

*Advances in*

# *Instructional Psychology*

VOLUME 1

Edited by  
ROBERT GLASS



# *Advances in Instructional Psychology*

VOLUME 1

*Edited by*  
ROBERT GLASER



LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS  
1978 Hillsdale, New Jersey

DISTRIBUTED BY THE HALSTED PRESS DIVISION OF  
JOHN WILEY & SONS  
New York Toronto London Sydney

Copyright© 1978 by Lawrence Erlbaum Associates, Inc.

All rights reserved. No part of this book may be reproduced in any form, by photostat, microform, retrieval system, or any other means, without the prior written permission of the publisher.

Lawrence Erlbaum Associates, Inc., Publishers  
62 Maria Drive  
Hillsdale, New Jersey 07642

Distributed solely by Halsted Press Division  
John Wiley & Sons, Inc., New York

**Library of Congress Cataloging in Publication Data**

Main entry under title:

Advances in instructional psychology.

Includes indexes.

1. Educational psychology. I. Glaser, Robert,

1921-

LB1051.A3176 370.15 78-13400

ISBN 0-470-26519-1

Printed in the United States of America

*Advances in*  
*Instructional Psychology*

VOLUME 1

## Preface

The rubric “instructional psychology” was first used to name an area of work in the 1969 *Annual Review of Psychology*. Since then, the field has taken on enough shape that it can be generally characterized as consisting of research on the acquisition of knowledge and cognitive skill and how this competence is developed through the design of conditions for learning. The emergence of this field marks a significant change in the relationship of psychology to education.

In the 1950s and early 1960s, experimental psychologists generally were not hospitable to the investigation of instructional problems. The border between basic psychological research and research on the acquisition of skill and competence in the subject matters of schooling defined a “no-man’s land” that relatively few had the training or the inclination to explore. During the intense activity of the years of teaching machines and programmed learning, those who cared about the relationship between behavioral science and educational technology were concerned that the rush toward immediate practicality would pull the field away from its loose ties with the scientific study of behavior. And as recently as 10 years ago, it was difficult to attract outstanding psychologists to consider working on problems that had an educational taint.

Psychology and education have not always been so separated; in the early part of this century, the psychology of learning and educational psychology were intimately connected in the work of many of the great figures of that time. The sporadic engagement of experimental psychology and educational psychology over the years provides an interesting perspective for viewing the field of instructional psychology, and a synoptic history is presented in the introduction to this volume.

At the present time, the scene has substantially changed as a result of the impact of behavioristic psychology's intrusion into the technology of teaching and the emergence of modern cognitive psychology as today's dominant theoretical force in the study of human learning and performance. This change has been accompanied by a change in research tactics. In the old mode of research, findings established in controlled laboratory environments were extrapolated to complex learning with little investigation of the limitations and boundary conditions involved. This has now been replaced by research that, in large part, picks its problems and develops its theory from complex realistic human performance. There is the growing realization that study of the acquisition of human knowledge and competence in relatively formal instructional situations can be a significant test of a theory's adequacy, as well as a useful social contribution. As a result, a psychology of instruction is emerging within the context of a rapidly growing science of cognition and learning.

The purpose of this new series is to foster this trend by publishing outstanding work that appears to be contributing to the knowledge and theories required to systematically address the problems of instruction. This serial publication is intended to provide a forum for psychologists in diverse areas engaged in research on specialized topics relevant to understanding instructional processes. Since the field is in an active and expanding phase, *Instructional Psychology* is broadly conceived and will be shaped by the workers in it. Toward this purpose, the *Advances* will be responsive to the current scene and not become committed to particular viewpoints. The activities of the field will determine the future scope and definition of instructional psychology, so it will be necessary to be eclectic in range of coverage. The major criteria for inviting contributions are that the authors have been actively involved in high-quality work of significant interest to the interaction of psychological science and the problems of instruction, and that they have something informative and provocative to say. In particular, the invited contributors are encouraged to present a detailed view of their current work and thinking, to relate it to other existing work, and to describe it as they see fit in a way they believe to be exciting and significant.

The chapters in this volume are representative of work now underway that is defining instructional psychology. Chapter 1, by James Greeno, is an example of research on the analysis of the structure of knowledge. He presents a model of problem solving in the domain of high-school geometry. The model is developed in the form of a computer simulation using the framework of current information-processing theory and includes a detailed representation of the thinking processes students use when they solve geometry problems.

Chapter 2, by Ann Brown, focuses on the development of certain metacognitive skills that influence learning and problem solving in young

children. These skills of thinking facilitate the active control of one's own learning by means of predicting, checking, monitoring, and reality testing, and they are indicative of efficient problem solving in a variety of situations. Brown reviews the empirical research on metacognitive skills, instructional attempts to train these skills in slow-learning children, and the cultural relativity of these abilities.

In Chapter 3, Robbie Case discusses the kinds of questions that must be addressed when applying principles of cognitive development to instruction. He takes Piaget's general principles of intellectual development and organizes them into a set of procedures for optimizing children's acquisition of the skills and concepts normally taught in school. He describes research centering around a neo-Piagetian theory of intellectual development that addresses questions that Piaget's theory leaves unanswered: how to identify the operational structures of relevance to skills taught in school, how to assess a child's current level of operational functioning, and how to bring children from their current level of functioning to the one desired.

Chapter 4, by Patrick Suppes, Elizabeth Macken, and Mario Zanotti, moves away from the cognitive-processing approaches of the previous chapters to more global models appropriate for organizing instruction. The authors present in detail two examples of global models and sketch how these models can be of use in systematic thinking about curriculum and teaching. In the first example, they develop a model for the prediction of student progress in computer-assisted instruction in three curriculum areas—language arts, mathematics, and reading—and use the model to regulate the amount of time spent in these curriculum areas. The second example investigates the use of radio as an instructional technology in developing countries. The concern here is with the use of a quantitative model for optimizing the organization of instruction for group learning.

In Chapter 5, Robert Gagné and Jacob Beard examine current formulations of measurement rationale and technology for the assessment of learning outcomes. The concept of criterion-referenced measurement is reviewed in the context of various categories of learned performance: intellectual skills, verbal information, cognitive strategies, motor skills, and attitudes. The authors consider questions involved in specifying the task domain to be assessed, the quality and quantity dimensions of performance assessment, the process of test construction, determination of the adequacy of assessment measures, and decisions required in test selection and design.

The completion of this volume has been a cooperative effort from its inception during a conversation between the publisher, Lawrence Erlbaum, and myself. Most obvious are the efforts of the authors who took time from their often overcommitted lives to make extensive presentations of research with which they have been concerned for some time. Less apparent, but an indispensable part of the final product, are the efforts of the busy individuals

who critically reviewed the early manuscripts: Lloyd Bond, Michelene Chi, Alan Lesgold, Jay Millman, James Pellegrino, and Alexander Siegel.

The details of all the stages involved in working with the authors and publisher were competently handled by my assistant, Joan Jewell. Without her assistance, this volume would never have reached the readers' bookshelves. My thanks also go to Marlene Daurora for typing the final manuscript, to Pat Stanton for typing and editorial assistance, and to Donna Rottman, who prepared all the figures and tables for publication. Throughout, the work on this book was facilitated by the resources of the Learning Research and Development Center of the University of Pittsburgh.

*University of Pittsburgh*

ROBERT GLASER



*Advances in*  
*Instructional Psychology*

VOLUME 1

# Contents

## **PREFACE** *ix*

## **INTRODUCTION: TOWARD A PSYCHOLOGY OF INSTRUCTION** *Robert Glaser*

- I. The Present Scene 2
- II. Historical Perspective 5
- III. Advances in Instructional Psychology 10

## **1. A STUDY OF PROBLEM SOLVING** *James G. Greeno*

- I. Introduction 13
- II. General Background 15
- III. Overview of *Perdix* 18
- IV. Perceptual Pattern Recognition 28
- V. Propositions for Inference 35
- VI. Strategic Knowledge 37
- VII. Implications for Instruction 59
- VIII. Implications for General Theory 64
- IX. Summary and Conclusions 72

**2. KNOWING WHEN, WHERE, AND HOW TO REMEMBER:  
A PROBLEM OF METACOGNITION**

*Ann L. Brown*

- I. Introduction 77
- II. Metacognition: An Epiphenomenon? 79
- III. Metamemory: A Selected Review of the Literature 81
- IV. Metamemory: New Thoughts and Old Problems 126
- V. Memory, Intelligence, and Instructions 143
- VI. Summary 157

**3. PIAGET AND BEYOND:  
TOWARD A DEVELOPMENTALLY BASED THEORY  
AND TECHNOLOGY OF INSTRUCTION**

*Robbie Case*

- I. Introduction 167
- II. Piaget's Theory of Intellectual Development 168
- III. Questions for a Developmental Theory  
of Instruction 170
- IV. A Neo-Piagetian Theory of Cognitive Development 177
- V. Research Related to the New Theory 195
- VI. Toward a Neo-Piagetian Theory of Instruction 204
- VII. From Theory to Practice: A Neo-Piagetian Analysis  
of a Classroom Task 213
- VIII. Conclusion 221

**4. THE ROLE OF GLOBAL PSYCHOLOGICAL MODELS  
IN INSTRUCTIONAL TECHNOLOGY**

*Patrick Suppes, Elizabeth Macken, and Mario Zanotti*

- I. Introduction 229
- II. Student Trajectories in Three CAI Curriculums 232
- III. Optimizing Review Exercises in the Radio  
Mathematics Project 250

**5. ASSESSMENT OF LEARNING OUTCOMES**

*Robert M. Gagné and Jacob G. Beard*

- I. Introduction 261
- II. Specifying the Task Domain 263
- III. Constructing the Test 277
- IV. Adequacy of Assessment Measures 282
- V. Decisions Required in Test Design 285
- VI. Some General Conclusions 289

**AUTHOR INDEX** 295

**SUBJECT INDEX** 301

# INTRODUCTION: Toward a Psychology of Instruction

Robert Glaser  
*University of Pittsburgh*

In increasing numbers, experimental psychologists are turning their enterprise to analyses and investigations useful to the study of the instructional process. This trend is apparent in many different fields of psychology, including the study of learning, cognitive performance, human development, and social processes. There are many reasons for this surge of interest: the increasing prestige that has come from working on socially relevant as well as purely disciplinary problems; the capability of current psychological theory for investigating more complex cognitive behaviors; and the conviction that the interaction between task-oriented and discipline-oriented research can be mutually beneficial for society and for psychological science.

For many psychologists interested in educational phenomena, the boundaries between basic and applied research are becoming increasingly blurred. Examination of recent work on the nature and development of human knowledge and intellectual skills makes it apparent that research directed toward educationally relevant areas, including the psychological processes underlying intelligence and aptitude, can be both highly fundamental in character and, at the same time, directed toward practical understanding. Much exciting work at the moment looks in these two directions — toward basic research and toward realistic educational events. Research of this kind can contribute to both application and basic knowledge by attempting to understand and improve instructional practices and, at the same time, advance scientific theory. This attitude is cogently stated by John Anderson (1976), who writes:

I am less interested in defending the exact assumptions of the theory and am more interested in evolving some theory that can account for important empirical phenomena. By a theory that accounts for “important empirical

phenomena" I mean one that addresses real world issues as well as laboratory phenomena. Such real world issues . . . would include how to improve people's ability to learn and use language, to learn and remember text, to reason, and to solve problems. This reflects my belief that the final arbiter of a cognitive theory is going to be its utility in practical application. Thus, I am proposing a change in our interpretation of what it means to understand the nature of human intelligence. I once thought it could mean unique identification of the structures and processes underlying cognitive behavior. Since that is not possible, I propose that we take "understanding the nature of human intelligence" to mean possession of a theory that will enable us to improve human intelligence [pp. 15-16].

The development of theories of this type requires an alternative approach to psychological research. The goal of most approaches is to describe, after the fact, phenomena of learning and performance. The alternative to be considered is theory and experiment that contribute to prescribing optimal ways for acquiring knowledge and skill. Indeed, there is a growing concern with the normative, prescriptive aspects of our knowledge of learning and cognition (e.g., Atkinson & Paulston, 1972; Bruner, 1964; Gagné, 1977; Glaser, 1976; Groen & Atkinson, 1966). This prescriptive task is different from the work of purely descriptive science but still requires, as the basis for optimizing learning and performance, a detailed description or hypothesis of underlying processes.

## I. THE PRESENT SCENE

Progress is now being made toward the integration required for building a psychology of instruction based on research and theory in learning and cognition. Some of the particular areas that show this interaction include: psychological task analysis of the subject matter of instruction; early childhood education and developmental psychology; the interpretation of intelligence and aptitude in terms of cognitive processes; learning from text and discourse comprehension; assessment of the outcomes of learning; and behavior modification. A brief description of the research in these areas provides an introduction to the problems that are shaping the field of instructional psychology.

*Task Analysis of the Subject Matter of Instruction.* Psychologists are expanding their attention to include the study of human behavior considerably more complex than that usually studied in the laboratory. The concepts of modern cognitive theory are being applied to understanding the stages of competence in many domains of knowledge and skill relevant to educational practice, such as text comprehension, reading music, theorem proving in geometry, and solving problems in physics. Techniques are being developed for specifying the nature of competent performance in terms that allow access to

theoretical concepts and experimental data but preserve fidelity to real-life situations. Task analysis is playing a central role in this work and instructional tasks are being studied by means of simulation techniques, information network analysis, cognitive process models, and learning hierarchies. Analytic description is required of what has been learned by an expert in a particular subject-matter domain. What is it that distinguishes a skilled reader from an unskilled one, a student skilled at mathematics from a less skilled one, or a chess master from a novice player? Task analysis is being used to describe such differences in terms of the cognitive demands placed on basic psychological processes, including attention, perception, memory, and language, and to identify structural units and sequences of instruction that might serve to facilitate the acquisition of knowledge and skill. Since an individual's capabilities change over time, task analysis must also consider the processes available at different stages of development.

*Early Childhood Education and Developmental Psychology.* Psychologists are showing increasing involvement in educational intervention and compensatory education programs for young children. This movement into the field of education coincides with increased interest in intellectual development and how it might be enhanced through instruction. Developmental psychologists are involved in research and development efforts that are multifaceted and varied, reflecting differences in psychological theory, the interests of psychologists and educators, and the complex goals of education. Overriding theoretical and practical issues continue to be the plasticity of intellectual development, the nature of cultural influences, critical periods of development, and the timing of educational intervention. Key questions concern the general and specific effectiveness of instruction or any deliberate form of intervention in altering or accelerating the biologically and culturally influenced course of intellectual development.

At present, the proliferation of new programs in early childhood education has diminished, and efforts are now focused on designing methodologies for evaluating their effects and on understanding the instructional processes that are involved. General tests of the trainability of Piagetian tasks are no longer in vogue, but more detailed analytical and experimental work is being conducted on the cognitive transformations that take place between the levels of competence that define developmental change. More precise thought is being given to what it might mean to design an educational environment on the basis of principles of cognitive development.

*Intelligence, Aptitude, and Cognitive Processes.* Many factors are forcing a breakdown between the traditionally separate areas of the psychometrics of individual differences and experimental psychology. These include questions about the use of and theoretical basis for tests of intelligence, research on the

interaction between individual differences and instructional variables, investigations of the process aspects of intellectual development, and cross-cultural studies of cognitive performance. These factors are making it necessary and possible for us to understand intelligence and aptitude in different ways than we have in the past and to change the way in which individual differences might be viewed and assessed for the purposes of education. One approach that seems likely to be fruitful for future progress is conceptualization of individual difference variables in terms of the process constructs of cognitive theories. Research along these lines is accelerating. The nature of the cognitive processes involved in the performance of test tasks used to measure and define intelligence is being investigated. As cognitive strategies and metacognitive processes are identified, attempts are being made to assess how they might be influenced by instruction.

*Discourse Comprehension.* There has been a pronounced increase in the number of studies concerned with meaningful prose materials of paragraph length, typical of the kind of material employed in textbooks and everyday written communication. This is in contrast to the more artificial materials of traditional verbal learning experiments or the specifically designed sentences and short paragraphs of early psycholinguistic studies. The organizational structure of text is being studied as it influences learning and retention. Work on text organization and the comprehension of meaning has essentially replaced classical verbal learning studies, and appropriate techniques are being developed for this new research. These studies are beginning to address directly the problem of how people learn from text. Investigators are asking how facts are organized by readers, how inferences and conclusions are drawn from written passages, and how to best instruct individuals in text-processing skills.

Study continues on the processes of beginning reading, such as letter and word decoding, phonemic analysis, and syntactic constraints. Accompanying this work, there is an increasing amount of research on the advanced semantic processes involved in comprehending discourse, including the influence of cognitive schemas and internalized representations of prior knowledge on understanding. Intensive task analysis of the nature of reading comprehension and the increased attention to learning from written materials constitute an exemplary trend in attempts to examine the relationship between knowledge, cognition, and instruction.

*Assessment of Learning Outcomes and Educational Processes.* The nature of psychological testing and its underlying discipline of psychometrics is now undergoing examination. With respect to the measurement of achievement, there are attempts to break away from the traditions of aptitude testing to measurement techniques more concerned with identifying the characteristics of levels of competent performance. Measurement models are being developed for the design of



tests that can be interpreted in terms of performance criteria rather than in terms of relative norms. The general goal is to more closely articulate assessment with the conduct of instruction so that constantly updated information about a learner's attained capabilities can be used in making educational decisions.

A related active area of investigation is concerned with detailed analyses of the conditions under which learning takes place in school contexts. There is a growing sophistication in the study of classroom processes. Past studies designed to evaluate curriculum innovations (1) attempted to describe school learning by relating the nature of student input to the quality of student output, and (2) only very generally described the processes intervening between the two. Detailed information was rarely obtained about differences between effective and less effective classroom processes in terms of some model of classroom instruction. Models now are being developed that attempt to explain the variance obtained in achievement measures in terms of the initial ability of the student, classroom process variables, and the interaction between the two. Of particular interest is the possibility that research on the dimensions of classroom instructional processes can be related to underlying theories of the acquisition of competence in the subject matters of schooling. Each endeavor should be able to reinforce or challenge the findings of the other.

*Behavior Modification.* Behavior modification, representing the application of operant theory and systematic reinforcement contingencies, first appeared in the context of clinical psychology. Educational applications now are burgeoning, and many guidebooks for teachers are available. Behavior modification practices are being implemented widely in elementary schools, and higher education is adopting operant techniques in the form of personalized systems of instruction. The successes and failures of these applications are influencing research. Classroom behavior modification studies are beginning to focus on intellectual performance, extending earlier work primarily focused on decreasing disruptive behavior and increasing attention to task. The cognitive aspects of behavior modification, represented by studies of modeling, of vicarious and self-reinforcing processes, and of self-regulatory performance are of increasing concern.

## II. HISTORICAL PERSPECTIVE

The activity just described roughly characterizes the current scene in the emerging field of instructional psychology. A synopsis of the history of the relationship between experimental psychology and education can be helpful in placing this work in perspective.

At the beginning of this century, many of the great psychological figures who were concerned with the development of a scientific psychology assumed that