applications (Arter and Jenkins, 1979; Burton, 1976; Ewing & Brecht, 1977), and job analysis training applications

(Cornelius, Carron & Collins, 1979; Arvey & Mossholder, 1977; Prien & Rosen, 1971). From the 52 articles and their references, ten representative articles containing fully-developed methods were retained for further examination.

From this sample, the components of task analysis were listed in the terminology and order presented in the article. A Q-sort procedure was used to group the descriptions of components by similarity of process content. A generic term and operational definition were then applied to cover each group of discrete processes. The rationale for these ordering and labeling procedures was to derive our basis of comparison from the models themselves as opposed to comparing the models to a predetermined schema as was done elsewhere (Andrews & Goodson, 1980).

Results

Task Analysis Methodologies

A matrix was prepared of the ten task analysis methods cross-referenced against common components that were present in one or more of the methods (see Table 1). The term the author used to name the components was reported as well as the order in which the component was addressed in each method. This general model of task analysis contained all of the nonredundant components of the procedures we examined: task inventory, ordering, refinement, needs, goals, objectives, learning hierarchy, learning taxonomy, training considerations, and product development specifications. A discussion of each method is presented next, followed by a description of the common components of task analysis listed in Table 1.

In the list of authors in Table 1, Gagne's name is conspicuous by its absence. Most of the components of task analysis were first described by Gagne in his explanation of learning hierarchies and the relation of task analysis to content analysis (Gagne, 1962, 1965, 1974, 1977). However, a review of Gagne's extensive work did not reveal a step by step operational methodology of task analysis for instructional designers.

Of the selected task analysis procedures, two were applied to educational tasks. Both Resnick et al. (1973) and Merrill (1973) began a basic level of educational task description. Merrill proposed a detailed eleven-step procedure starting at the level of operationally defined concepts and relational operators. In addition, he addressed current issues in the theory of task analysis such as the inclusion of horizontal hierarchy analysis while evaluating prerequisites. With Merrill's method of analysis, the sequence of operations in a task is flowcharted with decision points or branches noted. This information processing approach employs the techniques of observation of overt behavior and "thinking aloud" of covert behavior. Unique is Merrill's position that neither hierarchical analysis nor information processing analysis is adequate for all skills. Both forms of analysis may be used to supplement each other by identifying instructionally important behaviors that would be missed by either approach alone. Proposed in more recent work by Merrill and his colleagues (Reigeluth, Merrill, Wilson, & Spiller, 1980) is an elaboration model which follows a general-to-detailed pattern of sequencing, as opposed to the hierarchically based sequences derived from a Gagne type of task analysis.

Resnick applied task analysis in the development of an introductory mathematics curriculum. Resnick's method of analysis resulted in a task hierarchy containing the terminal task on top, sequentially related sub-tasks next, and a hierarchy of learning tasks below each subtask. Resnick's "chain of component behaviors comprising a skilled performance" was a synthesis of Gagne's hierarchical analysis, Merrill's information processing analysis, and Scandura's directed graphs. Resnick's method both sequenced tasks and prescribed teaching strategies. Resnick agreed with Gagne and Merrill that verbal knowledge, as described by Gagne, was not amenable to this type of analysis.

Many of the task analysis applications reviewed were industrial. Gard (1972) and Gilbert (1972, 1978) presented models of task analysis applied to industrial training tasks. Gard reporting on an application for training systems designers, described a four-step procedure for task analysis: Clarify tasks as activities, inputs, or outputs; organize a hierarchy; assign a taxonomy value; and achieve expert consensus of the analysis. Gard's method of analysis, which can be considered a gross level of information processing, was similar to Merrill's. Output of gross analysis methods served as input to other methods of analysis. Gilbert's rationale for his task analysis procedures was based on cost effectiveness considerations in achieving human competence, not psychological theory (Gibbons, 1977). He focused on reducing training costs by isolating deficiencies with a knowledge and learning taxonomy matrix when suggesting training in the deficient areas. The estimated payoff of reducing mismatches between actual and desired performance was used to set priorities for training.

The products of some of the industrial applications were highly detailed. Miller (1962) and Duncan (1973) formulated their task analysis procedures from applications to highly procedural jobs. For Miller, task analysis was "a process whose results provide data about human functions, which in turn are used to determine the character of the system and its components." The main difference between Miller and Duncan was the use of learning taxonomies. Miller prompted the use of a learning taxonomy to prescribe instructional methods while Duncan maintained that task analysis was prescriptive only for determining training sequences and not for specifying training methods. Another detailed product was Martin and Brodt's (1973) task-based curriculum for hospital corpsmen. The tasks were categorized by means of syntactic clustering, a method of classifying individual task statements by parts of speech such as verbs, direct objects, and so forth. Herschback (1976) synthesized the work of a wide range of educational, psychological, and industrial researchers such as Gagne, Davies, Mager, Bloom,

> We found ten nonredundant components: task inventory, ordering, refinement, needs, goals, objectives, learning hierarchy, learning taxonomy, training considerations, and product development specifications.

Table 1

Methods of Task Analysis Cross-Referenced by Components
(The order each author addressed components is indicated by numbers.)

	DESCRIPTION				ANALYSIS					
	Task Inventory	Ordering	Refinement	Needs	Goals	Objectives	Learning Hierarchy	Learning Taxonomy	Training Considerations	Instructional Specifications Development
Herschback	#6 Construct detailed task list	#7 Define tasks, task elements, and subelements		#2, 3, 4, 5 Define instructional specifications	#1 Define program aims	#10, 8, 9 Define specific behaviors, performance conditions, and requirements	#2 Sequence task information	#11 Behavior analysis		
Gilbert				#1d, e Description and impact of deficiencies	#2 Identify behavioral deficiencies relevant to each accomplishment	#1a–c Description of job accomplishments, requirements, and standards	#3 Plot deficiencies by knowledge progression	#3 Plot deficiencies by knowledge progression		#4 Construct a knowledge map which prescribes method and sequence
Gard				#3 Assign taxonomy values (i.e., difficulty, frequency of activity)	#4 Gain professional consensus (concerning needs)	#1 Identify: activities, inputs to activities, outputs from activities				
Merrill	#1 Identify all possible concepts in the selected content area	#2 Determine relational operators #3 Specify change operations	#4 Define concepts by relational operator #5 Represent each rule symbolically #6 Identify specific incidents for each generality	#8 Identify needs	#7 Identify goals	#9 Specify mastery model		#10 Classify behaviors (associated with defined problems) as rule using or rule finding		#11 Select and sequence course content
Miller	#1 General statement of job and task functions	#2 Breakdown of general statements into ordered job segments	#3a Identify major contingencies #4 Detailed task description			#6 Identify task behaviors #4 Identify behavioral conditions		#7 Taxonomize behaviors via defined information processing components	#8 Consideration of information processing components	#9 Methods derived from #8 Sequence derived from chronological task description of behavioral clusters

	DESCRIPTION			ANALYSIS						
	Task Inventory	Ordering	Refinement	Needs	Goals	Objectives	Learning Hierarchy	Learning Taxonomy	Training Considerations	Instructional Specifications Development
Hannum	JOB TASK ANALYSIS	#1 Development of job function/task hierarchy				#2 Identify learning outcomes #3 Identify behavioral contributors		#4 Classify capabilities into domains of learning (a la Gagne)		#5 Define training sequence as defined by prerequisite analysis
Martin/Brodi	#1 Develop task inventory	#2 Task/subtask analysis		#3a Task statement analysis (training need) #3b Categorical needs analysis (patient needs)		#4 Syntatic analysis #5 Define behavioral objectives and criterion tests				
Duncan	#1 Identify the major operations of the job #3 Define subordinate operations to correct "level of description"	#2 Hierarchize major operations	#4 Define the plan						#7 Identify non-training considerations (i.e., equipment, design, personnel considerations)	#5 Identify training sequence as prescribed by task description #6, 8 Hypothesize and test training methods
Gregory	#1 Generate a task activity			#5 Identify and diagnose training problems		#2 Develop an action model	#3 Elicit related action models #4 Roll action models to define the mode			
Resnick				#5 Need assessed by pretesting objectives		#1 Specify concept components in behavioral terms	#2, #3 Hierarchize terminal and enabling objectives by prerequisite analysis			#4 Sequencing based on order of performance #6, 7 Hypothesize, test and evaluate methods of instruction

Marsh, and Seymour. The result was a procedural description for deriving instructional content through task analysis. The description provided a good overview of the components common to many task analysis procedures; however, his procedures for formulating this overview were not systematic.

Hannum (1980) reiterated the generally accepted distinction between job task analysis and learning task analysis (Miller, 1956; Gagne, 1974; and others) and provided a multiphase description of the latter based heavily on the work of Gagne. Gregory's (1979) unique task analysis procedure was designed for jobs that were unusually nonprocedural. The tasks were described in terms of "action models" which incorporated mental events into the task structure. Full utilization of this model, still in the early development phases would entail the use of user-friendly computers for gathering task data from experts and novices. The computer program would delineate an action model for training analysis from the differences between experts and novices on answers to questions related to job performance. All of these applications of task analysis possessed what Gerlach, Reiser, and Brecke (1977) call "generality." That is, each contained a description of task analysis procedures complete with enough detail to be applicable to a class of problems as opposed to a single problem. Instructional developers could follow any one of the task analysis procedures discussed here. It was felt that generality was an important selection criteria in a review such as this one.

Two different sets of procedures for conducting task analysis seem to be needed: one for educational and one for industrial designers.

Common Components and Standardized Terminology

It seemed that the task analysis components could be divided into two phases: task description and instructional analysis. Description dealt with the inventorying, ordering and refining of task content. Analysis covered the use of task analysis for the analysis of instructional design specifications for a given task or series of tasks. In the latter phase the design procedures for systematic development were addressed by the specification of needs, goals, objectives, learning hierarchy, learning taxonomy, training considerations, and product development specifications. A discussion of the common components follows.

Most authors addressed the three task description components, although the order and mass they gave to these components varied. Task inventory involved a progressive redescription of task elements from global to detailed. Ordering referred to the arrangement of task elements according to their content or performance relationships. Refinement was defined as the iterative process used to derive an ordered task inventory meeting a set criterion and eliminating gaps and redundancies. A major decision in task description was the level of detail with which the tasks were described. Only one author, Duncan, identified a formula for level of description. His formula specified that description should cease when the cost of further detail exceeded the need for that detail. The second phase of task analysis, instructional analysis, contained the activities that most instructional developers would label "design activities": needs, goals, objectives, learning hierarchy, learning taxonomy, training consideration, and product development specifications. Indeed, the activities in the instructional analysis phase of task analysis overlapped many of those listed by Andrews and Goodson (1980) as the components of a model of instructional design and two of the five development stages outlined by Sullivan (1971).

The authors who conducted a needs analysis of students, tasks, or resources used the results as a means of determining the basis of instructional goals. Some authors, like Herschback, Gilbert, and Martin & Brodt, conducted needs analysis early in the task analysis procedure. All of these authors used the results of the needs assessment to plan subsequent development activities. In contrast, other authors, generally those concerned with education rather than training, conducted needs analysis late in their procedure. For instance, Merrill analyzed needs in step eight of his eleven-step procedure. Both Merrill and Resnick suggested compiling a statement of needs from the information obtained after administering a pretest to identify student achievement deficits. The nature of the needs varied among training needs, learner needs, and recipient needs. For example, Martin and Brodt conducted a task statement analysis for training needs. Other authors such as Resnick, Gilbert, and Merrill identified learner needs. This distinction reflected a difference between examining a task and examining a learner's behavior for determining need.

Goals were defined as broad statements of instructional aims. A noticeable finding from the matrix was that six of the ten authors did not include defining goals as part of their task analysis procedure. However, authors who did not use goals usually specified objectives. The specification of objectives appeared to be the product of the task description phase while the goals were the product of the instructional analysis phase. When the needs analysis centered on the task, as with Gard's procedure where the difficulty and frequency of specific activities were rated, objectives were viewed as synonymous with the final product of the task description phase usually in hierarchy form. For example, Gard did not begin task analysis with task description. Rather, he began by classifying tasks as activities, inputs, or outputs. Then he devised a behavioral hierarchy by sequencing this task information. Thus, for every activity there was an input and output. In theory, objectives are derived from goals (Mager, 1972). In practice, as reflected in the matrix, this was not how things worked. Gilbert and Gard, for instance, did not do a task description. Their objectives were not derived from goals but came from behavioral statements. In task-based models, there was not a clear relationship between goals and objectives, as basic tenets of development would lead one to expect.

Objectives were always stated in behavioral terms whether they were generated from the task description phase or a priori. Only one author, Duncan, did not include objectives in his task analysis. He went directly from his task description to a training sequence which he empirically validated. His approach circumvented learning hierarchies and taxonomies.

The learning hierarchies component was defined as an arrangement of behavioral objectives according to prerequisite learning requirements. It is synonymous with prerequisite analysis in Gagne's terms. It was found that not many authors devised hierarchies. Resnick formed hierarchies by prerequisite analysis of terminal and enabling objectives. Gregory's interactive procedure started with positing a task. With an action model, he expanded this initial task into behavioral objectives. Simultaneously, he derived the prerequisite and subsequent tasks, thus generating a learning hierarchy.

Gagne (1977) suggested that the learning hierarchy serve as a main source for determining training sequences. What is interesting to note was that some authors, namely, Miller and Duncan, derived their training sequence from the hierarchical description of the task as opposed to a prerequisite behavioral analysis. Implied is a treatment of the task hierarchy resulting from the task description as synonymous with a learning hierarchy.

Learning taxonomies were defined as the classification of task related behaviors within the parameters of predefined types of learning. Only four authors used learning taxonomies in their task analysis. Hannum followed Gagne's taxonomy. Information processing taxonomies were utilized by Miller and Merrill. Gilbert's taxonomy was what he called a knowledge progression going from theory to application in five steps without employing information processing terms. We concluded that the purpose of the learning taxonomy was for determining teaching methods, while the purpose of the learning hierarchy was for sequencing, so the two were not interchangeable in our model.

Training considerations were defined as an analysis of factors that constrained the scope of the instructional product. The educational applications of task analysis, Resnick's and Merrill's, ignored training considerations. Some industrial applications, such as Duncan's, included delimiting trainer responsibilities from those responsibilities that were rightly the organization's.

The final task analysis component, instructional specifications development, was defined as the prescription and sequencing of instructional methods. Authors varied in the techniques used for prescription and sequencing. Gilbert maintained that method and sequence were determined by the learning taxonomy. Hannum derived his sequence from a prerequisite analysis of subtasks. Miller utilized a chronological task description of behavioral clusters. In contrast with this group of authors were Duncan and Resnick who maintained that while sequence could be prescribed by the task description, instructional methods could only be hypothesized. That is, rather than using a taxonomy to prescribe given teaching techniques, they strongly suggested more freedom with regard to teaching methods as long as the results could be validated empirically.

Discussion

From the inspection of the rows, it can be concluded that no author's procedure was complete in addressing all components of task analysis. Also, from inspection of the columns, it can be concluded that no component was addressed by every author. Finally, the order in which the common components were addressed varies from author to author. Most, if not all, task analysis procedures were generated primarily for their idiosyncratic application. It is clear that the procedures for task analysis did not evolve systematically. Rather, different procedures proliferated in isolation, probably in response to the situation specific demands.

An exhaustive review was conducted of all articles dealing with theory or application of task analysis published between 1979 and 1982.

The most salient difference between approaches depended on whether the application was educational or industrial. People in industry approach task analysis differently from people in education, probably due to the nature of the tasks and an emphasis on cost-benefit analysis. The educational techniques focused on jobs which were then analyzed into tasks and subtasks.

Instead of breaking tasks into concepts, industrial developers divided jobs into sub-skills which were not concepts but were actions. In other words, educational applications worked at a cognitive level, while industrial training models worked on a directly observable level of behavior. Industrial applications of job analysis stopped just short of the cognitive analysis found in educational applications. Another difference between educational and industrial applications was in how needs were assessed. In educational applications such as Merrill's and Resnick's, needs were assessed by pretesting students or objectives. In industrial applications, training needs were identified before objectives were written.

In both industrial and educational models, specification of objectives did not routinely follow specification of goals. No author used goals only, but many authors used objectives only. Objectives were always stated in observable, measurable form. It may be that the specification of goals is passe.

There was confusion between task hierarchies and learning hierarchies. The task hierarchy is derived from the task description, while the learning hierarchy is the product of prerequisite analysis. They are not interchangeable. (**Editor's Note:** *See article by Medsker in this issue.*)

From the differences in the nature of the tasks analyzed by educational and industrial designers, it can be speculated that two different sets of procedures for conducting task analysis are needed. The designer would look at the nature of the task to be analyzed to determine if all of the procedures recommended in our general model of task analysis would have to be completed. Further research is necessary to determine the payoff for doing all of the steps. The results of this research would have implications for education and practice, should it prove necessary to prepare instructional designers in two methods of conducting task analysis. While the difficulties of researching the area of instructional design as a whole have been well articulated (Dick, 1981), and apply to task analysis, breaking task analysis into components and researching the components are feasible research activities.

Further research not only might be directed to validating the components of the general model of task analysis, but also might well determine the most efficacious way of accomplishing each component. From the columns of the table, it can be seen that there are at least a couple of ways of accomplishing each component, and the most efficient manner has yet to be determined from an empirical comparison or from well-documented case studies.

In view of the diversity of procedures, terminology, and applications and paucity of empirical comparisons, it is not possible to recommend one best method of task analysis for all problems. Rather, we argue for standard terminology and further research, including assimilating additional models into our schema.

References

Andrews, D. H., & Goodson, L. A. (1980). A comparative analysis of models of instructional design. *Journal of Instructional Development*, Summer, *3*(4).

Arter, J. A., & Jenkins, J. R. (1979). Differential diagnosis— prescriptive teaching: A critical appraisal. *Review of Educational Research*, Fall, *49*(4), pp. 517-555.

Arvey, R. D., & Mossholder, K. M. (1977).A proposed methodology for determining similarities and differences among jobs. *Personnel Psychology*, *30*(3), pp. 363-374.

Burton, R., et al. (1976). *A manual for assessment and training of severely multiply handicapped deaf-blind students*. New England Regional Center for Services to Deaf-Blind Children, Watertown, Mass.

Davies, I. K. (1973). Task analysis: Some process and content concerns. *A. V. Communications Review*, Spring, *21*(1).

Davies, I. K. (1981). Task analysis for reliable human performance. *National Society for Performance and Instruction Journal*, March.

Dick, W. (1981). Instructional design models: Future trends and issues. *Educational Technology*, July, pp. 29-32.

Duncan, K. (1972). Strategies for analysis of task. In J. Hartley (Ed.) *Strategies for programmed instruction: An educational technology*. London, England: Butterworths.

Ewing, N. A., & Brecht, R. (1977). Diagnostic/prescriptive instruction: A reconsideration of some issues. *Journal of Special Education*, *11*(3), pp. 323-327.

Fleishman, E. A. (1978). Relating individual differences to the dimensions of human tasks. *Ergonomics*, *21*(12), pp. 1007-1019.

Gagne, R. M. (1962). The acquisition of knowledge. *Psychological Review*, *69*(4), pp. 355-365.

Gagne, R. M. (1965). The analysis of instructional objectives for the design of instruction. In Glaser (Ed.), *Teaching machines and programmed instruction II, data and directions*. Washington, D.C.: National Education Association of the United States.

Gagne, R. M. (1974). Task analysis—Its relation to content analysis. *Educational Psychologist*, *II*(1), pp. 11-18.

Gagne, R. M. (1977). *The conditions of learning, third edition*. Holt, Rinehart & Winston.

Gard, D. E. (1972). An approach for doing task analysis to train system designers. *Proceedings of the conference on uses of task analysis in the Bell System*. American Telephone and Telegraph Company, Human Resources Laboratory, Training Research Group, October.

Gibbons, A. S. (1977). *A review of content and task analysis methodology* (Tech. Rep. No. 2, Courseware, Inc.). ERIC Document, Ed. 143 696.

Gerlach, V. S., Reiser, R. A., & Brecke, P. H. (1977). Algorithms in education. *Educational Technology*, October, pp. 14-18.

Gilbert, T. F. (1972). Levels and structure of performance analysis. *Proceedings of the conference on uses of task analysis in the Bell System*. American Telephone and Telegraph Company, Human Resources Laboratory, Training Research Group, October.

Gilbert, T. F. (1978). *Human competence*, McGraw Hill Book Company: New York.

Gregory, R. (1979). *Personalized task representation*. DRIC-BR- 69898.

Hannum, W. H. Task analysis procedures. (1980). *National Society for Performance and Instruction Journal*, April, pp. 6,7,14.

Herschback, D. R. (1976). Deriving instructional content through task analysis. *Journal of Industrial Teacher Education*, *13*(3), pp. 63-73.

Mager, R. F. (1972). *Goal analysis*. Palo Alto: Fearon, 1972.

Martin, M. C., & Brodt, D. E. (1973). Task analysis for training and curriculum design. *Improving Human Performance: A Research Quarterly*, *2*, pp. 113-120.

Merrill, M. D. (1973). Content and instructional analysis for cognitive transfer tasks. *A. V. Communication Review*, Spring, *21*(1), pp. 109-125.

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

Miller, R. B. (1953b). *Handbook on training and training equipment design*. Technical Report 53-136, Wright-Patterson Air Force Base, Ohio: Wright Air Development Center.

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

Prien, E. P., & Ronan, W. W. (1971). Job analysis: A review of research funding. *Personnel Psychology*, *24*, pp. 371-396.

Reigeluth, C. M., Merrill, M. D., Wilson, B. G., & Spiller, R. T. (1980). The elaboration theory of instruction: A model for sequencing and synthesizing instruction. *Instructional Science*, *9*, pp. 195- 219.

Resnick, L. B., Wang, M. C., & Kaplan, J. (1973). Task analysis in curriculum design: A hierarchically sequenced introductory mathematics curriculum. *Journal of Applied Behavior Analysis*, Winter, *6*(4), pp. 679-710.

Siegler, R. S. (1980). Recent trends in the study of cognitive development: Variations on a task analytic time. *Human Development*, *23*(4), pp. 278-285.

Spada, H. Understanding proportionality: A comparison of different models of cognitive development. *International Journal of Behavioral Development*, Vol. 1(4), pp. 363-376.

Sullivan, H. S. (1971). Developing effective objectives-based instruction. *Educational Technology*, July, pp. 55-57.

Swinton, S. S. (1977). *The role of short-term memory in the development of logical operation skills* (Tech. Rep. No. 445). Washington, D.C.: National Institute of Education (DNEW).

Wildman, T. M., & Burton, J. K. (1981). Integrating learning theory with instructional design. *Journal of Instructional Development*, Spring, *4*(3), pp. 5-14.