KLAHR

COGNITION AND INSTRUCTION

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COGNITION AND INSTRUCTION

To

A.R.K. and L.K.K.
Who turned me toward
thinking and learning

Preface

What contributions can current research in cognitive psychology make to the solution of problems in instructional design? This volume presents responses to this question from some of the best workers in an emerging field that I have labeled "Cognition and Instruction": people concerned with the investigation of the cognitive processes involved in instructional situations. The focus of this volume was presaged by comments made in a previous volume on cognitive psychology (Forehand, 1974):

> In what seems remarkably few years, information-processing psychology has come to dominate the experimental study of complex human behavior. That rapid success encourages me to speculate that within a comparably short time the approach will have as much of an impact on psychology in the field as it has had on psychology in the laboratory. In particular, its potential for illuminating recalcitrant problems in education seems evident [p. 159].

The chapters in this volume indicate the extent to which this potential has already begun to be realized.

The book is divided into four parts. The first three parts include sets of research contributions followed by discussions, and the fourth part contains three chapters that offer critiques, syntheses, and evaluations of various aspects of the preceeding papers.

The chapters in Part I represent different strategies for instructional research. In the first chapter, Carroll, raising some of the issues facing psycholinguistic theory, asks whether we yet know enough to intentionally teach language skills according to a systematic instructional theory. He summarizes three lines of theoretical development–naive, behavioral, and cognitive–that bear upon the issue, and finally suggests that an information-processing view of the cognitive processes underlying language behavior may ultimately provide the basis for a theory of language instruction. In Chapter 2, Calfee presents a

research strategy that focuses upon the interpretation of the empirical results obtained in both the laboratory and in instructional settings. He points out the potential pitfalls awaiting the instructional evaluator who has not carefully considered all possible sources of interdependency in the cognitive models. The statistical analyses proposed by Calfee may be useful to those faced with the task of identifying the extent and the pattern of the effects of instruction.

Resnick focuses upon the area of early mathematics instruction, and she reviews and evaluates the precursors of current procedures in task analysis. Her contribution traces the development of a strategy in instructional research that utilizes information-processing models of cognition to meet the practical demands of creating effective instructional procedures.

Atkinson provides a glimpse of the latest products of his extensive research program, which is aimed at developing what he calls "adaptive instructional systems." His research strategy is based upon the view that "an all-inclusive theory of learning is not a prerequisite for the development of optimal procedures."

Part I concludes with discussions by Gregg and Olson, and their comments further emphasise the variety of strategic approaches to research on instruction. Gregg argues for the importance of understanding and representing the learner's strategies in instructional situations, whereas Olson raises the issue of the ultimate social utility of what we decide to teach to children.

The chapters in Part II focus upon process and structure in learning. The emphasis is upon the precise, explicit, and detailed representation of what is learned, how it is utilized, and how it is modified. In Chapter 7, Greeno demonstrates what such an extensive representation might look like. He provides an elaborate statement of the cognitive objectives for three different areas: elementary arithmetic, high-school geometry, and college-level psychophysics. Knowledge in each area is represented by a different collection of building blocks taken from current information-processing theories.

One of the central issues in instructional research is how new knowledge is acquired. Hyman, in Chapter 8, describes a paradigm for exploring the ways in which memory is restructured when new information is discrepant from preexistent stereotypes. Hyman uses a paradigm borrowed from social psychological studies of impression formation, and shows that it has implications for the more general issue of information acquisition.

In Chapter 9, Norman, Gentner, and Stevens utilize tools–some of them already described by Greeno–to define the general notion of "schema." The analysis by Norman, Gentner, and Stevens is extremely fine grained; they develop detailed representations for an increasingly rich understanding of such basic concepts as "give" and "buy." They argue that such representations make it possible to be quite precise about how instruction should proceed.

Shaw and Wilson, in Chapter 10, address the issues of process and structure from a more abstract–almost philosophical–position, but they also provide

concrete examples from Shaw's work on perception. The central issues concern the ability to understand an entire concept from experience with just a subset of its instances. Such an ability, Shaw and Wilson argue, lies at the heart of an understanding of invariance.

The discussions by Farnham-Diggory (Chapter 11) and by Hayes (Chapter 12) offer stimulating critiques of the positions presented in Part II. Citing an alarmingly modern instructional program devised over half a century ago, Farnham-Diggory asks first "What's new?" and then "Is it better?" Hayes suggests some ways that one can begin to train students directly in cognitive skills. He focuses upon a recurring theme in the chapters of Part II: "What does the student know about his own cognitive processes?"

An essential but neglected element in instructional research is the role of instructions per se, and the contributions to Part III focus upon the processes that underlie the comprehension of verbal instructions. Just and Carpenter take the sentence as their unit of analysis. Using a sophisticated and explicit model of sentence processing, they are able to account for an impressive variety of empirical results. Then they suggest ways in which larger units, such as those used in reading comprehension tests, could be analyzed similarly. Simon and Hayes take a larger unit of analysis—the entire instruction set. They report on the development of an information-processing model aimed at explaining the processes that underly the understanding of instructions for complex puzzles. Then, using the unambiguous components of their model as points of reference, they sketch the broader implications that a theory of understanding could have for instructional research and practice.

In the discussions in Part III, Collins (Chapter 15) and Shaw (Chapter 16) suggest areas for extension of the models of comprehension described earlier. Collins asks about the nature of the comparison process—a basic unitary process in the Just and Carpenter model—and speculates that it might itself be composed of even more elementary subprocesses. Another issue raised by Collins is the role played by the broader knowledge base in which the comprehension processes for sentences or task instructions operate.

Shaw's comments range somewhat farther afield, touching on the papers in Part II as well as those in Part III. He outlines programs in two diverse areas—art instruction and treatment of aphasia—that derive from a theory of comprehension that draws upon elements of the models presented in many of the previous chapters.

The three chapters in the fourth and final section represent responses to many of the issues raised in previous chapters. Glaser (Chapter 17) addresses the issue of how we can take the results of scientific research and apply them to practical problems. He argues for the development of a linking science—a science of instructional design—that would transform our knowledge of cognitive processes into instructional procedures while at the same time providing tests and challenges for the existing theories. Cazden (Chapter 18) raises some very practical

questions based upon her varied experience as both a classroom teacher and a research psychologist. One example of the kind of issue that is central to a theory of instruction but still inadequately handled by our current theories is Cazden's question: "What is the value of practice?" Finally, Klahr (Chapter 19) sketches some of the issues that would need to be resolved before one could construct a model of a learner.

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The contributions to this volume are based on some of the presentations given at the Tenth Annual Carnegie Symposium on Cognition, during the first week in June, 1974, in Vail, Colorado. The Symposium was supported by a contract jointly funded by the Personnel and Training Research Programs, Division of Psychological Sciences of the Office of Naval Research, and the Advanced Research Projects Agency of the Department of Defense. It was held under the auspices of the Department of Psychology at Carnegie-Mellon University.

Several people who do not have chapters in this volume nevertheless have had an influence on its contents. These people presented workshops at the Symposium: informal descriptions of on-going instructional explorations. The workshops were distributed through the week of the Symposium in order to provide some concrete instances of interesting instructional problems. The workshop leaders were not requested to prepare formal papers; thus, the workshops are not included in this volume. There seemed to be no adequate way to convey the content of the workshops and the discussion they generated, although much of the intellectual excitement during the Symposium came from these sources.

The workshops included:

1. "The adaptation of instruction to individual differences: an information-processing approach," by J. G. Wallace, University of Southampton.
2. "On some cognitive processes presumed to be operating in computer assisted instruction," by Dexter Fletcher, University of Illinois.
3. "Intuitive and formal modes of representing music," by Jean Bamberger, Massachusetts Institute of Technology.
4. "Teaching problem solving," by J. R. Hayes, Carnegie-Mellon University.
5. "Teaching formal operations," by Robert Siegler, Carnegie-Mellon University.

I would like to thank each of these participants for enriching the Symposium with their informal presentations.

In organizing the Tenth Symposium and in editing this volume, I was assisted in diverse ways by several of my colleagues at CMU. Careful and critical readings of early drafts of various chapters were ably done by John S. Carroll, J. R.

Hayes, William Leaf, and especially Jola A. Jakimik. Bibliographic assistance came from Elaine Shelton, and Marlene Naughton did the lioness' share of the secretarial work for both the Symposium and the book itself. Symposium planning, execution, and follow-up were masterfully managed by Marcia Goldstein, assisted by Marshall Atlas, Michelene Chi, and Kenneth Kotovsky. I would like to thank all of these people for assisting a neophyte editor and symposium organizer. I would also like to acknowledge the constructive approach to contract supervision that was evidenced by Dr. Joseph L. Young, Assistant Director of the Personnel and Training Research Programs, Office of Naval Research. He played a key role in the initial conception of the Symposium topic and provided unobtrusive encouragement throughout the whole enterprise.

Finally, I gladly thank my wife Pat for her advice, encouragement, and wisdom, and for the assumption of responsibilities that this book at times caused me to neglect.

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Pittsburgh, Pennsylvania

COGNITION AND INSTRUCTION

Contents

Part I

STRATEGIES FOR INSTRUCTIONAL RESEARCH

It is often thought and said that what we most need in education is wisdom and broad understanding of the issues that confront us. Not at all, I say. What we need are deeply structured theories in education that drastically reduce, if not eliminate, the need for wisdom. I do not want wise men to design or build the airplane I fly in, but rather technical men who understand the theory of aerodynamics and the structural properties of metal . . . And so it is with education . . . I want to see a new generation of trained theorists and an equally competent band of experimentalists to surround them, and I look for a day when they will show that the theories I now cherish were merely humble way stations on the road to the theoretical palaces they have constructed [Suppes, 1974].

1

Promoting Language Skills: The Role of Instruction

John B. Carroll

Educational Testing Service[1]

Can language skills be taught? The answer to this question depends upon how we define "language skills" and what we mean by "teaching." There appears to be a fundamental divergence—usually between behavioral scientists on the one hand and educators on the other—as to what these terms mean.

In the context of behavioral science, *instruction* is often taken to mean definite, specifiable "behavioral" objectives, highly-controlled instructional settings and materials, and definite procedures for observing and measuring learning outcomes. But in the minds of educators, it is generally the case that:

> 'Instruction' is a word within the system (education) that has no operational definition. It refers to many different ways in which the relationships among students, teachers, learning materials may be structured. Discursive situations, at all levels of instruction, tend to be seen as effective. They, and other types of structured situations, are being defended against displacement by instruction geared only to operationalized episodes [Dickinson, 1971, p. 112].

Even McKeachie (1974), a behavioral scientist, is inclined to express his unhappiness with the term "instructional psychology," "for 'instruction' carries a connotation of teacher direction or building that is less pleasing . . . than the emphasis on the student implied in 'learning' [p. 162]."

Dispute over the meaning of "instruction" and "teaching" is found also among educational philosophers. It is commonly agreed that teaching is any activity that is designed to result in learning on the part of the individual being taught, but there is debate as to whether such an activity should be called teaching when there is no *intent* on the part of the teacher to teach, or when it is not *successful* in producing its intended outcome (Scheffler, 1960).

[1] Currently, Department of Psychology, University of North Carolina at Chapel Hill.

Consider the claim that the child learns his native language without being "taught," simply by "exposure" to adult models. To support such a claim, one would have to have in mind how he distinguishes between teaching and non-teaching, and how he means to define "exposure." On the other hand, it is commonly accepted that one can "teach" vocabulary knowledge, or a foreign language.

If we are to study rationally the problems of teaching language skills, we must embrace such concepts as "creativity in language" within a scientific, deterministic framework. If there is such a thing as a natively predetermined "language acquisition device" (McNeill, 1970) that accounts for the acquisition of language skills, we must describe it scientifically. If the system of language is "internalized" by language learners, the resultant internalized states must be open to scientific study by appropriate observation of the "behavior" (broadly defined) that occurs under specifiable conditions. Some of these "specifiable conditions" will fall under the concept of "instruction," but I assume that they will cover not only the kinds of deliberate, formal operations that a teacher performs in the classroom, but also the informal, largely nondeliberate actions of people interacting with each other through language and other means, for example, the interactions of a mother and her child, or the interactions of one student with another in a "discursive" situation. Whether these actions are taken with an "intent" to teach or produce learning, and whether these actions are "successful" in producing learning, are questions that are not of central interest. It does not much matter whether or not we say that the child learns his language "without being taught." What matters is what external influences, that we might be able to have under our option or control, there are upon the child's learning. There are many kinds of "language skills": speaking, listening, reading, handwriting, spelling, and written composition are the native-language skills that are given most attention in the schools, but we might also want to discuss what are often called "communication skills," including nonverbal communication skills. In all these skills, there is a developmental dimension as the individual moves from infancy to adulthood. In a previous publication (Carroll, 1971b) I have reviewed the literature on the development of these native-language skills beyond the early years. In addition, we may want to consider the problems of teaching a second or a foreign language, or of teaching a "standard" form of a language when the learner's native tongue is a "nonstandard" form of that language. I have reviewed research on many aspects of these matters in a number of publications (Carroll, 1963, 1966, 1968a, 1971a), and I do not intend to recapitulate these reviews here. Instead, I propose to focus attention on the *models of the language learner* that seem to be implicitly assumed by teachers, writers of instructional materials, and others in education, as well as such models as are offered by psychologists, psycholinguists, and linguists. We must see in what respects these models are inadequate or conflict with one another. We must also attend to what role these models assume for "instruction"—defined broadly