The Design of **Computer-Based Instruction**

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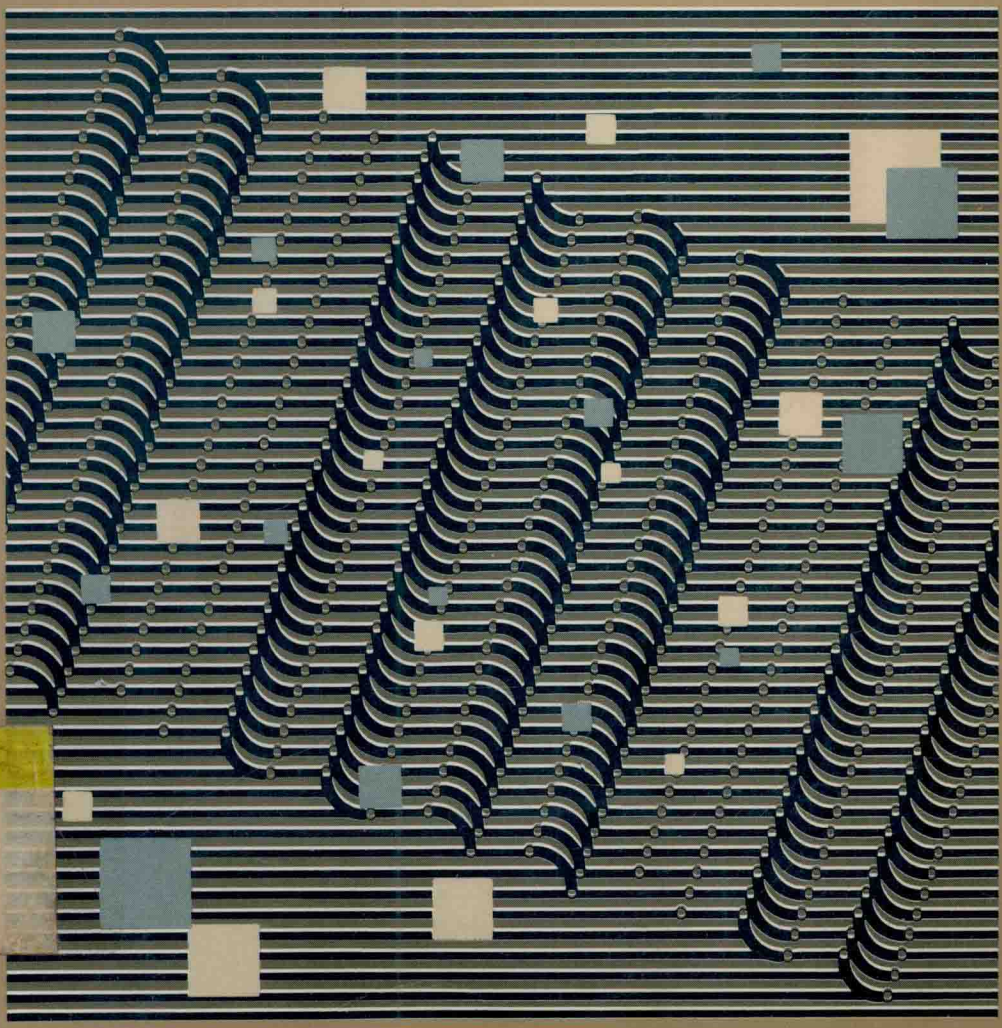

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Preface

This book approaches the design and evaluation of computer-based instruction (CBI) from psychological and practical perspectives. It emphasizes knowledge from psychology and educational research that is fundamental to CBI design and evaluation. It also describes a systematic design and evaluation process that produces successful courseware if this knowledge is used. These themes are in contrast to writings on CBI which discuss types and examples of CBI, technological advances in the computer industry, and computer code. The book provides the rationale for CBI design and is a "how to" for designers and users, not a CBI description.

This book is based on research from three specialty areas: learning psychology, cognitive science, and human factors. Learning psychology and the functional analysis of behavior offer the principles and processes by which students interact with new material and come to learn. Cognitive science deals with the structure of effective instructional material. Human factors psychology, the study of how people interact with inanimate objects, offers information about student–computer interfaces and advises how to lay out material on a computer screen to maximize student use of the material in an efficient manner. This book emphasizes findings from all these fields.

At the same time, the text is not a literature review. Much of the book consists of practical applications and examples. These examples illustrate the points and serve as a resource for CBI designers. The examples of CBI design and evaluation are based on research on CBI, research on instruction in other media besides the computer, and on professional experiences of CBI designers, including the author.

This book is for student and practicing CBI designers; most CBI de-

signers work in the areas of education, psychology, and computer science. The book is also for the many CBI designers who have found themselves, relatively unprepared, thrust into the field of CBI design by the computer revolution. As the field grows, consumers of CBI will quickly become more discriminating, and soon the marketplace will accept only that CBI which not only really teaches, but also teaches efficiently and pleasurably. This book teaches how to design effective, efficient, pleasurable CBI in any context, based on sound principles.

CBI designers work in diverse fields, from elementary school teachers who produce their own drill and practice programs to those who design innovative CBI for highly technical subject matter. In this book we discuss the teaching function of courseware—determining purposes and content, sequencing topics, increasing productive student interaction—and the evaluation function of courseware designers, writers, and teachers. Examples in the book portray a wide range in subject matter. The reader will be able to use the examples as a resource, given an understanding of the basic concepts. The use of jargon and invented terms has been avoided except in cases where the term has been well defined. This will make easier more general use of the material.

More people purchase and use CBI than design and develop it. CBI users must know about CBI design and evaluation so they will be able to select good courseware for their use. As more high-quality courseware becomes available, teachers will find that purchased software meets their needs, but they must know how to evaluate quality in the courseware marketplace. This book teaches how to evaluate quality: from a fine-grained analysis of any single practice interaction to an evaluation of the cost and training effectiveness of a CBI module.

The topic sequence of the book is design first, then evaluation. In Chapter 1 we introduce the history and types of CBI. Chapter 2 provides an integrated model of the processes involved in effective CBI design. In Chapters 3 through 7 we discuss CBI design in detail. Chapter 3 presents a 10-step process used to design, produce, and evaluate CBI. Special attention is devoted in Chapter 3 to context analysis, knowledge engineering, stating instructional objectives, communicating with the computer programmer, and programming languages. In Chapter 4 we describe the student–computer interface, especially the frame. This chapter was placed early so that readers would understand important aspects of frame display in the examples in subsequent chapters. In Chapters 5, 6, and 7 we describe sequencing and writing the important elements in CBI. In Chapter 5 we discuss ways to sequence topics. In Chapter 6 we discuss how to construct and intersperse introductions, interactions, remedial branches, reviews, and tests. In Chapter 7 we discuss how to tailor interactions for four stu-

dent performance levels: acquisition, fluency building, generalization, and proficiency maintenance. Courseware evaluation and revision is discussed in Chapter 8. Four types of evaluation are described: structural, functional, user opinion, and cost-effectiveness.

Study questions are provided at the end of every chapter. The questions cover the important points in the chapter. Definition questions require a short answer that comes directly from the text. Discussion questions require a longer answer and some synthesis. Students can answer the questions orally or in writing, alone or in class; instructors should determine how best to use the questions. Periodic review of the questions will help the student maintain mastery of the material.

Many people have encouraged me, pointed me toward literature, inspired me, and critiqued my ideas as I have written this book. I am most indebted to my husband, psychologist Dr. Bruce Wetherby. Bruce reviewed every chapter, discussed issues with me, and stimulated me to consider perspectives I had not yet considered. I am also indebted to the editorial staff at Macmillan and their book reviewers, who have been supportive throughout. Two of my associates provided thoughtful reviews: Dr. Ward Cates of George Mason University in Fairfax, Virginia, and Dr. Robert Hays of the Naval Training Systems Center in Orlando, Florida. In addition, Dr. Dexter Fletcher of Institutes for Defense Analyses in Alexandria, Virginia provided a valuable critique of Chapter 2. Several others graciously provided samples from CBI lessons they had developed which I have used as illustrations throughout the book: Dr. Nadine Hackler, University of Florida, Gainesville; Ms. Bonnie Hobson, U.S. Senate Computer Center, Washington, D.C.; Dr. Joseph Psotka, U.S. Army Research Institute, Alexandria, Virginia; and Ms. Catherine M. Taggart, Merrill Lynch, Training Technology, Plainsboro, New Jersey. Finally, I am appreciative of the support of my colleagues at Science Applications International Corporation.

E. L. C.

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CHAPTER 1

Introduction to Computer-Based Instruction

The main topics in this chapter are:

- *Definitions of terms in computer-based instruction (CBI)*
- *Optimizing the use of CBI*
- *History of CBI*
- *Scope of CBI applications*
- *Importance of hardware and software in CBI*

Definitions

The term *computer-based instruction* (CBI) refers to any use of a computer to present instructional material, provide for active participation of the student, and respond to student action. Very simply, the goal of CBI is to teach. The term "computer-based instruction" is used in this book; the terms "computer-assisted instruction" and "computer-aided learning" express the same concepts.

Learning is the relatively permanent change in the student's state of knowledge or skill. Learning is a process. Learning progresses from an initial level of poor knowledge and performance to levels of increased knowledge and much better performance, when and only when something or someone, such as a computer teacher, supports a student's progress.

Teaching consists of the teacher (human or computer) support activities that cause a student to learn. These activities include presenting new instructional challenges, providing enough practice, reviewing when necessary, informing the student about the correctness of his or her responses, allowing the student to discover for himself or herself when learning certain skills, and keeping track

of the student's progress. The understanding that learning progresses as a function of teaching activities is fundamental to designing CBI.

Teaching in CBI is accomplished by the use of a computer (hardware), programs to make the computer operate (software), and a program designed especially to administer the instruction (courseware). This book focuses on the design and evaluation of courseware.

Hardware includes the physical, electronic, and electromechanical components of computers. CBI may be designed for use on a variety of computers, from large mainframes that support individual student stations, to small home or personal computers. Effective CBI can be designed for a computer of any size.

Two types of *software* are involved in CBI. *Delivery system software* interfaces the student with the computer, and *authoring system software* interfaces the coursewriter with the computer (Bunderson, 1981).

Courseware refers, in a narrow sense, to programs that administer instruction (Futrell & Geisert, 1984), and in a broad sense, to those programs in addition to all handbooks and performance aids, and so on, which are the course material (Bunderson, 1981).

CBI in and of itself seldom constitutes an entire course. Usually, CBI is an adjunct to human instruction and is integrated into a course with other means of instruction. For example, course material might be presented by lecture, textbook review, or film, and by practice in the skill, provided by the computer. In some cases, CBI simulations provide advanced practice that would not be available in a classroom. Adjunct CBI can be used to present material and provide practice, and ancillary textbook reading may be assigned.

Optimizing the Use of CBI

CBI has been found to compare favorably with traditional instruction. A review of 51 studies conducted with sixth- through twelfth-grade students found that students in CBI classes scored in the 63rd percentile on final examinations, and students in conventional classes scored in the 50th percentile (Kulik, Bangert, & Williams, 1983). The effects of CBI tend to be greater for low achievers than for high achievers, and greater at the secondary level than at the college level, but this finding was not statistically significant in the review. The same review also found that students developed positive attitudes toward their CBI courses. As for a particular subject, CBI has been found to be more effective than traditional

methods in teaching elementary and high school mathematics, for example (Kulik et al., 1983). College-level CBI has been found more effective than traditional methods in teaching physics, anesthesiology, and Russian (Chambers & Sprecher, 1980).

When can CBI be used effectively?

- When the subject matter does not change significantly over time, because changes in the topic require reprogramming.
- When repeated presentations of the same course are needed, because computers are excellent at repeating courses over and over without a decrease in proficiency due to fatigue.
- When actual practice of the skill being learned is important, because students using CBI can practice skills that would otherwise not be possible.
- When human teachers thereby spared the teaching time may productively engage in other important instructional activities. CBI does not replace teachers, but it permits teachers to perform other activities.

Perhaps the greatest danger in using CBI occurs when it is not integrated properly into the total curriculum. CBI must be examined carefully by the teacher to determine exactly what the CBI teaches. For example, many CBI programs provide practice but do not present and teach the material. A student given a CBI practice program without being prepared for it may well flounder and despair. In other cases, some CBI is given to students as a time filler without regard to its place in the curriculum. Instructional games can be misused in this way—given to students unprepared to play them, or given to students in the hope that something (anything) useful will be taught, without analyzing the game to see if anything really valuable is being taught. Proper integration of CBI into the total curriculum is a key to its success.

History of CBI

The rapid development and spread of CBI has been encouraged by society's pressures to educate large numbers of people, our knowledge about the psychological principles of teaching and learning, and the availability of the computer. Large-scale demands for education are nothing new in the United States, but our solutions