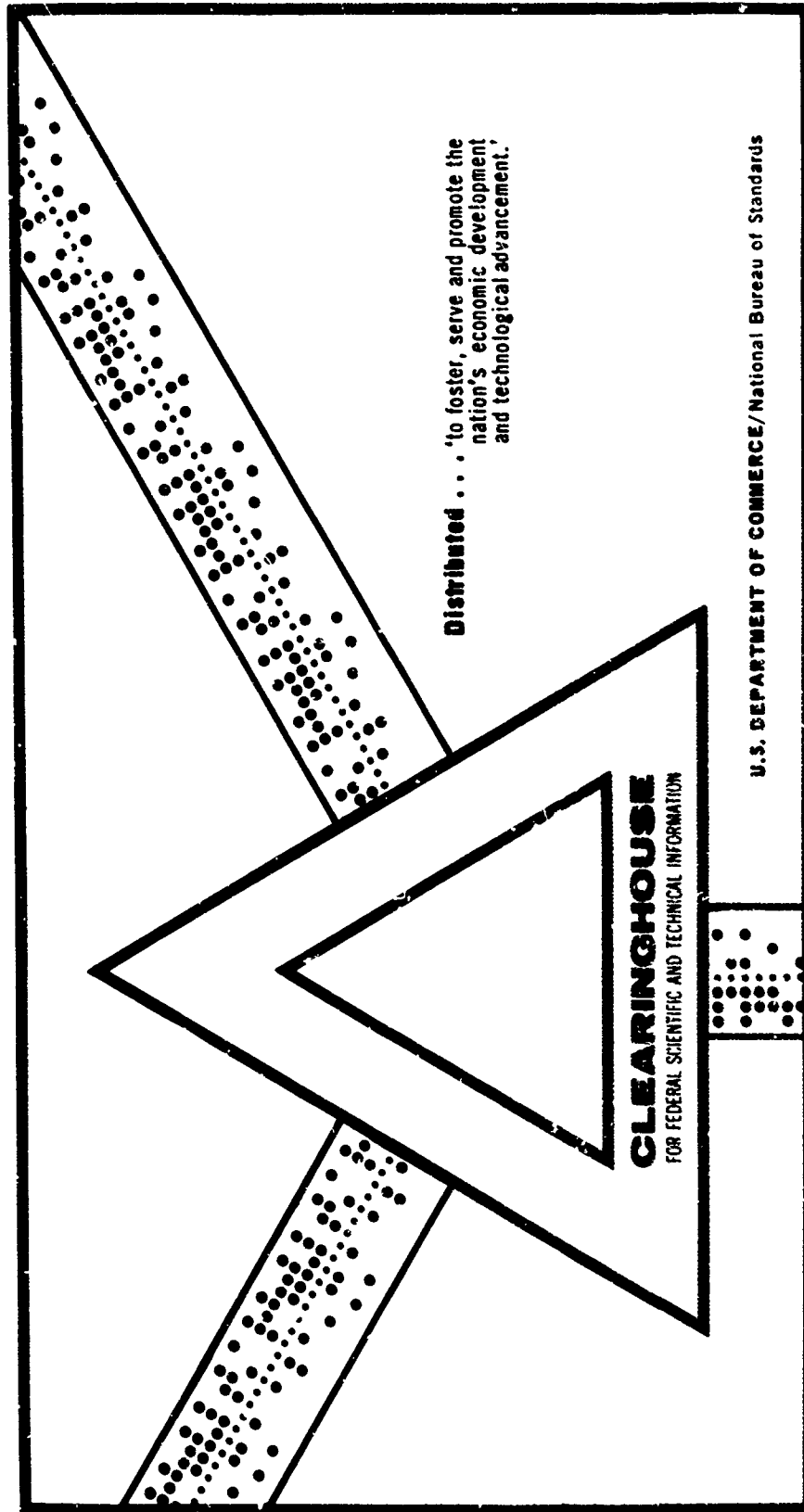


# INFORMATION MAPPING FOR LEARNING AND REFERENCE

Robert E. Horn, et al

Information Resources, Incorporated  
Cambridge, Massachusetts

August 1969



AD699201

INFORMATION MAPPING  
FOR LEARNING AND REFERENCE

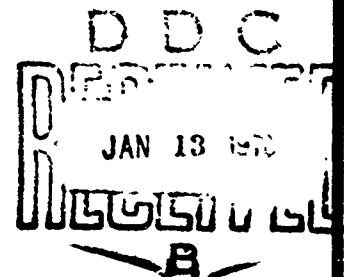
Robert E. Horn  
Elizabeth H. Nicol  
Joel C. Kleinman, et al.

August 1969



COMMAND SYSTEMS DIVISION  
ELECTRONIC SYSTEMS DIVISION  
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UNITED STATES AIR FORCE  
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**INFORMATION MAPPING  
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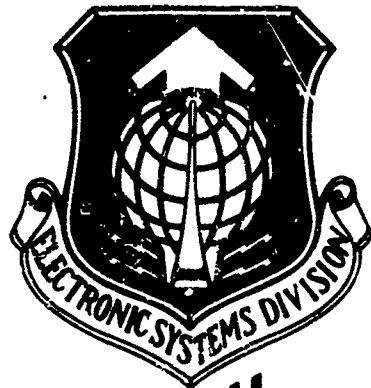
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## FOREWORD

One of the goals of the Air Force Electronic Systems Division is the development of design principles and specifications for automated training subsystems which could be built into Air Force information systems and used for on-the-job training of system personnel. These instructional innovations are aimed towards providing the improved coupling of training and operations which is essential for effective use of information systems.

Task 280104, Computer-Aided Instruction Techniques, under Project 2801, Information System Design Technology, is directed towards the fulfillment of the above technical need. This report is one in a series supporting that task. It presents research on new techniques for formatting and sequencing information in training subsystems. Although the principles involved are applicable to conventional, hard copy information display such as in military manuals, the research is aimed towards specifications and future experimental applications in dynamic, generative information displays sequenced by computer.

The study was performed between May 1968 and July 1969 under Contract F19628-68-C-0212 with Information Resources, Incorporated, Cambridge, Massachusetts, by Robert E. Horn, principal investigator, Elizabeth H. Nicol, Joel C. Kleinman, and Michael G. Grace. The Air Force task scientist and contract monitor was Dr. Sylvia R. Mayer.

This report has been reviewed and is approved.

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## ABSTRACT

Information mapping is a method of organizing categories of information and of displaying them for both learning and reference purposes. The method may be applied to the production of self-instructional books or to the organization of data bases for computer-aided instruction and reference. This report is itself written in modified information map form. The procedures and rules for information mapping were derived from educational research and technology as well as from the communications world. The emphasis is on formats to communicate quickly and to facilitate scanning and retrieval. The research and development work reported here deals with the book form of a twelve-hour course on sets and probability; significant achievement scores and favorable attitude results were found in several evaluative series with college students. Because information maps are composed of separable labelled information blocks, they can serve as the data base for computer systems where both learning and reference needs must be met. Preliminary work with simulated computer displays explored the flexibility with which a system so organized can respond with a range of user options and display variations. Cost for instruction hour is competitive with that of other methods, but the method has additional advantages in its versatility and ease of updating.

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# CHAPTER 1 INTRODUCTION TO INFORMATION MAPPING

## OVERVIEW OF THIS REPORT

Introduction	Information mapping is the name given to a method of organizing and displaying information for learning and reference purposes. This report describes the research and development work that has been done with the method in preparing self-instructional books. It also discusses exploratory work with simulated displays for computer-assisted instruction. This report is itself written in a modified information map form.
This Chapter	We describe what information mapping is, how it began, and how it was derived from learning research, educational technology, and other fields of knowledge.
The Next Chapter	The process of writing information map books is explained and illustrated with sample pages. Some content characteristics of a set of information-mapped materials are reported.
The Central Chapters	In several evaluative studies, college students learned from information-mapped books under different conditions. We report the results here.
Later Chapters	<p>We will:</p> <ul style="list-style-type: none"><li>• show how information mapping may be used in computerized systems for training and reference,</li><li>• report some exploratory tryouts with the simulated computer displays,</li><li>• describe some cost estimates for the preparation of information-mapped materials,</li><li>• summarize the present status of information mapping.</li></ul>



## OBJECTIVES OF INFORMATION MAPPING

---

**Introduction** In the past twenty years, we have seen a significant increase in research projects concerned with the man-information interface. The reasons for this scarcely need repeating. We have more information to handle in almost every job and discipline. This information is increasingly complex. People switch jobs more often, thus requiring more and speedier retraining. Technology changes; men must learn to use the new. The information-generating capabilities of the computer have surpassed all predictions.

Researchers are following many lines of inquiry in an attempt to augment the ability of human beings to interact with their new information environment. Hardware and software extend in many new and more flexible directions. Retrieval specialists are seeking new ways of indexing, abstracting, sorting, storing, and retrieving information. Computer-driven display units are becoming widely available. Time-sharing is enabling communities of workers to share the same data base. Psychologists and training specialists have given much more attention in recent years to the practical problems of how human beings learn. Enormous efforts are under way to refine programmed instruction and computer-aided instruction in a larger attempt to produce an "instructional technology."

---

**Basic  
Aims**

As one response to the burgeoning educational demands, information mapping has emerged as a system of organizing data bases for self-instructional and reference purposes. Research and development on information mapping have been concerned with these objectives:

- to make learning and reference work easier and quicker
  - to make the preparation of learning and reference materials easier and quicker
  - to develop economical procedures for designing and maintaining (e.g. updating) training and reference materials
-

## INFORMATION MAPPING: ITS SCOPE

### Basic Concept

Information mapping is a system of principles for identifying, categorizing, and interrelating the information required for learning-reference purposes.

The system can be applied to production of books for self-instruction or to the specification of data bases for computer-aided instruction. Most of the research and development work described in this report was concerned with information-mapped books.

### Books

Information map books are learning and reference materials in which categories of information are consistently ordered on the page and are clearly identified by marginal labels.

The arrangement of information blocks is dictated not only by logical analysis and classification of subject-matter concepts but also by analysis of the contingencies required for successful learning and reference use. Therefore, in addition to basic content material, information map books also have:

- introductory, overview and summary sequences
- diagrams, charts, trees
- feedback questions and answers in close proximity to material to be learned
- self-tests and review questions
- tables of contents, alphabetic indexes and local indexes with connections to related topics

### Computer Data Base

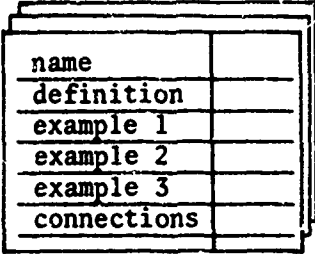
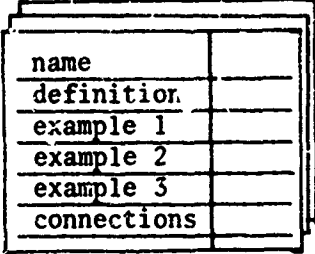
Through our studies with a book version of an information mapped subject, it has become clear that similar techniques could effectively organize a data base for computer-assisted instruction.

The data base would be composed of separable labeled blocks of information together with their interconnections. This would afford a flexibility in using only those parts of the system that are required for a particular purpose.

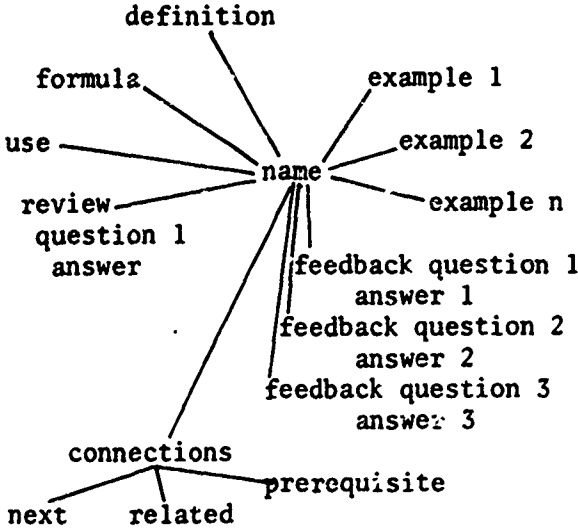
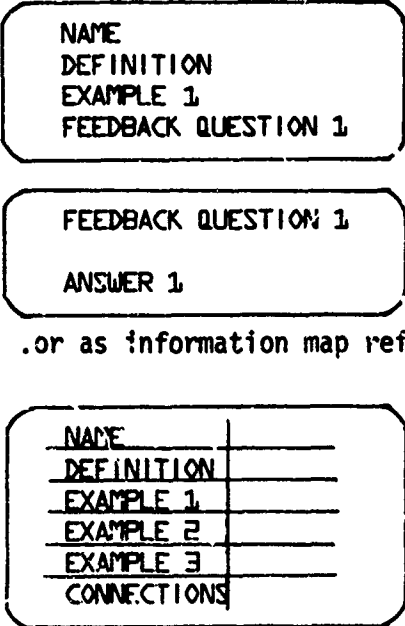
The flexible block-identified data base could be rearranged for:

- initial learning
  - for the naive student
  - for the sophisticated student
- relearning or review
- reference use

IN A BOOK FORM, INFORMATION MAPS ARE. . .

Stored this way. . .	. . .and displayed this way. . .
. . .on printed pages	. . .on the same pages
	

BUT WHEN USED IN A COMPUTER, THE SAME INFORMATION MAPS. . .

. . .are stored this way. . .	. . .and may be displayed in any of the following ways. . .
. . .in interconnected networks of electronically coded information blocks. . .	. . .as programmed instruction-like sequences. . .
	
	. . .or as information map reference. . .
	. . .and in several other ways depending upon learner control and dynamic display capabilities.

## VISIBLE AND INVISIBLE FEATURES OF INFORMATION MAP BOOKS

---

**Introduction** Information maps for self-instructional books are conspicuous for their physical features, the format in which they present information.

An equally important aspect of such information maps, however, is that the content itself is selected and organized according to a set of underlying principles.

The method of presentation and the organization of content may be thought of as the visible and invisible features of a mapped page.

---

### Visible Features

The more obvious visible characteristics are these:

- information is presented in blocks
- marginal labels identify the kind of information in each block
- a consistent format is used for each kind of information: procedures follow one format, concept maps follow another distinct format, and so on
- functional and uniform headings and subheadings are used to make scanning easy and to speed up reference work
- each information map begins on a new page and, in programs for initial learning, most maps occupy single pages
- feedback questions and answers are located in close proximity to the relevant information maps
- a local index at the bottom of maps provides page numbers for quick location of prerequisite topics

(The last two features are not used in technical reports.)

### Invisible Features

---

The arrangement and sequencing of materials presented in information map formats are the result of:

- detailed specification of learning and reference objectives in behavioral terms
  - specification of prerequisites for the subject-matter area
- 

continued on next page

VISIBLE AND INVISIBLE FEATURES OF INFORMATION MAP BOOKS, continued

(continued)  
Invisible  
Features

- 
- classification of the subject matter into component types (concepts, procedures, etc.)
  - definition of the contingencies required for successful learning and reference
-

## ORIGINS OF INFORMATION MAP FEATURES

### Introduction

In the effort to design more efficient materials for learning and reference, we drew upon accumulated knowledge in science and technology. Research findings, generalizations, and procedures from many areas were considered with a view to their possible practical value for instruction or reference.

### Fields Drawn Upon

Gradually we evolved the set of guidelines and rules for organizing and displaying information that we now refer to as information mapping. These guidelines have their origins in such areas as these:

- logical analyses of subject matters
- learning research findings
- teaching practice
- programmed instruction techniques
- display technology
- human factors research
- communications techniques, including effective writing principles

The implications of the various ideas were translated into practical form and were documented as rules or procedures for preparing information maps.

Example: A common research finding is that learning is enhanced when practice exercises and answers are given in close proximity to new material. This finding becomes the basis for the information map rule that a page of feedback questions and answers should generally be inserted after each map of new information.

### Coming Up

In the next few pages, we draw upon the field of education to illustrate how certain information map features were derived. We also outline briefly the process of designing and developing learning materials in book form.

The next chapter traces the actual process of writing maps from the present set of guidelines.

## INFORMATION MAP FEATURES DERIVED FROM LEARNING RESEARCH AND TEACHING PRACTICE

**Introduction** Although information map features have their origins in several fields, there is no doubt that their principal foundations lie in education and learning research. On the chart below, we indicate briefly some of the findings that led to the design of certain information map features. This chart (which is not intended to be exhaustive) is one example of the research support behind information mapping.

Naturally, the evidence is not all of equal strength, but we have tried to bring to bear on a practical task some of the most promising factors.

Because the experimental basis for some map features is extensive, we cite wherever possible research review articles to put the reader in touch with the main sources of evidence. In the citations below, such major review articles are marked by asterisks to distinguish them from reports of original research.

These results of educational research lead to . . .

... these implications for the design of instructional materials.

Active responding generally aids learning.  
(Lumsdaine and May\*, 1965;  
Briggs\*, 1968; Glaser\*, 1965)

The act of writing responses helps some learners.  
(Edling\*, 1968)

Feedback or knowledge of results (or 'reinforcement') often facilitates learning by:

- confirming or correcting learner's understanding
- providing a motivational effect
- improving scanning behavior

(Lumsdaine and May\*, 1965;  
Smith, 1964; Gagné and Rohwer\*, 1969; Glaser\*, 1965)

Insert feedback questions after introducing new materials.

Locate answers conveniently nearby.

continued on next page

INFORMATION MAP FEATURES DERIVED FROM LEARNING RESEARCH AND  
TEACHING PRACTICE, continued

These results of educational  
research lead to . . .

. . . these implications for the  
design of instructional materials.

The insertion of questions,  
"test-like events," after text  
segments has a positive effect  
on learning. Giving knowledge  
of results further increases  
the effect.

(Gagné and Rohwer\*, 1969;  
McKeachie\*, 1963)

Self-tests, pretests facilitate  
retention.

(Glaser\*, 1965; Briggs\*, 1968;  
Bloom\*, 1963)

Use feedback questions after maps  
with new information and use sets  
of review questions after natural  
clusters of maps and at the end  
of topic treatments. Provide  
answers as well.

In concept learning, a variety  
of examples promotes learning.

(Gagné and Rohwer\*, 1969;  
Lumsdaine\*, 1963)

Use examples and nonexamples to  
point up differences and similar-  
ities among concepts.

Instructions are useful in  
calling learner's attention to  
important features.

(Gagné and Rohwer\*, 1969;  
Gagné, 1965)

Use introductory paragraphs  
or previews to alert learner to  
importance of upcoming ideas.

Judicious use of underlining  
often helps to focus attention  
on key elements.

(Hershberger and Terry, 1963)

Underline important words in  
definitions.

continued on next page



INFORMATION MAP FEATURES DERIVED FROM LEARNING RESEARCH AND  
TEACHING PRACTICE, continued

These results of educational research lead to . . .



. . . these implications for the design of instructional materials.

"Cueing" or labelling appears to aid by alerting learner to nature of upcoming information and informing him what his learning task is.  
(Glaser\*, 1965)



Use marginal labels and informative map titles.

Pictorial materials often help learning.  
(Briggs\*, 1968)



Use diagrams and drawings to illustrate concepts and procedures.

For some kinds of materials, charts of the information are valuable.  
(Feldman, 1965)



Use tables and verbal matrices to display concept relations.

Simple sentence structures in the active voice make learning easier.  
(Gagné and Rohwer\*, 1969; Coleman, 1965)



In general, use active voice and simple sentences.

## ORGANIZATION AND INTEGRATION OF INFORMATION IMPORTANT FOR LEARNING

---

Introduction	Some important features of information mapping owe their origins to a topic of current theoretical interest among learning psychologists - namely, the logical and psychological structures of knowledge and their impact on learning and retention.
--------------	--

---

Theoretical Discussions	Piaget had long ago speculated that "learning . . . is facilitated by presenting materials in a fashion amenable to organization" (Flavell, 1963), but it is only in recent years that psychologists have actively taken up the problems of how cognitive structures develop and of the role of organization in learning and retention.
-------------------------	---

The 'atomistic' approach of most programmed instruction materials has been criticized (Stafford and Combs, 1967) and a firm case made for the advantages of "meaningful organization and holistic presentation of materials."

In a symposium on "Education and the Structure of Knowledge" (Phi Delta Kappa, 1964), P.H. Phenix remarked: "It is difficult to imagine how any effective learning could take place without regard for the inherent patterns of what is to be learned."

David Ausubel (1960, 1963, 1964, 1968) has developed a logical and psychological case for believing that learning and long-term retention are facilitated by 'organizers' which provide an 'ideational scaffolding.' He has now amassed considerable experimental support for his hypotheses.

The well-known studies of Katona (1940) with college students pointed up the importance of organization for learning and for retention.

The relation of organization of materials to ease of learning also finds support in the area of verbal learning research (Underwood\*, 1966).

---

Implications for Information Map Books	Although many issues remain to be settled by research, a strong case can be supported both logically and empirically for the advantages of organizing and integrating features in materials for learning. Both verbal and graphical means can be used to inject a sense of organization and direction into a subject-matter presentation.
--	---

---

In the practical effort to design effective learning materials, we have incorporated a number of features intended to help the learner integrate and organize the ideas for more efficient storage in memory. These are listed on the next page.

## FEATURES TO AID IN ORGANIZATION AND INTEGRATION

---

**Introduction**    The following list of features designed to promote integration of concepts and relationships contains some that we have already adopted on other grounds. For instance, the guidelines called for practice questions and answers throughout the text because learning research suggested their value in several ways; but questions can also be phrased to encourage integration of ideas over sections of learning materials.

Examples of maps showing some of these features are given in Chapter 2.

---

**List of  
Features**

- reviews and previews: to take stock of the ideas developed up to that point and to prepare the ground for relating them to new concepts about to be encountered
  - introductions to each map: to relate new idea to previous concepts or to familiarize with nature and importance of new idea
  - recaps or capsules: to summarize succinctly the essential ideas of rules or principles in nutshell form
  - tree diagrams: to sketch the ideas and procedures of a topic so as to show the role of each and its links to others
  - compare-and-contrast tables: to point up the similarities and differences between two concepts that are sometimes confused
  - summary tables: to chart in easy reference form the main concepts of an area
  - review tests after short sets of maps and at the end of units: to promote the integration of several concepts and to practice using them in problem solving
  - prerequisite charts: to show schematically the paths the learner can take through a subject matter in order to reach the learning objectives
-

## INFORMATION MAP FEATURES FOR EASE OF REFERENCE

**Introduction** In designing book-type materials for initial learning, we added features to facilitate the return to ideas previously encountered, an activity that is often frustrating with conventional texts where the contents of the paragraphs are unlabelled. Common sense, human factors research, and graphic technology were used in formulating aids for easy access to the learning materials. A list of these aids appears below.

It is clear also that these same features would be important for reference manuals or job aids. If information map materials were designed for those purposes alone, some of the introductions, explanations, and examples needed for initial learning would be omitted.

Again we note that some of the features needed for easy reference purposes have already been mentioned as desirable on other grounds. For example, labels on information blocks aid in quick retrieval of ideas but they also serve to alert the learner to the nature of his learning task and prepare him to take in a specific kind of information.

### List of Features

- Tables of contents for learning books are organized and formatted to speed location of topics and special features. (This report does not use the standard format but follows certain ESD report requirements)
- A predictable format for each type of map (concept, procedure, etc.) facilitates location of needed information.
- Map headings in consistent typography help in scanning for page topic.
- Marginal labels help not only in locating the kinds of information sought but also in skipping those not required.
- Local indexes at foot of each map permit quick location of concepts relevant to the given map.
- Decision tables display the choices appropriate for each possible situation.
- Summary tables assemble main facts and relations for easy review and reference.

continued on next page

## INFORMATION MAP FEATURES FOR EASE OF REFERENCE, continued

(continued)  
List of  
Features

- 
- Capsules provide "kernel" statements of key rules or concepts
  - Flow charts show graphically the sequences of events in a process
  - Indexes aid information retrieval.
-

## OTHER PARTS OF THE INFORMATION MAP SYSTEM

Introduction	<p>So far we have been concerned with what information maps look like, how they got that way, and how they are written.</p> <p>But the process of writing cannot begin until fundamental curriculum plans are worked out. Furthermore, the end of the writing task is by no means the end of the production process -- a crucial part of that process is the series of try-and-revise cycles through which the product is refined and the learning outcomes are brought closer to the program objectives.</p> <p>The information mapping system, then, includes guidelines for curriculum planning and for developmental testing.</p>
Curriculum Planning	<p>Once the subject-matter area of the project has been agreed upon, a series of interrelated decisions must be settled, including the type of audience for which the program is intended, the conditions under which it is to be used and so forth. When the scope of the program has thus been defined, charts showing the nature of the writing task are evolved through the following steps:</p> <ul style="list-style-type: none"><li>• The nature of the subject matter is explored and the potential topics are listed.</li><li>• The learning objectives for the specific program are determined and are stated in behavioral terms.</li><li>• The topics that are required to meet the specified learning objectives are organized into a schematic display called the "preliminary prerequisite chart" -- a chart working backward from the objectives to the topics that are required to meet those objectives.</li><li>• Analyze the nature of the learning tasks and plan the teaching strategies for achieving them.</li><li>• Revise the prerequisite chart to show the assembling of concepts into the networks of associations building toward the final instructional goals.</li></ul>
The Prerequisite Chart	<p>This chart of the topics and their sequencing plus special learning materials serves as a guide to the writer in his task. The process of writing is illustrated in Chapter 2.</p>

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OTHER PARTS OF THE INFORMATION MAP SYSTEM, continued

Successive  
Approxima-  
tions

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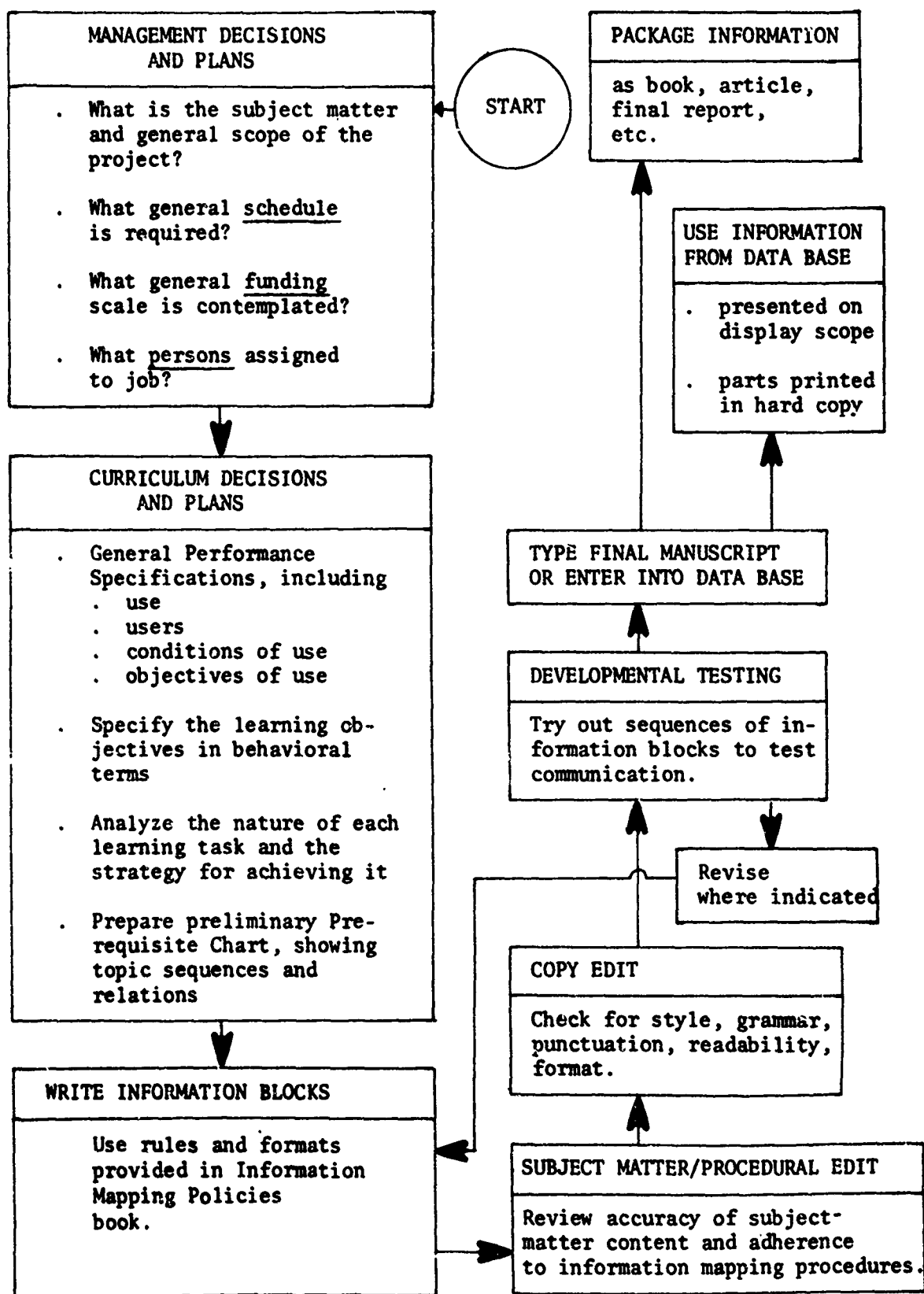
Because teaching and writing are both arts, we do not expect the first draft of a learning program to be totally successful. We rely heavily on the iterative process -- cycles of tryouts with students and revisions of the materials in response to their reactions.

The most important aspect of these tryouts is that the feedback questions and sets of review questions spaced throughout the program give us immediate evidence of the topics that need amendment or expansion.

Developmental tryouts and revisions are key tools in the production of effective information-mapped materials.

---

## THE PROCESS OF INFORMATION MAP PRODUCTION





## THE CONTINUING EVOLUTION OF THE INFORMATION MAP SYSTEM

Introduction	We have mentioned how the guidelines and processes of the information map system first came to be formulated. But the initial statements were only the beginning of a development process that continues into the present.
Developmental Testing	The rules and guidelines were tried out in the preparation of learning materials in several subject-matter areas. As these products took shape, they were subjected to tryout-and-revise cycles with college-age subjects. The students' responses to feedback questions throughout a given map series gave us a basis for continuing improvement of the learning units. But more important in the early stages was the value the responses had for refining the system itself. Rules were amended, format policies were changed, new procedures were introduced. The system continues to evolve gradually as our experience grows and as new situations are encountered.
Subject-Matter Experience	So far we have applied the system mainly to topics in mathematics. The major part of our experience was gained in writing, testing, and reviewing a 150 page introduction to sets and probability. This book of mapped learning materials constitutes a ten hour self-instructional course; it served as the main research vehicle for the studies reported in Chapters 3 to 7.

It was also an important influence on the development of the system itself. Maps from this work are shown in Chapter 2 to illustrate the writing process and to show the nature of the learning materials.

Other subject areas with which the system has been tried are:

SUBJECT MATTER	APPROX. NO. OF INFOMAPS
Computer programming	75
The binary number system	60
Convrs, an experimental computer language	150
Canard, a simulation language	150
Introduction to descriptive statistics	75
Introduction to matrix algebra	35
Permutations, combinations, and the binomial theorem	50

continued on next page

## THE CONTINUING EVOLUTION OF THE INFORMATION MAP SYSTEM, continued

(continued)  
Subject-  
Matter  
Experience

A wider range of topics was explored by a group of graduate students in a summer school course in 1967. They prepared brief units on:

- basic concepts of operant conditioning
- some topics in American history
- a variety of educational research concepts and procedures
- two dentistry topics: how to extract a tooth, and periodontology
- a topic in chemistry: the structure of the atom
- the Munsel color system in art
- darkroom procedure in photography
- several topics in mathematics

Comment

Experience with other subject areas will undoubtedly raise new classification and display problems for which guidelines will have to be devised. But we expect that the main impetus to the evolution of the system will come from continuing research.

## CHAPTER 2 WRITING INFORMATION MAP BOOKS

Introduction	<p>To show how the rules and policies guide the writing of information maps and to give the reader some experience with actual learning materials, we describe in this chapter some major types of maps and illustrate them with sample pages. These are taken mainly from the book on sets and probability that we used in the research to be reported in later chapters.</p> <p>Not all of the various types of information maps can be illustrated by this subject matter. For example, there would be no need in this material to use a <u>process</u> map, one that shows a structure changing over time.</p>
Map Classification Chart	<p>A full listing of the present classifications of map types with the kinds of information blocks that may appear on each is presented in the appendix. Because information mapping is a growing, changing system, we do not regard these lists as being fixed or complete. It is probable that deeper explorations into quite different subject-matter areas would reveal the need for other map types.</p>
The Guidelines	<p>This chapter describes the current state of the guidelines for writing some of the common types of information maps. Many of these are necessarily general in phrasing. And obviously, no matter how specific they might become, they can never eliminate the need for competent writers. Many of the more important maps (such as reviews, previews, and summaries) require a certain degree of "artistry" in order to be properly effective.</p> <p>The task of working up interesting examples and feedback questions is especially burdensome and demanding because information map books use so many of these. The skill with which this task is done makes all the difference between an amusing, challenging book and a dull, boring one.</p>
This Chapter	<p>In our descriptions on the following pages, we assume that decisions have already been made about the major curriculum issues: the scope of the project, the nature of the intended audience and specification of the desired learning outcomes. In this chapter we illustrate the nature of the writing task from that point on.</p> <p>The chapter ends with an account of some of the content characteristics of a completed set of information maps.</p>

continued on next page

Note on  
the Unit  
Map

---

The sample pages presented in this chapter are maps that take up only single 8 1/2 x 11 inch pages. This arises from the fact that the authors made a conscious effort to limit each map to the single page. There were certain practical and psychological advantages in this "modular" approach. However, in certain cases of difficult topics or long procedures, it occasionally became necessary to depart from that format. In such instances, the map might take up two pages; we have no cases requiring more than two. A map always begins on a new page.

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## PREPARING THE PREREQUISITE CHART

Introduction	<p>An important tool in specifying the topics that you want to present to your audience is the prerequisite chart. This serves to clarify the relationships inherent in the subject matter and the teaching strategy to be used. Prerequisite charts are not entirely new on the instructional scene, being occasionally used in curriculum planning. (The term prerequisite must not be taken to mean the prerequisite skills a student should have mastered before taking up a certain course of study.)</p>
Definition	<p>A prerequisite chart is a graphical presentation of the topics that will be covered in the information map book. It is called a prerequisite chart because in the network format the relation of each concept to others is immediately visible - for any given concept one can identify the topics that are prerequisite for it. It is intended to reflect not only the relationships within the subject matter but also the teaching strategy to be used in presenting the topics. (An example is shown on page 26.)</p>
Preliminary Step	<p>The first step in writing an information map book is to list all the topics that might reasonably be included in a course on this subject at the appropriate level. The point to keep in mind is that the topics listed should not cover the entire breadth of knowledge contained in the subject, but only those topics that are appropriate for the intended user population. This list is subject to revision as developmental testing proceeds.</p>
Example	<p>Our unit on sets was written for college students in the behavioral sciences, and was intended to serve as background material for a unit on elementary probability. The topics we thought should be included were:</p> <ul style="list-style-type: none"><li>• concept of a set</li><li>• elements of a set</li><li>• describing sets</li><li>• Venn diagrams</li><li>• subsets</li><li>• the number of subsets in a set</li><li>• null set</li><li>• universal set</li><li>• complement</li><li>• union</li><li>• intersection</li><li>• difference</li></ul>

continued on next page

## PREPARING THE PREREQUISITE CHART, continued

(continued)  
Example

- disjoint sets
- finite and infinite sets

Since the purpose of the unit was to give those aspects of set theory that would be helpful in presenting the elementary theory of probability to students with a minimal background in mathematics, we decided to omit the distinction between finite and infinite sets (our treatment of probability was only to cover finite sample spaces).

Planning the  
Sequence

Because the topics in the list are obviously interrelated, the order in which they are presented must be planned. This is where the prerequisite chart helps.

Two things must be kept in mind when ordering the topics. First, there is usually no one logical sequence inherent in a subject matter. Thus, it is up to the authors to decide upon the logical sequence of the steps. This would usually involve the philosophy and "esthetic sense" of the authors about the subject matter.

The second point is that the sequence of presentation involves a "teaching strategy." The logical order chosen in the initial charting of the subject matter may not be ideal from a teaching point of view. And so the prerequisite chart will be adjusted according to the authors' perception of the learners' needs and of the most effective means of serving them. The plan may still undergo considerable change after developmental testing.

Comment

The aim of this preliminary analysis is to get the topics down to single page map size. For example, "operations with sets" is a topic that must be broken down further since we could not cover all operations in a single map for students at the intended level. Again, developmental testing will indicate where topics need to be extended over two or more maps.

The graphical presentation of the prerequisite chart is also helpful in delegating writing tasks, since presence of nearly discrete clusters in the subject matter will be quite evident and can be taken into account when assigning the tasks.

## IDENTIFYING THE NEED FOR SPECIAL MATERIALS FOR LEARNING AND REFERENCE

**Introduction** In addition to subject-matter topics, additional materials to aid learning and review are needed at many points. Some of the information map forms that serve these purposes are: procedures, compare-and-contrast maps, tables, reviews, previews, summaries, and the presentation of certain important relations that follow logically from previous pages but which cannot be left to the students to discover.

The guidelines for writing can only indicate in a general way the kinds of places where these should be added. Many of them will be added after developmental testing has indicated some unanticipated difficulties.

MAP TYPE	DESCRIPTION	EXAMPLE
Procedure	Procedure maps explain a sequence of steps which must be followed in order to obtain a desired output.	A procedure map would be used to explain how to compute the standard deviation of a set of numbers.
Compare-and-Contrast Table	A compare-and-contrast table is used to show the relationship among certain concepts that naturally group together. It serves to remove confusion and create finer discrimination for the learner.	In set theory, a compare-and-contrast table would probably be useful for "union and intersection" and for "difference and complement."
Review, Preview, and Summary	These maps are presented before or after a group of maps that form a natural or arbitrary unit. They review what has been given thus far, showing how it fits together, and how it is related to what will follow. Since the best format for these maps will vary with the type of information that has preceded, no one guideline for these maps will be presented but different examples will be given.	One "natural" place to review and preview what is to come in the set unit is after the elementary language of set theory and before the maps on set operations. Another summary would be in order after the entire unit.

continued on next page

IDENTIFYING THE NEED FOR SPECIAL MATERIALS FOR LEARNING AND REFERENCE, continued

MAP TYPE	DESCRIPTION	EXAMPLE
Review Questions	In addition to review pages summarizing the ideas presented up to that point, we also insert at frequent intervals sets of questions requiring the learner to integrate previous ideas and to practice using them in problem solving. They are also provided at the end of units.	After maps on set union and intersection was a natural place to insert a set of review questions requiring the student to practice identification in various examples.
Implication	Some maps present information that is implied by previous material but which cannot be left to the student to discover. Theorems in mathematics certainly fall into this category, but developmental testing may point to the need for even simpler implications to be spelled out.	The theorem stating that a set with $N$ elements has $2^N$ subsets would be presented on a separate map. However, we also found that some students have difficulty forming unions of different types of sets. Thus we added a map called "Forming Unions from Sets with Different Memberships."

Comment

As a result of analyzing learning contingencies, certain of these special maps will be added to the prerequisite chart before the writer begins his task.



## Introduction

### Example

## WRITING CONCEPT MAPS

Introduction	<p>After preparing the prerequisite chart, we are ready to allocate writing tasks and begin writing. The most frequently used type of map is the concept map. This page describes the format rules for this map type and the guidelines for writing some of the information blocks that can appear in a concept map (a fuller listing of permissible blocks is given in the appendix).</p> <p>The details on this page may be easier to follow if the reader refers to the example on page 30.</p>
Definition	<p>Concept maps are used to introduce new terms or topics, and to present any information that may be regarded as a statement, concept, or definition.</p>
Format	<p>Each concept map starts with a title that may be a term or a sentence. The title is usually the designation in the prerequisite chart.</p> <p>The information explaining a concept can be sorted into various types, such as introductory remarks, definitions, diagrams, notation, etc. On a concept map, each type of information is blocked off separately and labelled in the margin. These marginal labels facilitate initial learning as well as scanning and reference. A student who prefers to see examples before definitions can do so easily. The labels used most often are explained below, but when nonstandard labels would be more informative, they may be used.</p>
Introduction Block	<p>An introduction appears with most concept maps in order to link the new concept to those that came before or to familiarize the learner with aspects of the new idea. If present, an introduction is <u>always</u> the first information block on a concept map.</p>
Definition Block	<p>The definition block obviously defines the concept being introduced. If the concept is not a new term, but an implication from previous material, the definition block may not be necessary. The term being defined is always underlined.</p> <p>A definition may be introduced anywhere on a concept map since in some cases it might be more beneficial (from a teaching viewpoint) after an example or two.</p>
Notation Block	<p>If appropriate, a notation block presents any notation commonly used for the term being defined. It follows immediately after the definition block.</p>

continued on next page

## WRITING CONCEPT MAPS, continued

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Theorem or Generalization Block	This block is usually present on a map that does not introduce a new term. A generalization block may be used if the authors do not consider the statement to be important enough to merit the word "theorem."
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Formula Block	<p>A formula may be used to restate a definition, theorem, or generalization.</p> <p>All formulas are first written in symbols and then in words directly underneath the symbols. For example, the formula expressing the definition of the mean of a sample is written as:</p>
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$$\underbrace{\bar{X}}_{\text{mean of the X's}} = \frac{\sum X_i}{n} = \underbrace{\frac{\text{sum of the X's}}{\text{the number of X's in the sample}}}$$

The formula block follows immediately after the definition, theorem, or generalization to which it refers.

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Diagram Block	Wherever appropriate, a diagram illustrating either a definition or generalization is presented. The diagram follows immediately after the formula or notation block.
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Example Block	A number of example blocks, labelled sequentially, can be presented at any point on the map. The number of examples depends on the difficulty of the concept being explained. Examples may need to be added after developmental testing; this is easy since each block is a separate unit. Diagrams should be used freely within the example blocks.
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Non-example Block	In some cases, a new concept may cause confusion with something the learner already knows. A non-example may anticipate the difficulty and help to clarify it. For example, students often confuse the null set with the set containing the number zero as its only element. Thus, on the map introducing the null set, a non-example block was used to make clear this distinction.
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Comment Block	A comment block may be used to present any additional information that might be helpful, but which cannot be sorted into another category.
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Related Pages Block	A local index listing those topics needed to understand the present concept (along with their pages) is presented at the bottom of the page.
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continued on next page

## WRITING CONCEPT MAPS, continued

(continued)

Related

Pages

Block

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Thus, if a student is having difficulty with a concept, the related pages may help him isolate the difficulty and clear it up by re-studying a previous topic. Only those topics directly connected with the concept being introduced should be mentioned; otherwise, the list would be prohibitively long.

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EXAMPLE OF A CONCEPT MAP

Introduction The following map introduced the concept of "Union" in the sets unit.

Example

30

UNION

Introduction

Some sets are composed of all of the elements of two or more sets.

Definition

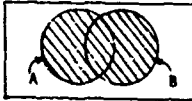
The union of two sets, P and Q, is the set of all elements that are members of P, or Q, or both. Remember that the union of two sets is itself a set.

Notation

The symbol for union is  $\cup$ .  $P \cup Q$  is read "P union Q".

Diagram

The shaded part is  $A \cup B$ .



Example One

Set A consists of the numbers 7, 8, and 9.  
Set B consists of the numbers 4, 5, and 6.


We can form new sets which contain all of the members of A and all of the members of B, and all of the members which are in both A and B, i.e.  $A \cup B = \{4, 5, 6, 7, 8, 9\}$ .

Example Two

$C = \{a, b, c\}$   
 $D = \{c, d, e\}$

The shaded portion is set  $C \cup D$ :

$C \cup D = \{a, b, c, d, e\}$

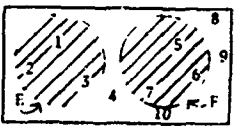


Example Three

Set E consists of the numbers 1, 2, and 3.  
Set F consists of the numbers 5, 6, 7.

The shaded portion is set  $E \cup F$ :

$E \cup F = \{1, 2, 3, 5, 6, 7\}$



Related Pages

elements, 6

set, 4

Venn diagram, 10

## WRITING FEEDBACK QUESTIONS

Introduction	<hr/> <p>An information map book has feedback questions after each map, but treats them as being optional for the learner. Thus, the student can choose whether he needs the feedback or not.</p> <hr/>
Definition	<hr/> <p>Feedback questions are based on the concept of the previous page and require a minimum amount of integration with previous topics. The purpose of feedback questions is to let the student find out whether he has understood the concept presented.</p> <hr/>
Format	<hr/> <p>Feedback questions are placed after almost every concept map (as well as after certain other types of maps). They are omitted only when the term introduced on a map is too simple to warrant any practice. This is, of course, a matter of judgment; developmental testing may point to the need for additional feedback questions.</p> <p>Answers are given with as much explanation as seems feasible. In our research program, the answers were placed at the bottom of the page. The students' reactions to this were mixed: about half liked the idea of not having to look up answers in the back of the book, but the other half thought having the answers at the bottom of the page was too much of a "temptation" - they tended to peek at the answer before trying to solve the problem completely.</p> <p>The type of questions varied: some were true-false, some were multiple choice, and some required constructed responses. In general, the types of questions written were those judged appropriate for the learning task.</p> <hr/>

## EXAMPLE OF FEEDBACK QUESTIONS

Introduction These feedback questions were placed immediately after the concept map on union.

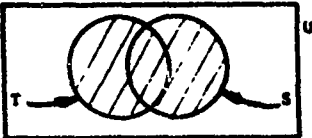
### Example

31

FEEDBACK QUESTIONS

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[Union]

1.  $G = \{ 10, 15, 20 \}$   
 $H = \{ 30, 40, 50 \}$   
 $G \cup H = \{ \quad \quad \quad \}$ .
2.  $J = \{ a, b \}$   
 $K = \{ c, d \}$   
 $L = J \cup K$   
 $L = \{ \quad \quad \quad \}$ .
3.   
The shaded portion is written                     .
4.  $A = \{ \text{All 4th grade students} \}$   
 $B = \{ \text{All girl students} \}$   
 $A \cup B = \{ \quad \quad \quad \}$ .
5. The union of  $A$  and  $\bar{A}$ ,  $A \cup \bar{A}$ , is (always/sometimes/never) the universal set.

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ANSWERS: 1]  $\{ 10, 15, 20, 30, 40, 50 \}$ . 2]  $\{ a, b, c, d \}$ . 3]  $S \cap T$ .  
4]  $\{ \text{All 4th grade students and all other girl students} \}$ . 5] Always (draw a Venn Diagram).

## WRITING PROCEDURE MAPS

Introduction	Some subject matters, especially in technical areas, have many procedures that must be followed in order to obtain a certain result. A formula in mathematics is a procedure since certain steps must be followed in order to obtain the result (e.g., the area of a triangle).
Definition	A procedure map presents the sequence of steps to be followed in order to obtain the desired result.
Format	A procedure map is always titled "How to..." and is divided in half vertically. The left side gives a general description of the procedure and the right side of the page follows through with an example. A box at the head of the page states what is given on the left and the example on the right. The procedure is followed step by step on the left and the example is worked out on the right.



EXAMPLE OF A PROCEDURE MAP

Introduction This map shows the general case and the worked example side by side.

Example

HOW TO COMPUTE THE STANDARD DEVIATION		
GENERAL CASE	A set of n numbers $X_1, X_2, \dots, X_n$	EXAMPLE. Find the standard deviation of the following test scores: 86, 82, 68, 93, 77, 58, 89, 95, 81, 71
STEP	PROCEDURE	EXAMPLE
1	Add the given numbers to get the sum: $\Sigma X_i$	The sum of the ten test scores is $\Sigma X_i = 86 + 82 + \dots + 71 = 800$
2	Square the sum and then divide by the number of cases to get: $(\Sigma X_i)^2/n$	$(\Sigma X_i)^2/n = (800)^2/10 = 640000/10 = 64000$
3	Add the squares of the given numbers to form $\Sigma X_i^2$	The sum of the squares of the test scores is $\Sigma X_i^2 = 86^2 + 82^2 + \dots + 71^2 = 65234$
4	Subtract the result of Step 2 from the result of Step 3: $\Sigma X_i^2 - (\Sigma X_i)^2/n$	$\Sigma X_i^2 - (\Sigma X_i)^2/n = 65234 - 64000 = 1234$
5	Divide the result of Step 4 by the number of cases minus one to get: $S^2 = \frac{\Sigma X_i^2 - (\Sigma X_i)^2/n}{n - 1}$	$S^2 = \frac{1234}{9} = 137.1111$
6	The standard deviation is the square root of the result of Step 5: $S = \sqrt{S^2}$	$S = \sqrt{137.1111} = 11.71$

## WRITING THE SUPPLEMENTARY MAPS FOR LEARNING AND REFERENCE

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Introduction	As we saw earlier, a number of maps give supplementary information to help the learner form finer discriminations, avoid possible confusions, integrate several concepts, or review previous ideas. They can also be previews to prepare him for the next learning sequences. No new information is presented on such maps.
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Compare-and-Contrast Tables	<p>A compare-and-contrast table displays two concepts, side by side, with their definitions, notation, and appropriate diagrams in order to show the student exactly where the similarities and differences lie.</p> <p>A compare-and-contrast table is always titled "Comparing -- and --" where the concepts being compared are inserted in the spaces. The page is divided in half vertically with the rest of the page organized as in an ordinary concept map.</p> <p>Usually, the definition, notation, and diagram blocks for the concepts are presented along with examples.</p>
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Reviews, Previews, and Summaries	The format for maps of this type is flexible. Certain parts of the subject matter may be suited to a summary table, while a more descriptive presentation may be better for other parts. The prerequisite chart itself serves similar functions of keeping the student oriented and aware of the direction the subject matter is heading. These maps are probably easier to write after all the others have been done. The prerequisite chart will show certain places where they will be appropriate. However, the need for more of these maps may be identified from the results of developmental testing.
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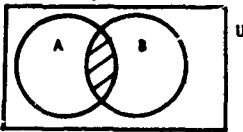
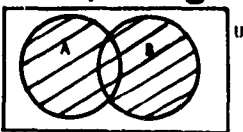
Review Questions	<p>Review questions are presented after a number of interrelated topics have been introduced - frequently before a review and preview page or after a summary map. The types of questions were similar to those in feedback questions. They are designed to help the student integrate the concepts or procedures that have gone before and to give him practice in working with the ideas.</p> <p>Answers are given along with as much explanation as seems needed. Page numbers are included to help locate the original topic treatment.</p> <p>(Since review questions closely resemble feedback questions, we do not give a sample page here.)</p>
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EXAMPLE OF A COMPARE-AND-CONTRAST TABLE

Introduction We found that the distinction between the concepts of union and intersection was frequently missed by beginning students of set theory. Thus, the following page was written.

Example

Comparing...	Intersection and...	Union
Symbol	$\cap$	$\cup$
Definition	The intersection of two sets P and Q is the set of all members belonging to both P and Q.	The union of two sets P and Q is the set of all elements that are members of P or Q or both.
Venn Diagram	The shaded part is $A \cap B$ 	The shaded part is $A \cup B$ 
Example One	$M = \{ 5, 9, 15, 33 \}$ $N = \{ 3, 5, 7, 9 \}$ Notice this intersection, $M \cap N = \{ 5, 9 \}$	$M = \{ 5, 9, 15, 33 \}$ $N = \{ 3, 5, 7, 9 \}$ Notice this union, $M \cup N = \{ 3, 5, 7, 9, 15, 33 \}$
Example Two	$E = \{ 1, 2, 3 \}$ $F = \{ 4, 5, 6 \}$ Notice this intersection, $E \cap F = \emptyset$ (There are no common elements)	$E = \{ 1, 2, 3 \}$ $F = \{ 4, 5, 6 \}$ Notice this union, $E \cup F = \{ 1, 2, 3, 4, 5, 6 \}$
Related Pages	elements, 4 union, 30	intersection, 35 set, 4

## EXAMPLE OF A REVIEW AND PREVIEW MAP

**Introduction** The following map was inserted after the elementary terms of set theory were introduced. It served as a quick capsule summary of all the concepts presented up to that point and gave a short rationale for introducing the operations with sets that were to come later.

### Example

	26
	REVIEW AND PREVIEW
Past	<p>In learning a new subject it often helps to pause and retrace the ideas covered. In doing this we can get a clearer picture of how the ideas fit together.</p> <p>In set theory we have now acquired some basic notions about the nature of sets:</p> <p>First we talked about what sets are and how to indicate them:</p> <ul style="list-style-type: none"> <li>a set is any <u>collection</u> of things or symbols; it is commonly designated by a capital letter;</li> <li>the things in a set are called <u>elements</u>, and the symbol <math>\in</math> shows that an item belongs to a set;</li> <li>to <u>specify</u> what elements are to be included in a set, we have two methods: <ol style="list-style-type: none"> <li>the <u>roster</u> method in which we list the elements of the set within braces, and</li> <li>the <u>rule</u> method in which we give a description or a definition that covers all the elements we intend to include.</li> </ol> </li> </ul> <p>Next the different kinds of sets were defined:</p> <ul style="list-style-type: none"> <li>the <u>universal set</u>, called <math>U</math>, which is the set of all units or things under consideration;</li> <li>the <u>null set</u>, which is a set with no members and which we refer to by writing <math>\emptyset</math> or <math>\{ \}</math>;</li> <li>the <u>subset</u>, a set than can be formed from <u>any combination</u> of one or more elements from another set, including <ul style="list-style-type: none"> <li>all the elements in the set, so we say "every set is a subset of itself," and</li> <li>no elements in the set, so we say "the null set is a subset of every set."</li> </ul> </li> </ul> <p>Finally, we learned that to determine the <u>number of possible subsets</u> in a set, we can:</p> <ul style="list-style-type: none"> <li>list all the possibilities and count them, or</li> <li>use the formula, <math>2^N</math>, which is more convenient when the number of elements (<math>N</math>) in the set is large.</li> </ul>
Present	Now that we know the basic kinds of sets, we are ready to start building with them. Many kinds of problems will require that we combine sets in different ways to form new sets.
Future	The operations that can be performed to make new sets from old sets will be explained on the following pages. They are rather similar to familiar arithmetic operations with numbers.

## EXAMPLE OF A SUMMARY MAP

**Introduction** This table seemed to tie up the topics related to conditional probability. Readers who are not familiar with the subject matter can nevertheless note several important features of the example. The introduction underlines the importance of the topic and suggests to the student the nature of his learning task. In the left column simple questions are paired with concrete examples to help the student remember the distinctions. Formulas are as usual accompanied by verbal descriptions.

### Example

POSTVIEW OF CONDITIONAL PROBABILITY	
<p><b>Introduction</b> Conditional probability is one of the most useful tools in probability theory. We have seen how the equation can be rearranged to give the multiplication theorem and the independence definition, both important concepts.</p> <p>The inter-relatedness of these ideas is a great boon to memory. If the conditional probability definition is thoroughly understood and stored in memory, it can serve as the key to unlock recollection of how the other formulas can be derived.</p> <p>For review, we re-state the definition of conditional probability along with the concepts derived from it.</p>	
QUESTION	CONCEPT AND FORMULA
<p>What is the probability of A, given that B has occurred?</p> <p>[Given a red-haired person, what is the probability that he has blue eyes?]</p>	<p><b>Conditional Probability:</b></p> $P(A B) = \frac{P(A \cap B)}{P(B)}$ <p>the conditional probability of A, given B = the probability that both events will occur divided by the probability of B</p>
<p>What is the probability that both A and B will occur?</p> <p>[What are the chances of winning Olympic medals in both track and swimming?]</p>	<p><b>Multiplication Theorem:</b></p> $P(A \cap B) = P(B) \cdot P(A B)$ <p>the probability that both events occur = the probability of B times the probability of A, given B</p>
<p>Are the events A and B independent?</p> <p>[Is the event "flunking math" independent of the event "flunking history"?]</p>	<p><b>Independence Definition:</b></p> <p>Two events are independent if and only if:</p> $P(A \cap B) = P(A) \cdot P(B)$ <p>the probability that both events occur = the product of the separate probabilities.</p>
<p>Given two independent events A and B, what is the probability that both of them occur?</p> <p>[If Tom and I both roll a die, what is the probability that we both get "sixes"?]</p>	<p><b>Multiplication Rule for Independent Events:</b></p> <p>[This is the independence equation just above.]</p>

## CONTENT CHARACTERISTICS OF A SET OF INFORMATION MAPS

**Introduction** The fact that subject-matter sentences are sorted into specified categories and are presented in labelled information blocks permits us to describe the contents of our learning materials with more precision than is usually possible.

We can count the number of definitions, examples, concepts, procedures, diagrams, and so on. We can also compute such things as the ratio of the number of new information pages to the number of old or redundant information pages.

The ability to make such descriptive statements opens up some interesting research possibilities.

**The Structure of an Information Map Book** The information map book on sets and probability that was used in the research of Chapter 6 was analyzed in terms of the number of information blocks of various kinds. The results are given in this table:

Map Type	Number of Maps		
	Sets	Prob.	Total
Concept Maps			
a. For new terms	17	27	44
b. For implications	2	4	6
Procedure Maps	--	4	4
Compare/Contrast Maps	2	3	5
Reviews and Previews	3	2	5
Summaries	3	5	8
Special Example pages	--	6	6
Feedback question pages	16	31	47
Review questions pages	4	8	12
Total	47	90	137

**Research Possibilities** The modular format of information maps presents a unique advantage to the researcher in that it permits him to determine the frequency with which different kinds of information appear in his materials. This means that he can manipulate experimental variables in the structure of his materials and determine the effects on the learning outcomes. For example, questions about the optimal frequency of worked examples or about the relative effectiveness of placing examples before or after definitions can be more easily researched because of the ease with which the information blocks can be moved about.

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## CONTENT CHARACTERISTICS OF A SET OF INFORMATION MAPS, continued

(continued) Research Possibilities	Subject matters themselves can be classified in terms of the relative frequency of concepts or of procedures. Optimal learning conditions may turn out to be rather different for the different types of subject matters.
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## CHAPTER 3 INTRODUCTION TO THE EVALUATIVE STUDIES

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**Introduction** With the advent of any new educational product, questions of its usefulness and of its attractiveness to potential users must be dealt with. To answer such questions for information maps our approach has been primarily to seek performance data from subjects using mapped units under different circumstances and to tap subjects' reactions to the materials through questionnaires.

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**Background** Our approach to the evaluation problem may be summed up by saying that we consider that:

- "media comparisons" are to be avoided,
- developmental testing with tryout-and-revise cycles is a key method for producing effective programs,
- pretest-posttest differences are meaningful evidence for judging whether or not a given instructional program has achieved its objectives.

In actual practice this means that we will evaluate specific information map products against explicitly stated learning objectives.

The spuriousness of "media comparisons" which abound in the literature of programmed instruction has been frequently discussed. In 1962, for instance, Stolurow detailed his reasons for judging media comparisons inappropriate and he expressed the "prediction and firm hope . . . that the comparative study will become extinct."

In their 1965 review of the educational field, Lumsdaine and May summarize the shortcomings of media comparisons and they applaud a decrease in "futile attempts to assess the over-all value of media by comparisons with 'conventional' instruction, and a corresponding increase in the proportion of studies which attempt to manipulate specifiable variables."

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**Our General Approach**

The evaluation program addresses itself to two issues:

1. The practical one of validating instructional sets of information maps, and
  2. The more experimental one of investigating certain parameters of these sets of information maps and of determining their influences on instructional outcomes.
- 

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(continued)  
Our General  
Approach

Attitude of the user toward the new method is recognized as being a very important facet of the evaluation program. It matters little if a program is strikingly effective in teaching, yet repels students from further contact with the subject matter. Many educators are now turning to attitude and user-preference data as being even more informative than performance data in assessing the value of instructional techniques. In our evaluative series we use several kinds of attitude questionnaires.

We also have relied heavily on developmental testing of each instructional unit. Preliminary tests of the materials were made as a matter of course to guide us in revising and improving the text. They were also used to perfect our instruction and attitude packages for the more formal tryouts. Only one of these was systematic enough to warrant separate attention here and it is included in the description of the final series.

The Evaluative  
Series

The instructional materials evaluated during this project dealt with topics in mathematics: the first units were entitled Mathematics Essential for Statistics; later units were concerned with elementary probability theory. All were aimed primarily at college students in the behavioral sciences and the intention was to make the topics understandable even to students with minimal mathematical backgrounds. The materials were to be self-instructional.

It is convenient to discuss the evaluations of information maps in terms of three main testing periods. These together with a brief designation of details are given in the table below. Each study will be described in subsequent chapters.

Study Designation	Date	Topics Covered	No. of pages	Comparative Conditions
Tufts University	Sept. 1968	permutations, combinations, binomial	84	controlled laboratory study versus home study.
Harvard University	Oct. 1968	sets, permutations, combinations, binomial	126	information map version versus a derived "prose" version
Spring Series	June 1969	sets, elementary probability	151	study for a closed-book test versus study for an open-book test.

## CHAPTER 4 THE TUFTS UNIVERSITY TRYOUT SERIES

Introduction	<p>The first planned evaluative study of learning from a set of information maps took place in September, 1968. The instructional unit was entitled <u>Mathematics Essential for Probability</u> and it consisted of pages of maps and of feedback questions covering the topics of permutations, combinations, and the binomial theorem.</p> <p>This first tryout was a simple, short-term one designed mainly to explore the effects of the information map unit when used both under controlled laboratory conditions and in a "natural" mode of use in home study.</p>
Basic Purpose	<p>The Tufts series was conducted to enable us to:</p> <ul style="list-style-type: none"><li>. estimate student achievement as a result of using the learning materials under two conditions:<ul style="list-style-type: none"><li>. in a supervised, timed study period,</li><li>. in home study over a week's time;</li></ul></li><li>. discover students' assessment of the Information Map as a communication technique and of its value in self-instruction;</li><li>. locate areas of the text that required adjustment;</li><li>. obtain estimates of the time required to study pages in information map form.</li></ul>
Subjects	<p>The 22 students for this study were members of a course in statistics for the behavioral sciences given in the Psychology Department of Tufts University. Eight students were graduate students in sociology, ten were psychology majors, three were joint psychology-mathematics majors, and one was a mathematics major.</p> <p>Typically, the class met once a week for three hours. Our tryout was carried out during the second and third meetings of the fall term; no materials duplicating the information map topics were assigned to the class before or during this period.</p>
General Plan	<p>The tryout of the information map was planned to consist first of a supervised study period in the students' classroom during which they would work through the book at their own pace for approximately 95 minutes. Pretests and posttests would tap the extent of their subject-matter knowledge and would record their attitude toward mathematics courses in general.</p>

continued on next page

THE TUFTS UNIVERSITY TRYOUT SERIES, continued

(continued)  
General  
Plan

---

Following that phase of the tryout, the subjects were to take the books home, work on them during the week and return at the next class period prepared to take a final exam.

In point of fact, the plan to have students study at home did not work well at all. The reasons appear to be unrelated to this project, but were rather a consequence of the fact that some students had erroneously enrolled in this course for which they were unqualified; they were therefore discouraged and demoralized during the home-study period. Ten of them actually withdrew from the course a few days later.

According to their notes and comments to us, the posttest given after the intervening week was for many a retention test rather than a test of their grasp of new material. The results section will reproduce the relevant data.

Data-  
Collection  
Forms

- 
1. Three subject-matter tests were used to measure the subject's understanding of the topics before and after studying the information map book under the laboratory situation and after a further home-study period.
  2. A pre-study attitude questionnaire was designed to record the subjects' feelings about mathematics courses and about previous experiences with learning research.
  3. A post-study attitude questionnaire tapped subjects' reactions to learning from the information map materials, to the presentation methods of the map book, to specific format features and toward the possibility of further study from such materials.
  4. Personal information about each subject's major, year in college, previous college courses in mathematics was collected.
  5. The instructions asked subjects to write criticisms and comments throughout the book whenever they wished.
-

THE TUFTS UNIVERSITY TRYOUT SERIES, continued

Procedural  
Details

STEP	PROCEDURE
1.	<u>Orientation.</u> General explanation of the plan for the tryout and the range of material to be covered was given. Students already familiar with the topic were encouraged to leave.
2.	<u>Attitude questionnaire.</u> Five brief questions were completed.
3	<u>Pretest.</u> This was administered under conditions where each subject's time was recorded, but no more than ten minutes were permitted (nor in fact, needed).
4	<u>Study instructions.</u> Books were distributed and instructions were given to answer feedback questions and to write criticisms as they read. One hour and thirty-five minutes were allowed, including time for a short break as each individual desired. Students were asked not to consult with one another during the study phase.
5	<u>Study termination.</u> At the allotted time, work was stopped and students were asked to record the number of the page on which they were working at that time. This record was collected.
6	<u>Post-study attitude questionnaires</u> were filled out under timed conditions.
7	<u>First posttest</u> of amount learned was conducted under timed conditions similar to those of the pretest: subjects were permitted up to ten minutes for this, but if they finished earlier, the experimenters recorded the exact time.
8	<u>Homestudy.</u> The class was instructed to finish studying the book during the coming week and to record time spent on the log provided; they were to prepare for a further posttest a week later.
9	<u>Second posttest</u> was administered as before after the books and time records had been collected.
10	<u>Books were returned</u> to students who requested them.

## THE TUFTS UNIVERSITY TRYOUT SERIES, continued

### Data- Analysis Methods

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Because this is simple study of learning outcomes and attitudes toward this kind of instructional materials, the data analysis methods consisted of t-tests of the two sets of gain scores:

- . gain in score from the pretest to the first posttest (given during the supervised, timed study period) and
- . gain in score from the pretest to the second posttest (given a week later after possible home study, although in fact many students did not do any home study).

Attitude data were simply summarized to indicate the strength of subjects' opinions about various features of the learning materials.

Comments recorded in the books were compiled as a guide to further revisions of the material. They had a practical objective and will not be recorded here.

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## RESULTS

### Achievement Scores

Scores on the subject-matter tests were stated in terms of the percentage of items successfully passed. These are given in the table below for the total results of this study and also for the separate topics covered in the information map material.

Posttest-1 was the test given at the end of the supervised, timed study period; posttest-2 was given a week later after the possibility of home study.

Section of Book	Pretest (N=22)	Posttest-1 (N=22)	Posttest-2 (N=19)
Factorials	68.2%	100.0%	92.1%
Permutations and Combinations	19.3%	61.3%	69.3%
Binomial Expansion	50.0%	31.8%	56.5%
TOTAL RESULTS	32.6%	72.7%	61.6%
TOTAL RESULTS WITH BINOMIAL EXCLUDED	29.1%	79.6%	65.1%

The total results line of the table represents a severe test of the learning materials; the reason for this is that when posttest-1 was given after one hour and thirty-five minutes of study, well over half of the students had not finished reading the book. Even so, the improvement is statistically significant.

A  $t$ -test of the differences in scores from pretest to posttest-1 is highly significant with a  $P < .001$  ( $t_d = 5.96$ ,  $df = 21$ ). Posttest-2 scores, those obtained a week later, are also significantly greater than the pretest scores. They are, however, considerably smaller than those of the first posttest. A possible reason for the decreased effect may be found in the students' time logs which show that a sizable percentage (50%) of them did not study the materials during the week.

If we exclude the final topic, the binomial, which many students had not read, the results are those of the last line of the table. After studying the book for about an hour and a half, the subjects scored correctly on almost 80% of the questions on factorials, permutations and combinations.

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## RESULTS, continued

(continued)  
Achievement  
Scores

---

Whether we evaluate the total results line or the results with the binomial excluded, the gains from pretest to each of the posttests are statistically significant.

The central point of the achievement score evaluation is simply that the learning materials have made a significant impact on the subjects' knowledge of the subject-matter area.

The differential rate of success on the separate topics showed that more developmental work was needed in certain areas. Subjects' comments supplement this conclusion.

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Time

During the timed, supervised study period in the classroom, subjects were allowed breaks if they wished to stroll about outside. The experimenters kept a record of these times and subtracted them in figuring each subject's total study time.

If the total time spent with the learning materials is divided by the total number of pages the subjects covered in the period, we have a first estimate of how long it takes to read information map pages. This estimate will be somewhat atypical because here the subjects were asked to answer all the feedback questions, whereas normally they would be told to work only those where they felt the need.

The total number of minutes divided by the total number of pages completed gives 1.6 minutes as the estimate of mean time for a page.

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## RESULTS, continued

### Attitude Results

Often the most important effects of an instructional program lie in its capacity to attract and sustain students' interest. For this reason we were particularly concerned to learn our subjects' reactions to the mapped material.

Items in the attitude surveys consisted mainly in statements to which the subjects responded by encircling one of these: strongly agree, agree, undecided or neutral, disagree or strongly disagree. In a few cases a slightly different set of response terms was used.

Rather than reproduce the questions verbatim, we shall give the gist of them more tersely along with the percentage of subjects expressing given views:

1. The learning materials were rated easy or very easy by 86.4%; no one found them difficult.
2. Learning by this method was rated effective or very effective by 90%; the remaining 10% of the subjects were undecided; no one rated them ineffective.
3. As to whether the learning materials progressed too slowly, 55% said no, 36% said yes.
4. Slightly over 86% said they would recommend the materials to other students; 9% said they would not.
5. As to whether it was difficult to adjust to the new manner of presentation, 95% responded no; 5% were undecided.
6. Asked whether there were too many worked examples, 64% said no; 23% said yes.
7. The feedback questions were found effective by 86%; the remaining subjects were undecided.
8. Asked if the feedback questions were too numerous, 95% said no; 5% were undecided.
9. Just over 72% of the subjects felt they would retain material learned from information map books better than that from standard textbooks; the rest were undecided.

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## RESULTS, continued

### (continued) Attitude Results

- 
10. In general the few subjects who were not enthusiastic about this way of learning were those who had taken between six and ten semester courses in college mathematics. These were students who should have followed our initial request that those well versed in mathematics not participate in this tryout since it was aimed at those with a minimal background in mathematics. The instructions here were unusual in requiring subjects to work out all feedback questions; several mathematics majors reported that this was especially slow and frustrating to them.
- 

### Summary of Major Findings

- 
1. After studying information map units on mathematics, a group of 22 college and graduate students showed a highly significant gain ( $P < .001$ ) in achievement test scores over pre-study levels.
2. They expressed a highly favorable attitude toward the learning materials.
3. A large majority (90%) found the materials effective or very effective, while the remainder were undecided.
4. Differential scoring rates on subtopics and comments obtained from the subjects served as guidelines in further refinement of the learning materials.
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### Limitations of the Study

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The gain scores, while highly significant, may be biased by inequalities between the pretest on the one hand and either of the two posttests on the other. Although we tried to make the tests equally difficult, no procedures were used to control for possible differences. In view of the limited objectives of the tryout, more elaborate methods and statistical analyses would not have been justified.

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## CHAPTER 5 THE HARVARD UNIVERSITY SERIES

### THE EXPERIMENTAL PLAN

#### Introduction

The second formal tryout of information map materials was carried out at the Harvard Graduate School of Education with students enrolled in an introductory statistics course.

The students studied a book of our learning materials in a "natural" setting -- at home where they usually study rather than in a controlled laboratory situation. They did however take the achievement tests and attitude surveys under timed, supervised conditions in the classroom before and after a week's study period.

The learning materials for this series consisted of the same counting-methods units that the Tufts group had used and in addition there was a 42-page unit on set theory.

While the tryout was aimed primarily at learning more about students' behavior with and reactions toward information mapped materials, this study was designed also to explore the effects of certain features of the maps.

#### Background

The Harvard series was designed as a first step in research to investigate experimentally the influences of certain features of information maps on instructional outcomes.

An earlier chapter distinguished between certain visible and invisible characteristics of information maps. The visible features included certain obvious aspects of formatting, spatial arrangements and labelling, while the invisible features referred to those analyses and classifications of the subject-matter area that determined the content of the information map text.

It was the visible features of the map that we chose to manipulate experimentally in the Harvard series.

#### The General Approach

Whatever may be the functions of these visible features, the structures that display the text materials, it is important to know whether or not they facilitate initial learning.

For this study two sets of materials were prepared:

- a set of information maps prepared in the usual manner, and
- a set of "prose" materials made by simply removing the visible, structural features, such as boxes, labels, unit pages, and by running the sentences along in standard prose paragraph form. The prose version retained the same sentences, the same feedback questions and the same learning

continued on next page

## THE EXPERIMENTAL PLAN, continued

(continued)  
The  
General  
Approach

features. For several charts and tables, we had to write in a few extra sentences to include the semantic content conveyed by the lines or boxes.

For example, the prose version of the union map given on page 30 looked like this:

### Example

#### UNION

Some sets are composed of all of the elements of two or more sets

The union of two sets, P and Q, is the set of all elements that are members of P, or Q, or both. Remember that the union of two sets is itself a set.

The symbol for union is  $\cup$ .  $P \cup Q$  is read "P union Q"

The shaded part is  $A \cup B$ :



Set A consists of the numbers 7, 8, and 9. Set B consists of the numbers 4, 5, and 6. We can form new sets which contain all of the members of A and all of the members of B, and all of the members which are in both A and B. i.e.,  $A \cup B = \{4, 5, 6, 7, 8, 9\}$

$C = \{a, b, c\}$   
 $D = \{c, d, e\}$   
 $C \cup D = \{a, b, c, d, e\}$

The shaded portion is  $C \cup D$ .



Set E consists of the numbers 1, 2, and 3.  
Set F consists of the numbers 5, 6, and 7.  
 $E \cup F = \{1, 2, 3, 5, 6, 7\}$

The shaded portion is  $E \cup F$ :



Related elements, 6  
Pages

set, 4

Venn diagram, 10

#### FEEDBACK QUESTIONS

[Union]

1.  $I = \{10, 15, 20\}$   
 $J = \{30, 40, 50\}$   
 $I \cup J = \underline{\hspace{2cm}}$
2.  $J = \{a, b\}$   
 $K = \{c, d\}$   
 $L = J \cup K$   
 $L = \underline{\hspace{2cm}}$

## THE EXPERIMENTAL PLAN, continued

### Experimental Groups

These two sets of materials will hereafter be referred to as the IM or P versions. Each of the two versions covering sets, factorials, permutations, combinations and the binomial was produced in book form with the title Mathematics Essential for Probability.

Subjects were assigned to the IM or P group at random. Otherwise the two groups were treated alike, being instructed and tested together as one group.

### Basic Questions of the Study

To extend our understanding of the value of information maps, the questions we asked were:

- To what degree can we measure the effect of the visible features of information maps on learning?
- Do the visible features appear to contribute to user acceptance of the learning materials?
- What are some of the operating characteristics of information maps when used in a "real" setting, i.e., where students use them at home?

### Test Materials

A pretest and a posttest were prepared to cover the subject-matter objectives; because class time available for such testing was severely limited, the tests had to be shorter than we would have liked.

For the same reason, the pre-study attitude survey contained only 5 items to tap students' reactions to their previous mathematics courses. A 16-item post-study attitude questionnaire was used to register the subjects' opinions about the form and content of the learning materials.

Each subject was also asked to provide supplementary information about their college and high-school mathematics backgrounds, their field of specialization, and any teaching or tutoring experience.

### Subjects

The subjects were all graduate students in the School of Education, Harvard University, who were enrolled in a course entitled Introductory Course in Educational Statistics. They had backgrounds ranging from recent college graduates to teachers to administrators of large universities on sabbatical.

## EXPERIMENTAL PROCEDURE

### Introduction

The idea of the experiment was presented to the class at their first regular meeting of the semester; none of the topics covered in our experimental books were discussed in class or in homework assignments during the period of the experiment.

### Procedural Details

STEP	PROCEDURE
1	<u>Orientation.</u> On September 25, 1968, we made a brief announcement to the class and distributed handouts explaining that we were trying out some new learning materials, that we sought volunteers, and how the try-out schedule was planned. Students were assured that in no way could this project affect their course grade.
2	<u>Instructions.</u> On September 30 the class was stopped 15 minutes early to enable us to carry out the pretesting of those students who wanted to volunteer for the study. Of the 66 students present, 52 volunteered. They were given brief instructions about the general plan and then were given both written and verbal instructions about the tests of Steps 3 and 4.
3	<u>Pre-Attitude Questionnaire.</u> 2 minutes were allowed (and were sufficient) for answering the 5 questions.
4	<u>Pretest.</u> Each subject took a ten-minute pretest on the subject matter.
5	<u>Random Assignment Process.</u> While Steps 3 and 4 were being carried out, the names of the students were entered on a previously prepared list of random numbers and an appropriate copy of the learning materials, either IM or P, was labelled with each student's name. These were distributed at the end of the test phase.
6	<u>Study Instructions.</u> Students were told that we were testing two versions of the materials and that we asked that they not discuss them with one another nor inspect the other version until after the experiment.  The subjects were asked to study the material at home, to record the amount of time and the number of pages involved in each session, and to write criticisms and comments freely on the text pages. The personal data record form was to be filled out as well.

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# EXPERIMENTAL PROCEDURE, continued

(continued)  
Procedural  
Details

STEP	PROCEDURE
7.	<u>Post-study Attitude Questionnaire.</u> On October 7, 1968, in the last 15 minutes of the regular class period, we began the posttesting with the 16-item questionnaire which required about three minutes. The learning materials were collected.
8.	<u>Posttest.</u> The ten-minute posttest was given to 41 subjects.
9.	<u>Followup.</u> Since 5 of the IM group and 4 of the F group were not present for posttests, several steps were taken to determine whether these dropouts differed from other students. Five of the 9 responded to requests for further information. We were unable to detect any differences between the dropouts and the complete subjects.
10.	<u>Choice of IM or P versions.</u> Since we had to retain the study copies of the books with their very useful comments and criticism, we invited the students who wanted their own personal copy of the materials to pick them up at our offices. This gave us the opportunity to inquire into user preferences through planned interviews.

## METHODS OF ANALYSIS

### Introduction

---

The primary question we were interested in was whether the two versions of the book were associated with differences in gains from pretest to posttest scores. While it is common in such cases to evaluate the differences in gain scores between the two groups, we chose to use the more precise method of analysis of covariance.

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### Analysis of Covariance

There is always the possibility that in spite of the random method of subject assignment, the two groups might differ in entering knowledge of the subject matter. To guard against this, we carried out the analysis of covariance using the pretest score as covariate.

In effect what this accomplishes is to adjust the posttest scores so that the effects of any initial difference in pretest scores between the groups is eliminated. (Details of the method and rationale may be found in Snedecor and Cochran, 1967)

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### Other Analyses

We were of course also interested in determining for the total subject sample whether learning gains were significant regardless of the book version studied. An ordinary t-test for paired comparisons was used for this.

In addition we shall present brief summaries of the following classes of data:

- the amount of time spent in studying the materials,
- attitude scores of the subjects,
- mathematical backgrounds of the groups,
- subjects' preferences as revealed in choices of IM or P versions for their personal libraries,
- comments on the books and on learning experiences with them.

It will be recalled that a major point of the study was to obtain detailed criticism of the books; thus for our own use, we compiled the subjects' comments as a guide to identifying points of common concern. Some of the kinds of changes suggested will be mentioned.

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## RESULTS

### Achievement Scores

The IM group contained 20 subjects and the P group 21. For both groups the gain scores from pretest to posttest were statistically significant. The mean pre- and posttest scores are shown in the following table.

Group	No. of Subjects	Pretest Mean Score	Posttest Mean Score	Adjusted Posttest Mean Score
IM	20	9.50	19.10	19.56
P	21	11.52	18.10	17.65

Our primary interest lies in the comparison of learning effects for the two groups. The analysis of covariance, it will be recalled, afforded a method of adjusting the posttest means for differences in the initial proficiency of the two groups. Those adjusted means are shown in the final column of the table above.

Although the IM posttest mean is larger than that of the P group, the difference has no statistical significance, the  $t$  of the difference being only 1.17 (38 d.f.,  $P < .2$ ).

The complete details of the analysis of covariance are provided at the end of this chapter.

### Time Data

Students were asked to keep a time sheet on how they used the materials. It included the following categories:

Study Period Number	Day	Time Begun	Time Ended	Pages	How did you use the material? Comments...
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18 of the IM group and 20 of the P group gave us this information. It was tabulated to provide answers to several questions about the use of the books:

How many of these finished the book?

75% of the IM group finished or got within the last 5 pages of finishing (these were pages that contained no new information).

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## RESULTS, continued

(continued)  
Time Data

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. 47.6% of the P group finished or got within the last 5 pages of finishing.

How long did the subjects study?

Based on those subjects who finished or got within the last 5 pages:

the IM group spent an average of 5.21 hours (N = 15)

the P group spent an average of 3.87 hours (N = 10)

The subjects' times were highly variable and the difference between the two groups was not statistically significant ( $t = .644$ , 23 d.f.,  $P < .5$ ).

There was, however, a significant difference between the mean pretest scores for the two groups of complete subjects:

	<u>IM</u>	<u>P</u>
Pretest Mean	8.73	14.00
No. of Subjects	15	10

$$t = 2.22 (P < .05, 23 \text{ d.f.})$$

This may indicate that the P group knew more of the subject-matter than the IM group and so went through the learning materials more quickly.

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## USER PREFERENCE DATA

### Introduction

We invited the participants to pick up their own personal copy of the materials at our offices after the experiment was over (Information Resources, Inc. offices are 3 1/2 blocks from the Graduate School of Education, Harvard).

The record of their choices provides an interesting indication of their reactions toward the two books and some insight into their thinking about learning materials.

When they came, they were given the two versions, IM and P, and asked to examine them and decide which one they wanted. They were not permitted to take both. The interviewers insisted gently that they really had to examine both versions before choosing.

In one instance, the interviewer refused to accept the choice of an IM version by a person who said "Oh, I'll take this one because I haven't used this kind." The interviewer insisted that the person have a reason based on a preference for one or the other kind of materials.

We also interviewed the subjects about

- . the experiment
- . the learning materials
- . their learning habits

The interviews lasted between 5 and 45 minutes and averaged about 1/2 hour.

### Data on User Preference

Twelve students came to our office; 11 chose the IM version.

Here is the tabulation:

		Version Chosen	
		IM	P
Version	IM	6	1
Used	P	5	0

USER PREFERENCE DATA, continued

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Interview Data	Our subjects made these comments after they had examined both IM and F versions in response to the question, "Why did you pick this version?"
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Picked IM	<p>"The format in boxes is more tidy. I like it better. It's easier to read."</p> <p>"The relationships are implied. Things are parallel. If you have things related, you can go through the material much faster. This book is organized better than an ordinary text. I liked the examples. You knew not only what it was, but what it wasn't. You could see the same example in different settings. You could see just how inclusive an example could be. People were amazed to see how complicated statistics was in our text compared to how simple it seemed here. Our author can't write clearly."</p> <p>"This is the one I really want. I'll get more involved in it... The layout is better for me. I can always grasp it better when it's in blocks."</p> <p>"Oh, I prefer the boxed-in one. I'll choose it."</p> <p>"The text in our course goes much too fast for me. 15 pages to cover what you cover in 105. But yours went faster than our text because it was easier. I didn't have to make up the steps in between."</p> <p>"I especially liked learning how to learn from your materials. By the way, I noticed that the blocked version had a value of telling me just how much I had learned... it also gave me a clear stopping place. I could feel comfortable at stopping at the bottom of the page."</p> <p>"The boxes really appeal to me. I like having things categorized in that fashion. When I was using the other book (P) I felt that I was getting it. However, when I took the post-test I realized that I hadn't. I'd like to go through the box version. I think I might be able to get more out of it. In class, we did the perms. and combs. the next week. Those students who didn't participate in the experiment were lost. The rest of us found it easy."</p>
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USER PREFERENCE DATA, continued

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(continued) "It's compressed and the organization is better. A mathematical  
Picked format. Yeh! That's the way to do it. Maybe this [P] is  
IM organized just as well, but flow charts are much better. The  
trouble with most texts and this book [P] is that they're so  
damn verbal. You should arrange things in a matrix form --  
it's so logical, so mathematical -- it makes more sense in  
mathematics to present things in this form."

"I am the ex-president of a college. One of the interesting things  
about your book was that I was initially turned off because some  
of the pages resembled 'organization charts'! And I have unfavor-  
able associations with organization charts. But I decided to try  
the material anyway. My attitude changed abruptly to a favorable  
one, because I began to have confidence in the material. There  
were places where the materials broke down, that is, they didn't  
teach me what I wanted to know, but I still felt confident that  
I could go on and figure it out. You never get this feeling from  
an ordinary textbook."

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Picked P "I don't think that they are useful...those tree-type things.  
There seems to be more verbiage cut out of this one[P]. I think  
I'll take it. There's a psychological factor, I guess....It looks  
easier to get through."

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## SUPPLEMENTARY RESULTS

- 
- Attitude Results
1. 45% of the IM group and 68% of the P group rated the materials easy or very easy.
  2. Learning by this method was rated effective or very effective by 80% of the IM and 73% of the P group; the rest were undecided.
  3. 11% of the IM and 31% of the P group thought the material progressed too slowly, while 79% of IM and 47% of P disagreed with this statement.
  4. 90% of IM and 94% of P groups said they would recommend the material to another student; the rest were undecided.
  5. When asked whether the presentation was hard to adjust to, 85% of the IM group and 80% of the P group said no. Curiously enough, 5% of the IM group and 10% of the P group said yes.
  6. Asked whether there were too many examples, 85% of IM said no (the rest undecided) but only 55% of P said no, 22% said yes and the other 23% were undecided.
  7. 95% of IM thought feedback questions were effective (the rest undecided) while 84% of P thought they were effective and 5% thought they weren't.
  8. Asked if there were too many feedback questions, 85% of IM said no (rest undecided), 83% of P said no, and 17% of P said yes.
  9. 40% of IM and 57% of P group thought they would retain material learned this way better than by a standard text (the rest were undecided).
  10. 70% of IM and 84% of P would like to use similar learning material for other topics in the course (only 1 student in each group disagreed, the rest were undecided).
-

## SUPPLEMENTARY RESULTS, continued

### Other Findings

- 
- . An analysis of the personal background information of each subject showed that the two groups were comparable in terms of sex, high school and college mathematics courses taken, undergraduate degree patterns, teaching experience, and attitude towards mathematics in general.
  - . Male subjects judged the learning materials more favorably than their female counterparts in both groups.
- 

### Limitations of the Data

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No special measures were taken to control for possible differences in pre- and posttests. Biases here could influence the magnitude of the gain scores which for both groups of subjects were highly significant.

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## DISCUSSION

Interpretation of the Findings    The lack of a significant difference between the gain scores of the two groups suggests one or more of the following:

- The visible features of IM's may not contribute so much to initial learning as do the content analysis or feedback provisions.
- The experimental procedure, constrained by the time restrictions dictated by use of this formal class, was not sensitive enough for demonstrating any differences that may exist between the two versions.

The latter possibility seems especially reasonable to us. The visible features of IM might be expected to operate primarily to alert one to the nature of the incoming information and to facilitate scanning for new material or for review. In a one-time read-through of a short text, perhaps one should not expect effects of the visible features to emerge very strongly. Rather it is in situations requiring information retrieval and integration where their advantages might show up. A different set of tasks in a less time-bound testing situation should be more sensitive to such effects.

Students found the visible features useful and appealing. The time data as well as the interview and choice data support this generalization.

- Students also singled out specific pages for favorable unsolicited remarks. These types of pages drew such remarks: feedback questions, compare-and-contrast pages, tables, overviews, summary pages.

We obtained some solid information for revision relevant to constructing information maps for books:

- Put classification trees and prerequisite maps at the end of units rather than at the beginning (where they tended to scare more students than they helped).
- Build in self-tests instead of objectives pages at the beginnings of units.
- Increase the number of maps in some areas where students had difficulties.

## NOTE ON STATISTICAL DETAILS

### Analysis of Covariance

In order to compare the learning effects for the two groups, we used an analysis of covariance of the posttest scores using the pretest scores as covariate, summarized on page 57.

The results of the analysis of sums of squares and products were:

Source	d.f.	$\Sigma x^2$	$\Sigma xy$	$\Sigma y^2$
Total	40	1405	593	1270
Between groups	1	42	-20	9
Within groups	39	1363	613	1261
Reduction due to regression	1	-	-	275.7
Deviations from regression	38	-	-	985.3

Regression coefficient:  $b = 0.45$

Deviations mean square = 25.9

The estimated standard error for the difference of two adjusted means is:

$$s_D = \sqrt{\frac{2}{20} (25.9) \left( 1 + \frac{42}{1363} \right)} = 1.63$$

$$t = \frac{19.56 - 17.65}{1.63} = 1.17 \text{ (38 d.f., } P < .2)$$



## CHAPTER 6 ASSESSMENT RESEARCH STUDIES, SPRING 1969

### INTRODUCTION

#### Background

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In order to obtain a set of learning materials extensive enough to serve as a serious research vehicle, we developed a unit dealing with those topics in elementary probability that are basic to an understanding of statistics.

The subject matter was approached through the concepts of set theory, which formed the first unit of the learning package. (The materials on permutations, combinations, and the binomial theorem were set aside for the time being with the intention of using them later as a unit preceding elementary statistics.)

The probability unit was developed by the usual route of try-out-and-revision cycles. When these reached the point of dwindling criticisms from learners, we designed a more formal assessment of the program's effect.

Although the set unit was included as an integral part of the package, it was not evaluated in this assessment study because it had already been evaluated in the Harvard series, and because time pressures induced us to limit the tests to the new materials.

#### General Objectives

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The probability unit was used in an assessment study that would permit us to describe some of the effects that can be expected when the unit is used for initial learning under various conditions.

The assessment includes statistical tests of pretest-posttest gain scores.

The study was planned to reveal how subjects with different backgrounds and degrees of mathematical proficiency would interact with the learning materials under different conditions of use. We were interested in obtaining information not only about the changes in students' achievement scores, but also about their attitudes toward various features of the learning units and toward possible future study with such materials.

The design was one which would permit us to indicate the range of effects that might be expected from learners who aspired to different levels of proficiency in the subject area. And finally, we wanted to obtain information about the usefulness of the materials for reference work as opposed to use in initial learning.

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## CERTAIN RESEARCH ISSUES

Introduction	<p>In planning experimental programs, we consider alternative approaches and decide upon a research strategy that we believe will yield the most informative results under the given circumstances. In the present case we will describe the reasoning behind certain decisions in the experimental plan.</p>
The Issues	<p>Three particular questions concerned us:</p> <ol style="list-style-type: none"><li>1. Objectives for studying the materials,</li><li>2. The relevance of time pressures in assessing performance,</li><li>3. Test sensitivity and the problem of a reference point.</li></ol> <p>Each of these will be discussed in turn.</p>
Learning Objectives	<p>When we considered the variety of purposes for which one might engage in studying a particular subject matter, we realized that it is neither realistic nor helpful to potential users to phrase an objective in terms of what percentage of students will pass an examination at a given level of proficiency.</p> <p>A student might take up a course because he wants a general understanding of the major concepts of the area and a knowledge of where to look for details or procedures when the need arises. His way of using a program would differ from that of a student who was trying to achieve a thorough mastery of the subject in order to pass the Graduate Record Examination.</p> <p>It would be most helpful to know how each used the materials and how long they spent to achieve their given goal.</p> <p>It is clear also that in many formal courses it is the instructor who formulates the objectives -- usually without consulting the victims. Whether or not the two sets of goals agree no one seems to have inquired.</p> <p>Against this background we decided to try to make the validation testing more informative and relevant to realistic learning situations. In brief, our plan called for students to use the information map book under one of two sets of instructions that are designed to simulate common learning situations:</p> <ul style="list-style-type: none"><li>• where a student uses the book in a course that requires a thorough understanding of concepts and procedures and an ability to work problems in <u>closed-book examination</u>; and</li></ul>

continued on next page

## CERTAIN RESEARCH ISSUES, continued

### (continued) Learning Objectives

where the student uses the book to acquire a general knowledge of the area and enough familiarity with procedures to pass an open-book test.

It seemed to us that performance figures from these two types of test, when coupled with time data and personal information about the subject, would afford a more realistic picture of the effects of the instructional program.

In order to get a lead on the subjects' own goals, as distinguished from those we set down for them, we asked them just before the posttest to record the grade they expected to get on the test. To complement this, one of the questions on an attitude survey asked about the level of proficiency they usually aspired to in mathematics courses.

In actual use in an educational system it is quite possible that these learning materials would be used in conjunction with other methods of instruction -- with an instructor and classroom discussion, for example.

In the assessment of this program, however, we were interested primarily in the effects of the materials when used alone. This gives us the strictest test of the units and permits us to estimate the minimum effects these units are capable of producing.

### The Time Factor in Proficiency Measurement

Many measures of proficiency depend upon the amount produced in a given time period and a premium is put upon producing the greatest number of responses in the shortest time. While such a rating may be desirable for assembly-line performance, it seemed to us that a time-based criterion was of limited relevance to many learning situations.

Accordingly we devised a posttest situation that permitted the students' performance to be measured both under a condition of time pressure and under a condition of a generous time allowance. The latter condition seems to be more compatible with the objective of acquiring a general facility with an area and a knowledge of where to find things when they are needed. Speed of production would not be especially important here.

In preparing for certain entrance examinations for college or graduate school, however, speed and accuracy are both sought.

continued on next page

## CERTAIN RESEARCH ISSUES, continued

(continued)  
The Time  
Factor in  
Proficiency  
Measurement

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To secure posttest performance scores relevant to situations both with and without time pressure, we used the following method:

1. During the initial test phase, a time limit of twenty minutes was imposed; subjects were asked to work as quickly as possible. They were required to write with black pens.
2. At the twenty-minute signal, green pens were substituted for the black pens and the subjects were allowed to continue another forty minutes if they liked or to turn in their papers when they were satisfied with their effort. They were free during this period to correct any black answers they wished to change.

This technique was used for both the open-book and closed-book test conditions. It was not used in the pretests because except for two or three cases the subjects knew too little about the topic to require more than the twenty-minute allotment or they knew it so well that they finished well within the twenty-minute period.

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Test  
Sensitivity  
and a  
Reference  
Point

In a study such as this where the goal of assessing the educational value of the material is combined with the goal of determining how its effects vary with certain conditions of use, the construction of achievement tests must be considered from several points of view.

In the first place, it is important to have a test that is sensitive enough to pick up differences in comparative conditions. In our study, to be able to measure the results of both open- and closed-book tests, for example, we must have a test that permits students to demonstrate the full range of their proficiency in the easier open-book situation. This means that the tests must be constructed to include difficulty levels that we do not expect our subjects to attain. It must be complex enough so that it does not set a ceiling on the scores of superior students. Thus, we are not here trying to write a "criterion-referenced" test where students are expected to pass the majority of items.

Consequently the test was designed to be difficult and beyond the expected capacity of our subjects.

But with such a test, we have the problem of how to judge the subjects' scores. We can no longer judge them by saying we expect a certain percentage of the subjects to pass a given percentage of items. In order to have a reference point

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## CERTAIN RESEARCH ISSUES, continued

(continued)  
Test Sensitivity  
and a  
Reference  
Point

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with which to compare their scores, we devised a competence standard based on the scores that certain "experts" made on the same tests. Our "experts" consisted of 6 advanced candidates for the Ph.D. in Statistics at a local university. Four of them had completed all Ph.D. course and examination requirements; all of them had had at least one full-year course in probability and mathematical statistics. Their mean scores on the subunits afford at least a reasonable yardstick for speaking about the subjects' achievements.

We shall be able to make statements of this form:  
after 8-10 hours study over a two-week period, X% of the subjects reached a level equal to about 70% of the experts' scores, etc.

---

## DEVELOPMENTAL TESTING

### Objectives

In order to prepare for a formal evaluation of the revised units on Sets and Probability, we used a preliminary group of 8 subjects to try out and criticize the various materials for us. These latter included not only the information map units but also the achievement tests, attitude questionnaires before and after study of the books, and instructions on use of the units.

The purposes of this tryout were to debug the learning and test materials, to obtain comments and reactions to the total package, and to gather study-time data to aid in planning the formal evaluative study.

### Subjects

The 8 subjects may be classified as follows:

- 2 graduate students, Harvard School of Education
- 4 undergraduates, Harvard College
- 1 housewife who had finished 1 year of college
- 1 high school senior

In terms of the College Qualification Test N (Form A), a standard test for college freshmen, our group of subjects was high in mathematical ability: 5 of them scored above the 94% level; the scores of the remaining 3 were 74%, 60%, and 24%.

### Procedure

The numerical ability test just mentioned, the pretest, an attitude questionnaire and a personal information sheet, were all filled out by the subjects in their first session. Then the two units were given to them to work on at home, keeping a time record and comments on the log provided. After approximately two weeks, the subjects returned at a time of their choice and took the posttest and further attitude questionnaires. They were also interviewed to get reactions in addition to the comments written in their study books.

### Results

The achievement tests given before and after study can be broken down into separate scores for the sets and probability units:

	Mean Pretest Scores	Mean Posttest Score
Sets	67.5%	95.5%
Probability	57.1%	89.8%

The attitude data showed that these subjects reacted favorably to the materials: all thought that learning by this method was effective, no one found difficulty in adjusting to the style, 6 felt that they would retain the material better than

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## DEVELOPMENTAL TESTING, continued

### (continued) Results

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with a standard text (the other 2 felt there would be no difference), and 7 expressed an interest in studying other topics written in the information map style.

The average time for completion of the text was 7.23 hours and the median time was 6.5 hours.

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### Project Decisions

As a result of these tryouts, a number of changes were made in the materials intended for the evaluative experiment:

1. First of all, the learning materials were revised to meet the comments of the subjects; the material on conditional probability was expanded because some experienced difficulty with the topic.
  2. Because the various tests took up more time than we judged desirable, attempts were made to shorten them. The prerequisite test, which had required thirty-five minutes, was shortened to include only items especially relevant to probability problems -- that is, those concerned with manipulating fractions and solving algebraic expressions. The test was reduced to twenty items and a time limit of ten minutes was imposed.
  3. In the achievement tests, given before and after study of the book, important changes were made. Because the students (with only one exception) had made very high marks on both pretests and posttests, we added items, made some questions more complex, and deleted easy questions passed by most subjects. This kind of change was required by our need for tests that would be sensitive to differences in conditions of the open- and closed-book tests and would set no ceiling on the showing of superior students.
  4. Nondiscriminating questions in the attitude surveys were omitted and some new questions were inserted.
-

## THE EXPERIMENTAL PLAN

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Introduction	The experiment through which we wanted to study the effectiveness of the revised learning materials was designed with certain built-in controls and certain procedures for eliminating spurious influences.
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Test Materials	To measure the subjects' knowledge of probability before and after reading the book, we drew up two achievement tests, which we shall call A and B. These were equal in length and as equivalent in difficulty as we could make them. Copies of the two tests are given in the appendix.
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To eliminate the possibility that there was in fact some difference between them, we arranged the test plan so that Test A served as pretest for half of the subjects and as posttest for the other half; similarly Test B was the pretest for half of the subjects and the posttest for the other half. This assignment was done at random.

With achievement scores obtained in this way, any differences in scores made before and after reading the book could not be ascribed to the fact that one test was more difficult than the other.

We mentioned in the previous section that as a result of developmental testing, these achievement tests were made more difficult. Another result was that the test of numerical ability, which we refer to as a prerequisite test, was shortened. The attitude surveys which were to tell us what the students thought of the learning materials had similarly been revised.

Those students who were given an open-book test also filled out a very brief questionnaire about their use of the book during the test.

Early in this chapter we mentioned that one point we were interested in was how the subjects' own goals for the course may be related to the amount of time they spent with the materials and to their achievement scores on the posttests. We tried to get an estimate of the subjects' own objectives in this way: those achievement tests that were slated to be posttests were furnished with a cover sheet on which subjects were asked to record the grade they expected to make on the test. This "level of aspiration" figure, we conjectured, would give us an estimate of the subjects' goals for the course.

The last page of the test booklet asked what grade they thought they made. Each subject would also fill out a personal data sheet asking about his educational history, field of major interest, and experience in the area of mathematics.

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## THE EXPERIMENTAL PLAN, continued

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Experimental Design      Each subject was assigned to one of three groups:

- . open-book,
- . closed-book test group, and
- . control group.

A brief description of each of these will be given before we take up the procedure in detail.

The Control group took the prerequisite test, filled out the personal data sheet, and then took two achievement tests in a row. They did not see the learning materials at all. The purpose in having this group was to find out how much information might have been gained from the tests themselves and to provide a standard by which the increase in score from pretest to posttest for the other groups could be judged. The achievement tests A and B were each used equally often for pretest and posttest.

The Closed group filled out the personal data sheet, pre-study attitude questionnaire, the prerequisite test, and finally the timed pretest in their first session. They were then given the material to take home to study and to record the time spent on it. An instruction sheet explained that they would be given a closed-book test when they returned. The post-study attitude survey was inserted at the end of the book and was to be filled in before the subject came back for the posttest. When subjects in this group returned, they were given a closed-book test. Approximately two weeks elapsed between pre- and posttest.

The Open group went through the same routine as the Closed group the first session. Afterwards in their instructions in the front of their books, they were informed that the learning objectives would be evaluated by an open-book final test.

The tests were in essence individually administered, although often several students would come together and would be tested in the same room. But each was given special materials, dictated by the plan, and each was timed separately.

The intention was to secure approximately twenty subjects for each group; in practice we fell slightly below that number.

The group of experts, whose scores on the achievement tests were to serve as a reference point, were given the tests under conditions similar to the control subjects. Half of them took Test A first and Test B second; the other half received the tests in the opposite order. The order for each expert was determined at random. They were not given a time limit but only two of them took longer than 20 minutes on the pretest and all took less than 20 minutes on the posttest.

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## THE EXPERIMENTAL PLAN, continued

### Subjects

These learning materials were intended mainly for students in the behavioral sciences who were often lacking in mathematical background but who needed to be prepared for statistics. Accordingly we sought as subjects persons primarily of college age and we imposed no requirements of previous mathematical training beyond elementary high school algebra.

Because of the time of year, however, we expected shortages of test subjects. As a result the subjects were not assigned to groups strictly at random. When a subject called about the experiment, he was assigned at random to a group and given information about the work required and the pay for that group. At times, however, a subject would consider the pay not worth the trouble of coming down for the tests (if he was in a control group), or the work required taking too much time (if he was in an experimental group). If this happened, he was told of the other possibility. The assignment of the experimental subjects to the Open and Closed group was strictly at random since there was no difference in the work required.

The 18 subjects who agreed to take part in the experiment as controls varied in age and background:

- . 9 were college students (2 in social science, 2 in education, 2 in the arts, 2 in natural sciences, 1 in nursing, 1 in dental technology, and 1 uncommitted);
- . 2 were college graduates who were now employed;
- . 2 had 1 year of college and were looking for jobs;
- . 3 were graduate students (in psychology, education, and political science)

The backgrounds of the 35 experimental subjects were:

- . 20 were college students (5 in social sciences, 5 in education, 6 in the arts, 2 in biology, 1 in physics, and 1 uncommitted);
- . 5 were high school graduates (2 were employed, 3 were about to enter college);

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## THE EXPERIMENTAL PLAN, continued

(continued)  
Subjects

- . 6 were college graduates who were now employed;
- . 4 were graduate students (in psychology, economics, government, and art history).

The prerequisite and pretest scores for the three groups were:

	<u>Prerequisite</u>	<u>Pretest</u>
Control (N = 18)	13.22	8.44
Open (N = 17)	13.53	7.35
Closed (N = 18)	13.11	8.89

The similarity of backgrounds and initial test scores for the three groups seems to indicate that no serious bias resulted from the non-random groups assignments. If there were any differences in initial test scores the method of analysis used would control for this.

The group who served as experts were six graduate students in Statistics at a local university. Each had at least one full year graduate level course in probability and mathematical statistics. Four of the six had passed the qualifying examinations for the Ph.D. degree.

# THE EXPERIMENTAL PLAN, continued

## Operational Procedure

STEP	PROCEDURE
1	<u>Recruitment.</u> Subjects were recruited by advertising at local colleges and using acquaintances of the investigators. Subjects in the Open or Closed group were paid \$20 and Control subjects \$5.
2	<u>Randomization.</u> Sixty-two numbers were assigned to the groups (and to each order of tests A and B within a group) at random. When a subject called, he received the next available number on the list and was assigned to the group corresponding to that number with the exception explained in the subject section.
3	<u>Orientation.</u> When a subject arrived, we gave him a brief account of the purpose of the experiment. (Control subjects were merely told that we were testing the effectiveness of the examinations he would be taking.)
4	<u>Form and test administration.</u> We gave the subjects the appropriate forms and administered the prerequisite test (10 minutes), the pretest (20 minutes) and the pre-attitude questionnaire. They were then given the learning material and asked to follow the instructions printed inside, and return for the posttest in 2 weeks at a time they arranged by phone.
5	<p><u>Posttest.</u> When the subject returned for the posttest we checked to see that his post-attitude questionnaire was complete, and then administered the posttest in two stages: during the first 20 minutes, the subject wrote with a black pen; then a green pen was substituted and he was allowed to continue up to 40 minutes more. If he finished before that (as many did), the exact time he used was recorded.</p> <p>If the post-attitude questionnaire had not been filled out the subject did so after the posttest. If the subject was in the Open group, he also filled out the reference attitude questionnaire.</p>
6	<u>Follow-up.</u> If a subject did not arrange for the posttest in the expected interval, we called him and he came within a day or two. We were not able to locate two subjects, three returned the material for personal reasons, and four were dropped from the study because of a mistake in assignment of test forms to them.

## METHODS OF ANALYSIS

### Introduction

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In addition to presenting descriptive results, we shall report a statistical analysis of the differences between the experimental groups and the control group using the technique of multiple analysis of covariance. The rationale for this has been described in the chapter on the Harvard series.

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### Description

In the Harvard study we explained how the analysis of covariance provides a method of adjusting posttest scores for differences in the initial proficiency of the groups, and we described how we used the pretest as the covariate.

In the present experiment the same considerations led us to make a similar analysis, which is generally considered preferable to t-test comparisons of simple gain scores (see Experimental and Quasi-Experimental Designs for Research, Campbell and Stanley, Rand McNally, 1963).

In the Harvard study only the pretest was available as the covariate but in the present series, we have pretests and pre-requisite tests as well. Thus we were able to use both of these covariates in our analysis of the posttest scores. Such a multiple analysis of covariance is described in Snedecor and Cochran (1967).

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## RESULTS

### Introduction

Instructional programs have many outcomes. In everyday usage programs are studied for different reasons by students who differ in background knowledge, in natural aptitude, and in study habits.

Our aim was to produce learning materials that the student could proceed on in his own way with a minimum of previous experience. Our test of the program simulated two common everyday situations where the instructor imposes the objectives of a course in terms of an open or a closed book test.

In addition we recognized that students have their own goals regardless of the demands of the instructors.

The things we want to know about a program are the evidences of learning and the amount of time spent for the different proficiency goals, as well as evidences of aversive or attractive powers of the materials as revealed in the students' comments and responses to attitude probes.

### Achievement Scores

The posttests yielded two scores: those obtained in the 20-minute time period and those obtained within an hour. For both of these measures the means and standard deviations are displayed in the table below for each of the three groups of subjects:

TEST	OPEN (N=17)		CLOSED (N=18)		CONTROL (N=18)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Prerequisite	13.53	4.80	13.11	4.28	13.22	4.97
Pretest	7.35	5.59	8.89	6.72	8.44	8.57
Posttest-1						
Unadjusted	17.18	8.30	17.72	9.10	9.33	7.68
Adjusted	17.62	5.72	17.41	5.72	9.24	5.72
Posttest-2						
Unadjusted	22.41	10.35	22.22	9.20	---	---

The primary analysis, the multiple analysis of covariance, was applied only to the posttest-1 scores, using the prerequisite test and pretest as covariates. This is the "strictest" assessment of the data, showing the effect that occurs under the pressure of limited test time. As a result of this analysis, the posttest-1 scores were adjusted as shown in the table above.

continued on next page

## RESULTS, continued

### (continued) Achievement Scores

When these adjusted means are compared, we find that each of the experimental groups, Open and Closed, is different from the Control group to a highly significant degree. The note at the end of this chapter gives the statistical details.

These posttest-1 results show that even with the time restrictions, the learning materials have significantly influenced the students' understanding of probability problems.

Since posttest-2 mean scores are higher than those of posttest-1, they are obviously also significantly different from the pretest scores.

For neither set of posttest scores would the Open and Closed groups be statistically different from each other. There was no apriori reason for expecting a difference.

### Test Forms Compared

In the results cited above, the use of Forms A and B of the achievement tests was equalized over conditions, as the test materials section explained. Thus any differences in the two test forms could not account for the results obtained. In other analyses where we want to look into the results in relation to subjects' attitudes, backgrounds, and so on, the two test forms may not happen to be equally represented. Therefore it is interesting to inquire first whether in fact the two forms do differ.

Pooling Control, Closed and Open groups, we find the following scoring rates on the two test forms when each was used as pretest and as posttest-1, and for the two combined:

TEST	MEAN SCORES AS PRETEST	MEAN SCORES AS POSTTEST-1	OVERALL MEAN SCORE
Form A	6.73 (N=26)	17.00 (N=27)	11.96
Form B	9.70 (N=27)	12.31 (N=26)	10.98

The mean totals for the two forms are not significantly different.

### Incomplete Subjects

In a number of the analyses we wish to discuss later, it will be necessary to make allowance for the fact that all subjects did not finish studying the book. The principal reason for this is that the assignment was too heavy for them to cover in a two-week period in addition to their other work. For the ninety per cent who were employed during the day, the topic of probability must not have seemed appealing leisure-time fare.

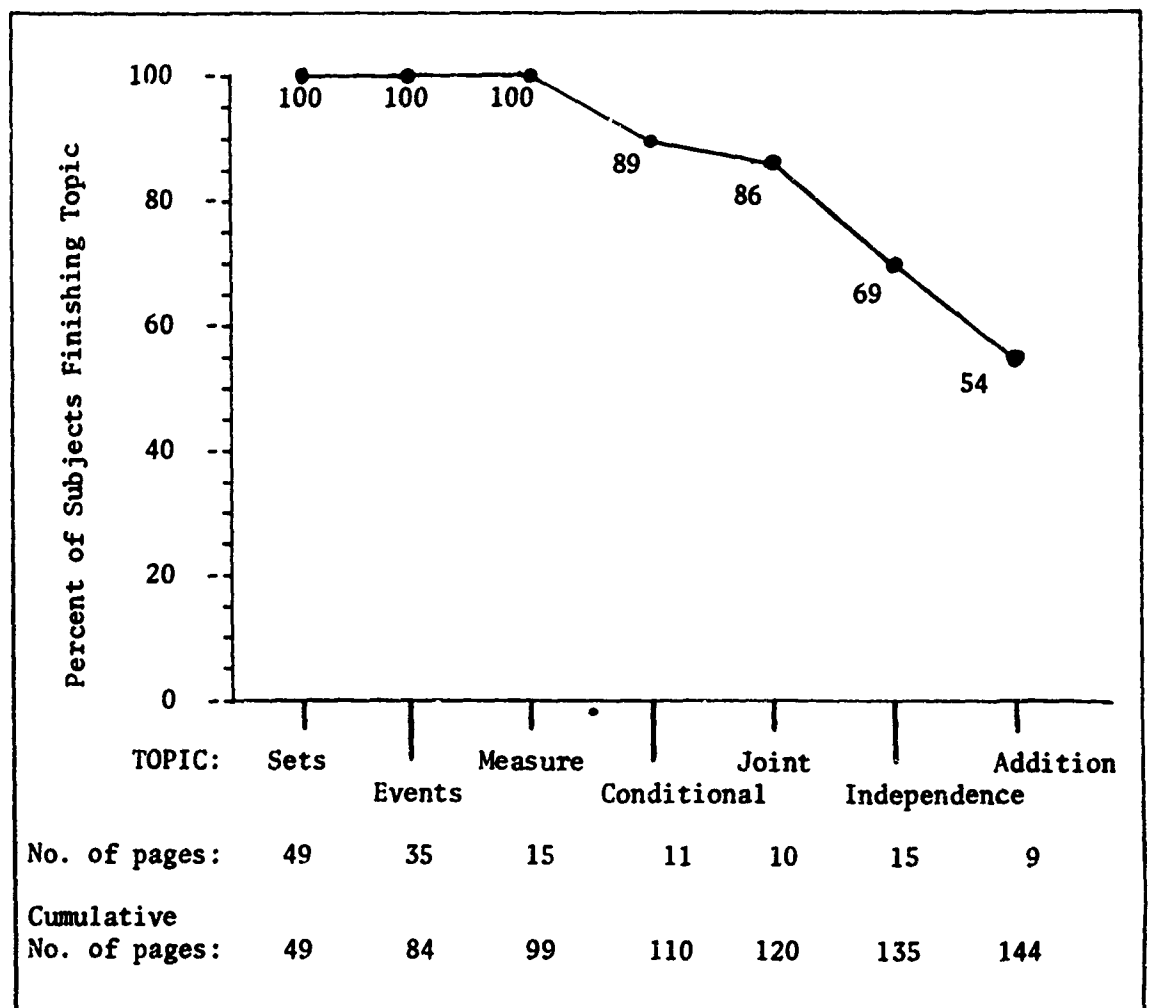
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## RESULTS, continued

(continued)  
Incomplete  
Subjects

The amount each subject did complete was determined jointly by the time log (where the page coverage was recorded) and by the evidence of completed feedback pages.

The graph below shows the percentage of subjects who completed the various topics of the book. Beneath the graph, the topics themselves are given in order along with the number of pages involved and the cumulative page total from beginning to end of the book.



continued on next page



## RESULTS, continued

(continued)  
Incomplete  
Subjects

These data will enter into an analysis we shall describe presently concerning success rates for the various topics. Since we want to compare our subjects' performance on these topics with that of the experts, we must pause first now to describe the experts' scores.

Experts'  
Scores

Each of the six experts who served as our comparison group took the two achievement tests, Form A and Form B; thus we have twelve scores to average for our reference point.

The highest possible score on each test was 46. The mean of the experts was 40.16. The scores ranged from 32 to 46; the median was 40.5.

Subjects'  
Scores Com-  
pared to  
Experts'

In the two experimental groups, Open and Closed, 19 subjects completed studying the entire book. Four of these obtained posttest-2 scores equal to the mean of the expert group. Four more scored between 70% and 90% of the experts' mean score. Thus, 8 out of the 19 subjects obtained scores exceeding 70% of the experts' mean score. The table below gives all the results:

	Percentage of Experts' Mean Score				
	100-91	90-81	80-71	70-61	Below 61
Number of subjects scoring	4	2	2	5	6
Per cent of subjects scoring	21.1	10.5	10.5	26.3	31.6

The unfinished subjects naturally did not do as well. Only 6 of the 16 exceeded 50% of the experts' mean score.

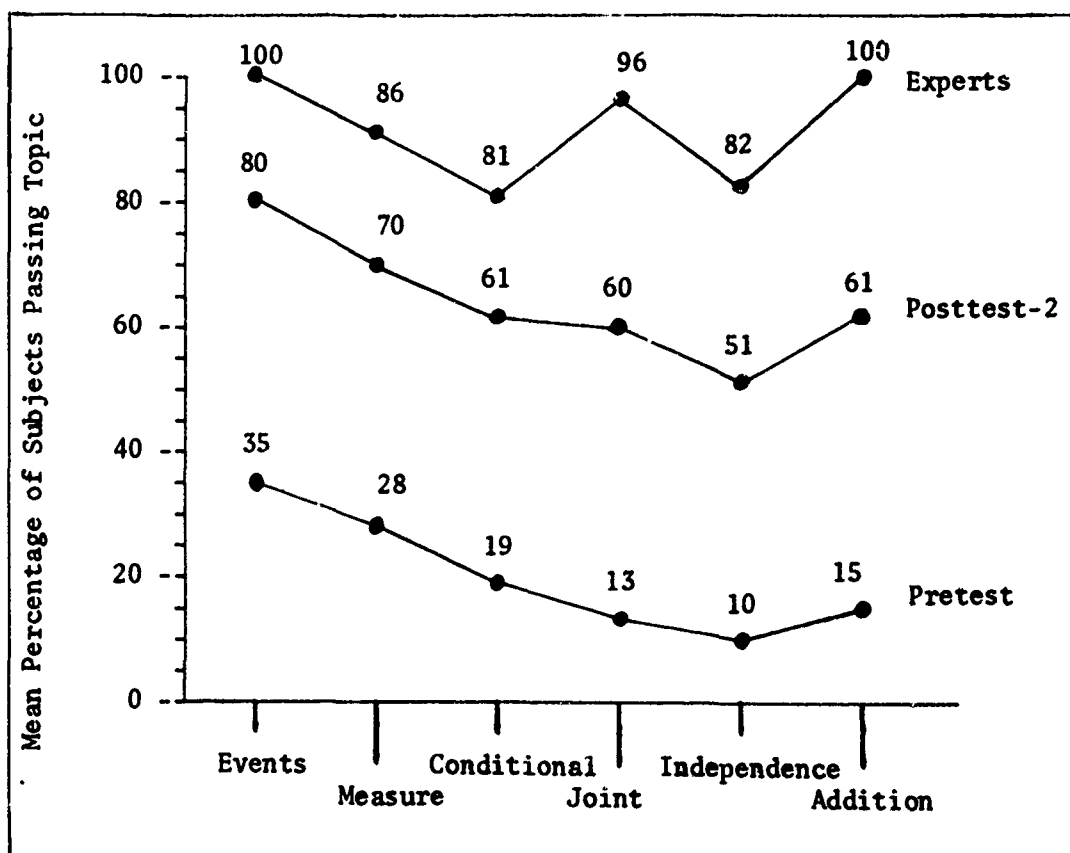
## RESULTS, continued

### Success Rate on Separate Topics

The learning materials can easily be subdivided into separate topics and a success rate computed to see if the sections are equally effective.

Pretest and posttest-2 scores were plotted for each topic using only the data of those subjects who had completed study of the given topic. Posttest-2 scores were used because we are more interested in over-all amount of learning apart from any skill in rapid retrieval. For this analysis of topic effectiveness, Open and Closed groups were combined since their scores were very similar.

The graph below plots the results in terms of the mean percentage of subjects passing the items for a given topic.



continued on next page

## RESULTS, continued

(continued)  
Success Rate  
on Separate  
Topics

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The decline in scores from left to right is interpreted as indicative of the difficulty of the topic; for example, conditional probability is more complex to grasp than is simple event terminology. The fact that the distance between pretest and posttest-2 lines is almost equal right across the graph is encouraging evidence that the topic treatment has been uniform.

The top line in the graph plots the standing of our group of experts on these various topics. For the most part they follow a trend much like that of our subjects.

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## RESULTS, continued

### Time Data

We next took up the question of whether students who are preparing for an open-book examination study as long as do students anticipating a closed-book test.

The time data were obtained from the students' logs.

Data bearing on this question are of interest to prospective users who may wonder what time investments they must make for given learning outcomes. The information is also of interest as an indication of students' reactions to the two different test prospects.

In presenting the time data for the two subject groups, we separate those who finished the book and those who did not:

SUBJECTS WHO FINISHED BOOK					
Condition	Mean Pre-requisite Score	Mean Pre-test Score	Mean Post-test-1 Score	Mean Post-test-2 Score	Mean Hours of Study
Open (N = 8)	15.63	9.27	19.88	28.00	8.08
Closed (N=11)	13.27	9.73	21.73	26.45	10.27

SUBJECTS WHO DID NOT FINISH BOOK					
Condition	Mean Pre-requisite Score	Mean Pre-test Score	Mean Post-test-1 Score	Mean Post-test-2 Score	Mean Hours of Study
Open (N = 9)	11.67	5.22	14.76	17.43	7.43
Closed (N=7)	10.87	7.58	11.44	15.73	8.28

The more informative and cleaner comparison is to be found in the data of the complete subjects. Here we see that those in the Closed group spent over two hours longer in study than did the Open group students. It is interesting to note that in posttest-2 they scored almost as high as did the Open group who had their books to consult.

In this connection the students made some spontaneous comments about their attitudes toward preparing for tests: several

continued on next page

## RESULTS, continued

(continued)  
Time Data

remarked that one must study just as much for an open-book test because otherwise it is easy to become confused and panicky leafing through a book under test pressures. At the post-test sessions, a considerable number (62%) of the Open group subjects even reported forgetting that they were to have an open-book test. Yet the group as a whole did put in less study time than did the Closed group.

The data for the unfinished subjects have several points of interest also. In the Open group the unfinished subjects studied almost as long as did those who finished, so apparently the fact that these subjects did not get finished was not from neglect of the task. If we look at their other data, we find that these Open incomplete subjects had low scores on their prerequisite test and on their pretest as well.

A rather similar picture emerges from the data of the incomplete Closed subjects -- their prerequisite test scores were not so bad but they too did poorly on the pretest for the probability unit. They studied two hours less than did the members of their group who finished the task. In a later section we shall look into the relation of test scores and the mathematical background of the students.

Briefly, then, the time data show:

- The probability and set units require about 8 hours of study for an open-book test and 10 hours of study for a closed-book test.
- Students who are not so well prepared mathematically can be expected to take longer.

Open Book  
Use During Test

We mentioned above that some students remarked that they did not rely on the book much during open-book tests and that some of our students even forgot that they were to get an open-book test.

Fortunately after the test we gave the Open group an extra short questionnaire which asked in what per cent of the test questions did the student use the book.

The answers ranged from zero to 35%. The 10% mark divides the subjects into approximately equal groups. In the table below the scores obtained by those who used the book more can be compared with those of subjects who used it less (as usual, finished and unfinished subjects are separated):

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# RESULTS , continued

(continued)  
Open Book  
Use During Test

Open Group Subjects Who Had Finished Book					
Use of Book	N	Mean Prerequisite Score	Mean Pretest Score	Mean Posttest-2 Score	Posttest-2 Expressed as Percentage of Experts
Over 10%	4	16.0	9.22	32.0	80%
10% or less	4	15.25	10.00	24.0	60%

Open Group Subjects Who Had Not Finished Book					
Use of Book	N	Mean Prerequisite Score	Mean Pretest Score	Mean Posttest-2 Score	Posttest-2 Expressed as Percentage of Experts
Over 10%	5	12.4	4.50	19.4	48.5%
10% or less	4	10.8	6.25	13.5	33.8%

For both finished and incomplete subjects, those who used the book more during the test were more successful.

Subjects'  
Goals

Just before the posttest, subjects wrote down the grade they expected to obtain on the test. If we take this as some indication of the goals the subjects set for themselves, it is interesting to see how well they succeeded.

In the table below we have grouped the subjects' grade estimates into three classes: the first represents A's and B's (only one subject expected an A); the second, C's; and the third, D's and below. The body of the table shows the mean posttest-2 scores expressed as percentages of the experts' mean score.

Scores Predicted By Subjects	Open Group		Closed Group		Total	
	N	%	N	%	N	%
81 -100%	5	78.0	6	71.3	11	74.3
71 -80%	8	48.5	6	44.6	14	46.8
Below 71%	3	42.5	4	41.0	7	41.6

continued on next page

## RESULTS , continued

(continued)  
Subjects'  
Goals

Those who expected to score between 80 and 100 on the material emerged with a fairly high score, 74.3% - which falls short of their aspirations, yet is a respectable showing on a difficult test after only two weeks' exposure to the topic.

Those who expected to make a C on the test were considerably short of the mark. Only six of the fourteen in this group had finished the book, so one wonders at the confidence of those who expected to score 70-80 without having finished it.

Even those six who did finish it did not do as well as they hoped - their average was 52.5% of the experts.

Those who anticipated doing poorly on the test were quite right; their score was only 41.6% of the experts. Five of the seven in this group had not finished the book.

The pre-study attitude survey asked subjects to indicate the grade they usually aspired to in their mathematics courses. If we separate the subjects into three approximately equal groups on the basis of their responses and then look at the posttest-2 scores for each of these groups, we get the following table:

Usual Grade Aspirations	N	Posttest-2 Means as Percentage of Experts' Mean
91-100	9	70%
81-90	12	51%
Below 81	8	36%

Naturally if we single out those who both had high expectations on this particular test and generally expect to do well in mathematics courses, we find a high-scoring group - average 78% (N = 4) on posttest-2 scores. Those who did not expect to do well either here or in their courses came off very poorly - 29% (N = 3). It is not feasible to consult other interesting combinations of the two goals indicators because the number of cases becomes even smaller.

In general the results on the probability test do follow with measures of the subjects' expectations (at least in terms of the ranking of the means). Among the important determinants of the goal indicators will be the students' general scholastic aptitude and his level of competence in mathematics at the time he came to the project.

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continued on the next page

## RESULTS, continued

(continued)  
Subjects'  
Goals

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The latter would be an especially strong influence presumably in the grade expected for the probability test. We examine the students' scores in relation to their mathematics background in the next section.

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Mathematics  
Background

The prerequisite test gave us a measure of our subjects' present proficiency in simple math and algebra problems while their personal data record provided a listing of the college math courses they had taken.

From these two kinds of information we derived a loose measure of mathematics background by this procedure:

- for each kind of information a cutoff point was arbitrarily chosen to separate the subjects into a high and a low group. For instance, for the prerequisite test, those scoring over 75% were called "high," those under 75% went into the "low" group. In terms of mathematics courses, those who had taken calculus and beyond were called "high," those who had not had college calculus were put in the "low" group.
- for a composite mathematics background measure, we placed in a High group those who were high on both of the above dimensions. Those low on both went into a Low group, while those who were high on one but low on the other were assigned to a Medium group.

This classification resulted in twelve subjects in the High group, eight in the Medium group, and fifteen in the Low group. Since different members in each group finished the book, the results in this section will be based on complete subjects only. This reduces the number of subjects in the High group to nine, Medium group to three, and Low group to eight. Only 25% of the High group failed to complete the book while almost 50% of the Low group did not finish. This seems to be a result of the two week time limit imposed since the High group ( $N = 12$ ) spent an average of 7.9 hours on the book while the Low group ( $N = 15$ ) spent an average of 9.5 hours.

The probability-unit results for each group are shown next for those subjects who finished the book (Open and Closed groups pooled). The same data are shown in the accompanying graph.

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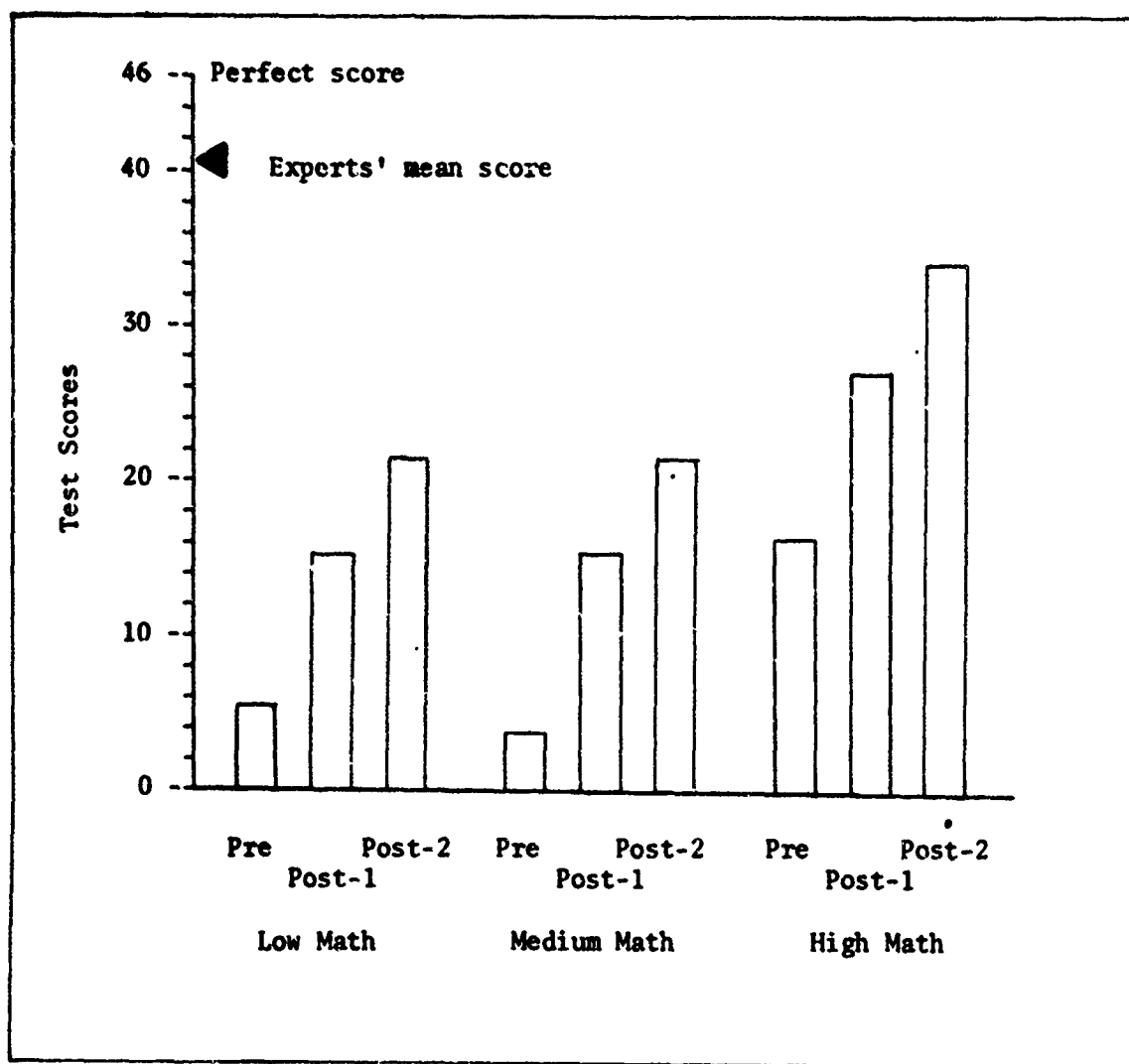
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# RESULTS, continued

(continued)  
Mathematics  
Background

Aptitude Group	N	Mean Prerequisite Score	Mean Pretest Score	Mean Post-test-1 Score	Mean Post-test-2 Score	Post-test-2 as % of Experts' Mean
High Math	9	18.22	16.00	26.27	33.67	84.2%
Medium Math	3	13.67	3.67	15.67	21.67	54.2%
Low Math	8	9.25	5.50	15.50	20.88	52.2%



## RESULTS, continued

(continued)  
Mathematics  
Background

Those who are better prepared in mathematics do score higher on the pretest and posttests than do those in the Low group. It is interesting to note, however, that the gain scores for the groups are not dissimilar:

Aptitude Group	Mean Gain from Pre-test to Posttest-1	Mean Gain from Pre-test to Posttest-2
High Math (N=9)	10.7	17.7
Medium Math (N=3)	12.0	18.0
Low Math (N=8)	10.6	15.4

Reference Use  
Of Information  
Maps

On a logical basis the advantages of information map books for reference purposes seem obvious. Experimental evidence on the question, however, is not easy to come by because it is difficult to design realistic reference situations that are not "straw-man" demonstrations of information map superiority. We do have a few data that bear on the question, however.

The Harvard series had shown us that students in initial learning of a short course where the grade is inconsequential do not leaf back and forth, reviewing, comparing, integrating as they do in a semester-length college course. Thus their experience is not a very strong base from which to judge the book's utility as a reference tool. Consequently we decided to incorporate in the next tryout a task that would require moving back and forth through the book.

The open-book test for the probability course was made part of the experimental plan in order to obtain data on the book's use in reference for a real task - answering test questions. We have already reported that a disappointingly small number of students actually used the book during the test. And we have also reported that those who did use the book scored higher than those who used it very little.

For these same subjects we have responses to a short posttest questionnaire about their experience in looking up things in the book. We asked:

"When compared with standard textbooks, looking up things in the information map book is . . . . ."

Of the seventeen subjects in the Open group, one wrote "no opinion," two felt the books were the same, and fourteen wrote that the map book was "easier" or "better" or some such phrase.

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## RESULTS, continued

(continued)  
Reference Use  
Of Information  
Maps

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Many of the latter group added comments such as:

"interesting -- easy to find -- usually exactly what one is looking for."

"much easier and very direct."

"very easy reference."

"it was clear and easier to use because I could follow through with examples."

"easier. This is more concise and with the Related Pages much easier."

"much easier and quicker. I can go right to the page to find the needed information."

Those who had used the book more during the test and those who rarely used it were equally favorable in answering this question. Two of the three subjects who were noncommittal or neutral on the comparison were from the High mathematics background group, and the third was from the Medium group. But the fourteen who responded favorably were almost equally distributed over the High, Medium, and Low groups (4,5,5, respectively). Thus opinion about the book's utility for reference was not related to the mathematics background of the users.

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## RESULTS, continued

### Attitude Results

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Since the attitude questionnaire for this study was longer than the ones used in the two previous studies, it is easier to present the results in two separate parts: attitude towards learning features of information mapping and attitude towards format.

The questions about learning features give the following results:

1. 89% thought that learning sets with the materials was effective; one (out of the 35 subjects) thought that the material was ineffective; the rest were undecided.
  2. 63% thought that learning probability with the material was effective; 9% thought the material was ineffective, and the rest were undecided.
  3. 75% thought they would retain the material presented better than with a standard text, two subjects disagreed with this, and the rest were undecided.
  4. 85% would recommend the materials to others, one subject would not, and the rest were undecided.
  5. When asked whether the material progressed too quickly, 26% agreed, 29% disagreed, and the remaining 45% said it was "just the right pace."
  6. The section on sets was rated easy by 89% of the subjects, and just right by the remaining 11%.
  7. The probability section was rated easy by 17% of the subjects, just right by 20%, and difficult by the other 63%.
- 

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## RESULTS, continued

### (continued) Attitude Results

The questions relating to the information map format evoked these responses:

6. 37% of the subjects agreed that there were not enough feedback questions and 51% disagreed; the rest were undecided.
9. 89% of the subjects thought the feedback questions were effective, one thought they weren't, and three were undecided.
10. 80% were interested in studying other subject matter written in this style, one subject didn't care one way or the other, and the others were not too interested.
11. 61% felt that they were able to work with the book for longer periods of time than with a standard textbook. 14% disagreed with this statement and the other 25% thought there was no difference.
12. 86% thought that the use of diagrams simplified the material, two of the subjects disagreed with the statement, and the other three were neutral.
13. 69% thought the examples in the book were interesting, 9% thought them uninteresting, and the other 22% had no opinion.

In addition to these multiple choice questions, there were a number of open-ended questions which asked about various features of the material.

When asked to list the ways this book was different from a standard text, some of the responses and the number of subjects who gave each were:

- talked, asked questions, and explained answers (7)
- clear examples (2)
- more simplified and clarified (5)
- logical grouping of ideas (16)
- repetitious (2)
- immediacy of feedback questions (11)
- easier to stop and start studying (1)
- explained material better (1)

We also asked which features of the book were not helpful:

- some introductions too long (2)
- explanations too involved (1)
- confusing formulas (1)
- two week time limit too short (1)
- having to work completely independently (1)

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## RESULTS, continued

(continued)  
Attitude  
Results

Some of the responses to what features of the book were helpful:

- . diagrams explaining formulas (4)
- . numerous examples (5)
- . alternative approaches to a given problem (3)
- . feedback questions (13)
- . reviews with answers given (11)
- . division into concepts (5)

When asked how we could improve the book we got the following responses:

- . add more interesting examples (2)
- . add more review sections (2)
- . add more detailed explanations (2)
- . add more examples on complex material (7)
- . add more time on complex probabilities (4)
- . add more feedback questions (2)
- . delete some of the material on sets (2)

Some of the individual comments were (the letters H, M, and L refer to the subject's math group - high, medium or low):

- . first math "course" that ever got through my mental block (L)
- . with this text I was secure with a math book. This is phenomenal for me! (L)
- . much more boring and repetitious than a standard text (H)
- . more fun to read (M)
- . reader more active in learning (M)
- . compared to other math books I found this to be a great improvement (L)
- . extremely repetitious (H)
- . bored with approaching each topic in the same way - organized but not stimulating (L)
- . missed having a teacher for aid (L)
- . don't like feeling like an automation machine - want to select information not react to it (H)
- . easy to work with; efficient means of learning (H)

General Discussion

Based on their answers to all the attitude questions, thirty of the thirty-five subjects (85.77%) had a favorable reaction to the learning materials, three were indifferent, and two had an unfavorable reaction. The subjects who were weak in mathematics were very favorably disposed and perhaps would have done better on the achievement test if they had more time to study.

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## RESULTS, continued

### (continued) General Discussion

Most of the unfavorable comments came from those subjects who were quite good in math. Their usual comment was that explanations were too long, boring, etc. When we looked at their books it was evident that they had gone through all the material and all the feedback questions even though we stated in the introduction that the book was designed so that examples could be skipped and feedback questions answered only when the student was having difficulty.

The few unfavorable comments of those who had weak math backgrounds were generally confined to lack of time and the desire to have a teacher available to answer questions that came up so they could go on with confidence.

### Limitations of the Study

The principal shortcoming of this study lies in the atypical motivational conditions. One of the key principles of modern learning research relates learning and memory to the degree of motivation aroused. Among the important incentives commonly employed to motivate students are grades and the approval of the instructor. In the laboratory situation, monetary rewards are often used to manipulate the subjects' motivational level.

In our evaluative experiment with the probability book, these common incentives were absent. The grades the student achieved on our tests were of no consequence to him, would not affect the future course of his educational career one bit and in fact would never even become known to him. Although he was paid for coming to take part in the series, his rate of pay was in no way geared to his level of achievement; as we saw, many subjects did not finish reading through the materials. There was not the "cramming" for an exam that so often typifies (unfortunately) the college course.

The time of year when this series occurred was one where student morale and enthusiasm for study were at their lowest ebb -- at the end of the school year just after final exams. Most subjects had just started on their summer jobs.

What motives were operating to make them take part in the experiment and to study the book as many hours as they did (5 to 14)? We know that many came because the project seemed a painless and interesting way to earn some much needed money; some came as a favor to the investigators; a couple came because they saw an opportunity to prepare for a similar course required next term by their college program.

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## RESULTS, continued

(continued)  
Limitations  
of the Study

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Whatever may be the needs and interests that drew our subjects to participate in the study, we are confident that they were less intense than the motives ordinarily operating in the situations for which these learning materials were intended.

Of our results it is safe to say that they represent outcomes obtained under minimal motivational conditions. In other circumstances (in college courses, job-training classes, etc.) where internal and external incentives are operating at customary levels and where sufficient time is available for assimilation, we can reasonably predict markedly increased effects.

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# NOTE ON STATISTICAL DETAILS

## The Multiple Analysis of Covariance

The multiple analysis of covariance used the prerequisite test ( $X_1$ ) and the pretest ( $X_2$ ) as covariates for the posttest ( $Y$ ). The analysis of sums of squares and products was as follows:

	d.f.	$\Sigma x_1^2$	$\Sigma x_2^2$	$\Sigma x_1 x_2$
Between groups	2	1.63	21.71	-5.95
Within groups	50	1141.12	2700.10	897.27
Total	52	1142.75	2721.81	891.32

	d.f.	$\Sigma y^2$	$\Sigma x_1 y$	$\Sigma x_2 y$
Between groups	2	787.09	6.89	-21.79
Within groups	50	3512.08	1152.63	2166.72
Total	52	4299.17	1159.52	2144.91

The regression coefficients are estimated by solving the simultaneous equations:

$$\begin{aligned} 1141.12b_1 + 897.27b_2 &= 1152.63 \\ 897.27b_1 + 2700.10b_2 &= 2166.72 \end{aligned}$$

which results in:

$$\begin{aligned} b_1 &= .513 \\ b_2 &= .632 \end{aligned}$$

The deviations sums of squares were:

	d.f.	SS	MS
Total	50	2348.68	
Error	48	1551.36	32.32
For testing adjusted means	2	797.32	398.66

The F test of the adjusted means results in:

$$F = 12.33 (2, 48 \text{ d.f.}; P < .001)$$

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NOTE ON STATISTICAL DETAILS, continued

(continued)  
The Multiple  
Analysis of  
Covariance

---

The effective mean square per observation is:

$$s^2 = 32.72$$

(This is an adjusted error mean square - see Snedecor and Cochran, 1967, p. 441)

The Studentized Range Test (Q) may be used to compare the differences between adjusted means. The upper 1% point of Q for three means and 48 d.f. is approximately 4.33. The average standard error of a mean is 1.39. Thus, any difference which is greater than  $(4.33)(1.39) = 6.019$  is significant at the 1% level. Since the difference between open and control is 8.38 and the difference between closed and control is 8.17, both of these differences are significant at the 1% level.

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## CHAPTER 7 OVERVIEW OF THE EVALUATIVE STUDIES

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Introduction    First of all, two points about evaluative studies in general:

- The experimental data bear on the specific product and not on the method. Just as one given textbook cannot be considered as representative of so broad a category as "textbooks in general," so the information map units we have tested are only one sample of the possible products of the information map method.
- There are limits to what can be accomplished by one series of researches on any topic.

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Achievement  
Data

The evaluative studies have shown some of the effects that we can expect from the use of this information map book under different conditions. After 8 to 10 hours of study in a setting free of the usual educational pressures, students showed significant evidence of learning. That fact in itself is not surprising in view of the empirical tryouts and revisions that the program underwent throughout its development.

The problem of trying to say anything meaningful about the magnitude of gains from learning materials is a perennial one in educational research. The arbitrariness both of the criteria set by the program developers and of the difficulty level of the tests make it impossible to compare gains across evaluative studies. One set of criterion tests may be very easy and a spectacularly high percentage of students pass them compared with the gains from another program with more difficult criterion tests.

In short, since the criteria and the difficulty level of the tests are the result of the individual developer's judgment, much of the data from evaluative studies are properly termed "ipsative" - self-serving, without an external reference point.

Our own test of the probability unit were purposefully made difficult for reasons of experimental design, as Chapter 6 explains. In the absence of any standard achievement tests to use for comparison, it is difficult to assess the size of the gains.

In an effort to provide some external anchor point for judging the effect of the probability unit, we resorted to comparing the students' scores with those of our "experts" on the same test.

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(continued)  
Achievement  
Data

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To further aid in weighing the value of the program, we present in the appendix the actual tests used for the probability unit. There the reader may note the range of content covered and the difficulty level of the material. These together with the performance data reported in Chapter 6 constitute the main evidence for the unit's value.

In the end, whether or not the program has achieved worthwhile results is a matter of individual subjective judgment, and that is related to the use for which the specific product is being considered.

Attitude  
Data

---

The difficulty of trying to establish an objective standard for comparing educational programs has led some researchers to turn to attitude data as being more revealing about the attractive power of a program. Although we do not abandon hope of solving the methodological issue, we do attach importance to the user's reactions to the learning materials. His willingness to approach and to interact with the materials encourages the hope that the materials may communicate with him.

The reactions of our students to information maps were generally quite favorable, especially among those for whom the materials were intended, those with weak backgrounds in mathematics.

In general, our subjects rated the materials effective, said they would recommend them to others, and singled out many of the special features for favorable mention.

Whether the effects of the sets and probability book are attributable to the novelty of the method cannot be determined in the time-framework within which we operated. The so-called Hawthorne-type reactions can be both hostile and enthusiastic. Only in extended tryouts with the same subjects can we determine whether the learning materials are still looked upon favorably by students.

Conclusion

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In working with a new system, we have made only a beginning at collecting information about how subjects react to the learning materials. We have sampled only a narrow range of subject matters. We have only begun to ask questions about how specific factors or features of the materials contribute to the learning outcomes. One set of experiments with a single product can only begin to map out the areas that may be important.

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(continued)  
Conclusion

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Our initial task was to explore the effects of information-mapped learning materials and to decide upon the feasibility of further work with the method. The initial research is promising but more experiments and wider experience are needed if we are to be able to generalize about the method. This is not to say that a strong logical case cannot be made for the method's advantages. We will consider this in the final chapter.

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## CHAPTER 8 INFORMATION MAPPING AND COMPUTERS

### A LEARNING-REFERENCE SUBSYSTEM

Introduction	<p>During the development of information map books, we began to see how the information mapping categories could be applied to organizing a computer data base for learning and reference purposes. We explored some of the aspects of developing a multi-purpose data base organized in this way and we carried out exploratory design work on animated display possibilities. Some preliminary tryouts of learning from information map displays re made with a simulated display unit.</p>
Background	<p>The capabilities of a large computer facility permit it to be a significant training vehicle for its users. Therefore, it is desirable for such a facility to include a learning-reference subsystem. The success of such an information utility depends in a very critical way on the organization of the underlying data base and the flexibility with which it can serve different purposes.</p>
Data Base	<p>We conceived of a data base as consisting of interrelated networks of information segments. This gives a flexibility in using only those parts of the system that are required for a particular purpose. Since information maps are composed of separable labelled blocks of information, they can easily be adapted for this type of data base.</p>
Sequence Generators	<p>A common data base to serve varied purposes would require a set of "sequence generators". These would be rules or patterns for assembling and displaying information blocks, depending upon the objective of the user. The browser would obviously not want to see the information in the same sequence as would the user with a specific reference problem. The purposes of initial learning, reviewing, briefing, updating, and so on would all require different information sequences. The information map books are arranged according to sequence generators derived from considerations of learning theory, instructional technology, and human factors engineering.</p> <p>For some purposes, the sequence generator could allow considerable control of the system by the user -- for reviewing, browsing, and reference uses, primary control should reside with the user. For initial learning, the sequence generator could permit a limited number of user options, but major control should probably remain with the system.</p>

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## A LEARNING-REFERENCE SUBSYSTEM, continued

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### Query Language

User control of the system is provided by the query language which is the set of all commands that are available to the user. For example, the user may have available commands which allow him to look up a particular page or topic, go to a set of feedback questions (or omit such questions), etc.

The extent of user control in the system is indicated by the complexity of the query language.

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### Updating

From time to time, there will arise a need to modify the data base. An information mapped data base, because of its separate blocks of information, would probably minimize the cost of updating or improving the data base.

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## ADVANTAGES OF USING INFORMATION MAPPING FOR A LEARNING-REFERENCE SUBSYSTEM

Multiple Purposes	<p>The flexible block-identified data base can be rearranged for:</p> <ul style="list-style-type: none"><li>• initial learning<ul style="list-style-type: none"><li>• for the naive student</li><li>• for the sophisticated student</li></ul></li><li>• relearning or review<ul style="list-style-type: none"><li>• for a comprehension test</li><li>• for a performance test</li></ul></li><li>• reference (reminder or look-up of a specific bit of information)</li><li>• briefing and browsing (what is this subject matter about in general terms?)</li><li>• updating skills and information (unlearning and new learning)</li><li>• job-aid (preparing checklists, menus, and other types of job aids)</li></ul>
User Options	<p>The user may:</p> <ul style="list-style-type: none"><li>• exercise a preference in sequencing of information blocks</li><li>• choose different levels of feedback questions</li><li>• choose when to see the feedback question answers</li><li>• choose whether he wants personal or system control of review</li><li>• choose details of a personal review method (e.g., via feedback questions, condensed summary pages, definitions only, etc.)</li></ul>
System Options	<p>The system can respond to individual differences such as learner purposes. It can give mathematical proofs to the mathematically inclined learner and omit them for the person who is only interested in learning the subject matter procedurally.</p>



## DISPLAY OPPORTUNITIES

**Introduction** Computers with display scopes have great potential for making learning and reference work more effective. Considerable research is needed to explore the advantages of different scope applications.

The capacity of the computer to permit the user to exercise his individual preferences may be an important part of effective man-machine partnership. One option that could be made available to the user would be the choice of a number of types of displays.

Not everyone wants to have information displayed to him in the same way. For example, if you are learning something for the first time you may want a complete version of the text. If you are reviewing or just browsing through a large body of material you may want less.

Many people like tables, charts, and graphs, while others prefer their information in uninterrupted prose. Information mapping can easily be adapted to accommodate both.

**Dynamic Displays** Another promising possibility is the development of animated displays along with research into their impact on learning and reference work. Five possible uses of dynamic displays are given below:

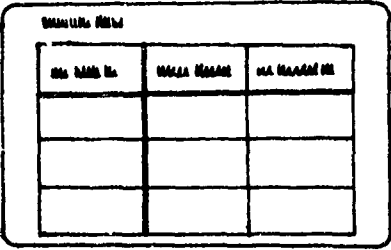
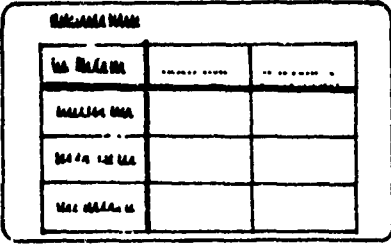
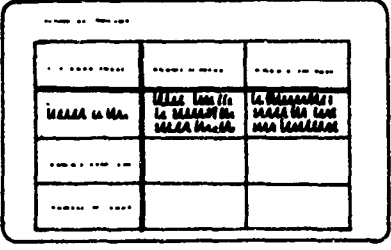
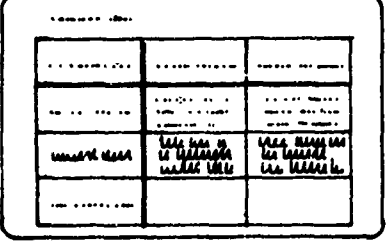
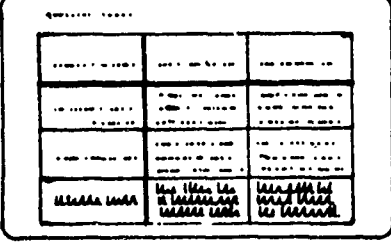
Uses	Description	Possible Advantages
Guided reading	In the guided reading type, we reveal parts of a display to the user. For example, different parts of a table might be shown.	<ul style="list-style-type: none"><li>• Ensures that new users of information maps use them to full advantage.</li><li>• Paces reading rate.</li><li>• Focuses attention.</li></ul>
Vary level of detail	In this type, different levels of detail or abstraction appear during the display. For example, a tree is shown with just the names of main concepts, then with the next sorting into finer level groups.	<ul style="list-style-type: none"><li>• The user's field of vision is not over-clogged with detail.</li><li>• Relationships between different levels of abstraction and detail are revealed.</li></ul>

continued on next page

# DISPLAY OPPORTUNITIES, continued

Uses	Description	Possible Advantages
Show movement in a sequence network	In sequence networks, there is a movement either logically or in time. We can display this movement in a dynamic display. We can also show interrelationships between two moving systems.	<ul style="list-style-type: none"> <li>Highlight thing being talked about.</li> <li>Focus on parts and relationships in whole.</li> </ul>
Explode, implode parts of structure	Structures are made up of parts. Diagrams can be "exploded" by a common drafting technique in dynamic terms.	<ul style="list-style-type: none"> <li>Show how structures fit together.</li> </ul>
Highlight an important learning point	Flashing (or momentarily appearing) arrows, labels, and other visual techniques adaptable from the world of movie and television.	<ul style="list-style-type: none"> <li>Focus attention of user.</li> <li>Maintain attention of user.</li> </ul>

ONE APPLICATION OF DYNAMIC DISPLAYS

Time Segment	Display Screen	Comment
1		Name of table, main headings, and outline of table flash onto screen.
2		Names on left axis appear while names of main headings recede (but do not disappear).
3		Successive horizontal blocks of information appear.
4		As each "line" of blocks appears, the other lines recede to a lesser character size or are reduced to a lesser brightness.
5		

## EXAMPLES OF DISPLAY OPTIONS








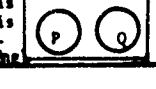
**Introduction** The next two sample pages illustrate how the same information can be presented in two different ways. Even for initial learning purposes some students prefer a chart where they can observe the relationships themselves, while others would rather have a verbal description of the material. For later review and reference work, however, the tabular format would presumably be most favored.

The first example shows the summary table from the end of the sets unit.

### Example

47

**CONDENSED SUMMARY OF SET THEORY**

SYMBOL(S)	NAME	MEANING	VENN DIAGRAM	SEE PAGE
$U$	Universal Set	The set of all elements in a given study.	Shaded part is $U$ . 	14
$\emptyset$	Null Set	The set containing no elements		13
$\subset$	Subset Symbol	"...is contained in..."	Shaded part is subset. 	11
$P$ $Q$	Names of Sets	Any capital letters may be used to name sets, e.g. A, B, ... Z.		4
$\bar{P}$	Complement	Set of all elements in $U$ <u>not</u> in $P$ .	Shaded part is $\bar{P}$ . 	27
$\epsilon$	Element Symbol	"...is an element of..."		6
$\notin$		"...is not an element of..."		6
$P \cup Q$	Union	Set of all elements in $P$ or $Q$ or both.	Shaded part is $P \cup Q$ . 	30
$P \cap Q$	Intersection	Set of all elements common to $P$ and $Q$ .	Shaded part is $P \cap Q$ . 	35
$P - Q$	Difference	Set of all elements in $P$ but not in $Q$ .	Shaded part is $P - Q$ . 	44
$P \cap Q = \emptyset$	Disjoint Sets	Sets which have no members in common.	Shaded part is $P \cap Q$ , which is empty (therefore no shading). 	42

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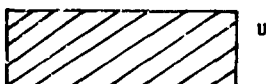
## EXAMPLES OF DISPLAY OPTIONS, continued

(continued)  
Example

The second example shows the same information presented in prose form (only half of the information in the first table is given in this example in order to save space; in practice, of course, all the information would be presented):

### CONDENSED SUMMARY OF SET THEORY

The symbol  $U$  stands for Universal Set, which is the set of all elements in a given study. Venn Diagram:



The shaded part is  $U$ .

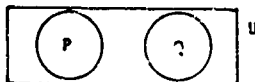
The symbol  $\emptyset$  stands for the Null Set, which is the set containing no elements. There is no Venn Diagram of the Null Set.

The symbol  $\subset$  is the Subset symbol and means "...is contained in." Venn Diagram:



The shaded part is the subset.

Any capital letters may be used to name sets, e.g.,  $A, B, \dots, Z$ . Venn Diagram:



The symbol  $\bar{P}$  stands for the Complement of a set, which is the set of all elements in  $U$  not in  $P$ . Venn Diagram:



The shaded part is  $\bar{P}$ .

The symbol  $\in$  is the Element symbol and means "... is an element of..." There is no Venn Diagram.

The symbol  $\notin$  is the symbol which means "...is not an element of..." There is no Venn Diagram.

## SIMULATED COMPUTER DISPLAY UNIT

**Introduction** In order to have a glimpse of the difficulties and possibilities of applying information mapping to computers we constructed a simulated computer device.

The "computer" is operated by a research assistant who follows an algorithm that tells him how to respond to different commands given by the user. The user communicates with the "computer" by writing commands on cards.

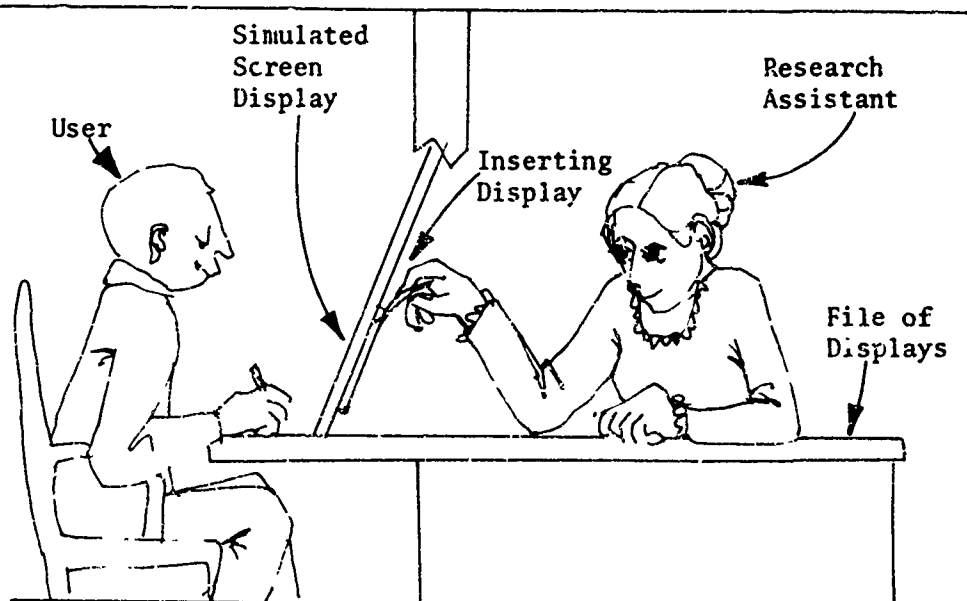
The research assistant finds displays manually in a file box, slips them into the display device and records data on the interaction such as time, display asked for, etc. The displays used were the pages of the information map book on sets and probability.

**Objectives** This display unit was built primarily as a tool for possible future research in application of information mapping to computers. Thus, we were primarily concerned with the following questions:

- Is the simulation a reasonable one, i.e., does the user actually react as he would with a computer based learning-reference system?
- How complex a query language could the research assistant handle?
- Can we identify specific pages that cause the student trouble?

The last question, of course, is concerned with revision of the book pages. Thus, the simulated display unit served as a developmental test vehicle.

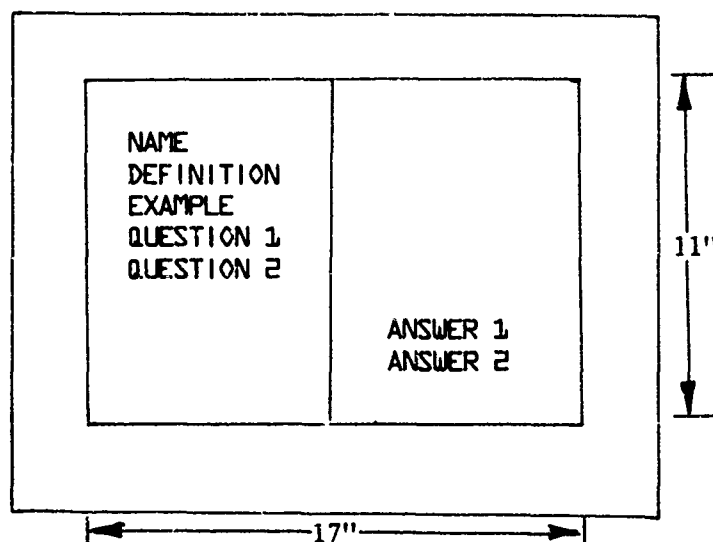
**Diagram**



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## SIMULATED COMPUTER DISPLAY UNIT, continued

### Dimensions of Display Screen



### User Behavior

Only a few students were run on this device so a more definitive answer to the first question is not possible. However, from interviews with those who tried it, we got the impression that the user easily entered into his role, became forgetful of the research assistant behind the screen, and tended to act as if it were a "real machine."

### Query Language

The query language we used had provisions for referencing a table of contents or any previous page or topic. In addition the user was able to determine whether or not he wanted feedback questions or review questions.

The average time for an experienced research assistant to respond to a user command was about 7 seconds. We found this delay to be acceptable to the users (although we hope it can be reduced still more).

### Developmental Test Aspect

The results of the data on time per page gave us an indication of those pages that gave students trouble. Other indications came from questions asked by the user during the session. These pages were, of course, revised.

In addition, since the student always had the opportunity to ask for feedback questions after each topic, we were led to insert a few of these pages where we previously thought them unnecessary.

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## SIMULATED COMPUTER DISPLAY UNIT, continued

(continued)  
Developmental  
Test  
Aspect

Some time data for two subjects who learned from the sets and probability units are shown here:

Time Factor	Fastest Student	Slowest Student
Average time spent per IM page	1.1 min	2.5 min
Range of time spent per IM page	0.25 - 2.50 min.	1.00 - 6.33 min.
Average time spent per feedback question page	2.4 min	2.8 min
Range of time spent per feedback question page	0.25 - 5.92 min.	0.50 - 8.83 min.
Total time at display	2 - 1/6 hours	4 hours

Conclusion

The simulation approach was a feasible way to begin investigating properties of query languages and different types of displays in an inexpensive setting without the long waits associated with hardware installation and software preparation. We found it was possible to collect meaningful experimental data on various display research issues and we believe that much useful work can be done with such simulated units.



## CHAPTER 9 PRODUCTION COSTS

### Introduction

During the project we wrote a total of approximately twelve hours of material on sets, probability, and permutations and combinations. Although we kept records of the amounts of time spent on the different aspects involved in production, these time figures are confounded with the time we spent defining and redefining the information map system. Now that the system has been established, these records are not representative of the time an experienced writer would spend at the task.

In order to obtain a more realistic estimate the authors tried to adjust the figures to reflect what might be involved in the production of an information map book. Thus, the costs we present are estimates based on the consensus of the authors.

### Cost Estimates

The total cost of the production was approximately \$12,000. As indicated in the evaluation chapters, the combined average time to study the book was about twelve hours (note that no single group in the evaluative studies actually went through the entire book; some read only sets and probability, while others read only sets and permutations and combinations).

We estimated that the breakdown of time spent on the different aspects of the production system was as follows:

Curriculum planning	25%
Writing and editing	55%
Developmental testing	20%

Thus, the cost-per-hour breakdown is as follows:

Curriculum planning	\$250
Writing and editing	\$550
Developmental testing	\$200

Total     \$1000

### Training the Writers

Since we have developed the system, we have no data on the training costs which might be involved. However, we do have experience with training of one new writer who came on the staff after the preliminary system was developed.

The indication from this experience points to the need for a one or two week training course (reading appropriate research

continued on next page

(continued)  
Training  
the  
Writers

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and actual examples of information map books) plus a month or two of writing experience under a competent editor. This assumes that the potential writer is a subject matter "expert" and that the editor is well versed in the application of learning research to instructional materials.

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Comparison  
with Pro-  
grammed In-  
struction

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Based on his experience as Vice President of Marketing with Basic Systems, Inc., Murphy (1967) estimates that a typical cost-per-hour of programmed instruction might run between \$2500 and \$3000.

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Murphy's figure includes direct costs plus an overhead estimated at 100% of direct. Deleting the physical production costs, Murphy's direct cost-per-hour runs between \$1125 and \$1375.

Murphy's figures also include analysis of training requirements which involve in his case working with a client. We would expect that our curriculum planning involves the same type of work and so is more or less comparable.

Thus, we expect that information mapping costs will be approximately the same as those of programmed instruction. However, we feel that we have produced a more versatile product (one that serves both initial learning and reference uses).

Comparison  
with Compu-  
ter-Assisted  
Instruction

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Stolurow (1969, p. 308) says "It is difficult to determine the cost, but one approach is to estimate that as little as 100 hours of development time goes into one hour of student time. Estimates up to 400 hours have been made, but definitive data are not available. If the average cost per hour for the writers and technical personnel is estimated at \$12, then the cost would vary from \$1200 to \$4800 to produce one hour of student instructional material. Other costs also are involved, but hard to estimate. They include key punching, typing, artwork, machine loading, and the like."

Carter and Walker (1969, p.333) use the Suppes figure from Stanford University of \$5,000 per student hour for a drill and practice mode and assume a \$50,000 cost per hour for tutorial. They do usefully point out that spread over 100,000 users, the instructional materials development costs are only 3 to 6 percent of the total CAI system.

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## Conclusions

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Perhaps the only consensus that can be reached on "average" costs of either computer-assisted instruction, programmed instruction, or information mapping is that definitive data are not available.

Even if data were available, however, their interpretation would be subject to a great deal of debate. In discussing decision-theory approaches to the problem of instructional research, Lumsdaine (1963, p. 667) pointed out "our general inability to make reasonable estimates of the costs, and, particularly, the anticipated payoff of educational procedures."

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## CHAPTER 10 SUMMARY OF INFORMATION MAPPING

### REVIEW

What It Is	Information mapping is a method of organizing categories of information and of presenting them in formats that communicate quickly with the user.
What It Is For	Learning and reference work are the primary applications anticipated for the system.
Where It Came From	The procedures and techniques of information mapping are derived from the resources of the education world and incorporate effective applications in display and communication technology.
How It Is Used	<p>Information mapped materials may be produced in book form or organized into data bases for computer-aided instruction.</p> <p>In books designed for initial learning and reference, the information is carried in clearly labelled information blocks, arranged in an order prescribed for the kind of information involved. Other features of these self-instructional books include feedback questions and answers, special maps to facilitate learning and retention, charts and displays for easy retrieval of topics for review and reference purposes.</p> <p>For multi-purpose computer systems, an information mapped data base would be composed of separable labelled blocks of information together with their interconnections. Only those parts of the blocks required for a specific purpose need be called up. This flexible system would permit the user to organize sequences of blocks and to display them in the order that best serves his purpose, whether it be learning, reference, or browsing.</p>
Main Product	Most of the research and development work so far has involved book versions of topics in mathematics and computer languages. The primary product of this new system for which we have experimental data is a self-instructional book on sets and probability theory for college students with minimal preparation in mathematics.
How It Was Developed	One of the main tenets of information mapping is that the most reliable way to obtain program effectiveness is to make empirical testing and revision an integral part of the design and development process. Thus the book on sets and probability was shaped, corrected and improved by tryout-and-revision cycles.

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## REVIEW, continued

### Evaluative Studies

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The information mapped book served as the research vehicle for several evaluative studies of initial learning by college students. We have described the significant effect the book had on the students and we have presented the results of attitude studies showing that students find the materials attractive and valuable. Whether this favorable response is colored by the novelty of the approach cannot yet be determined for so new a technique.

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### Computer Simulation

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Preliminary spadework was carried out with simulated computer displays. This was done mainly to see whether the simulation approach was feasible for exploring whether certain options might be desirable in future computer applications: query languages, information-sequencing rules, dynamic displays, and so on. The approach seems a useful and economical way of researching practical issues without a heavy investment in computer facilities.

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### Cost Estimates

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The production of learning materials in college-level mathematics was estimated to cost about the same as programmed instruction. However the versatility with which information mapped materials can be adjusted to a variety of purposes gives it obvious cost advantages over single-purpose methods.

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## THE INFORMATION MAP METHOD

### Introduction

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We said earlier that our research related primarily to the specific product tested, the sets and probability book. It would be a logical fallacy to interpret the results as validating a method if this be conceived of as the whole class of products that might arise from information mapping techniques.

Our research had the practical objective of evaluating the specific program, but it was also a beginning in the task of learning more about the method by testing hypotheses about the influence of certain factors and variations in conditions.

The results of a short series of experiments are necessarily limited in their generalizability, but we consider the effects strong enough to warrant further development work.

### The Logical Case

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If we cannot generalize from the empirical data to the "method," we can nevertheless make a logical case for believing that the method is a promising one. In the first place, it draws upon the resources of the education world, embodying factors for which there is already support in research or practice.

Another reason for expecting the products to be effective is that they are developed by the process of "formative evaluation," as Scriven (1967) has called the process of empirical testing and revision throughout development. In this respect, the information map product has the advantage of a steady stream of learner-response data from all areas of the program. These are the basis for program improvement so that a desired level of proficiency can be obtained - in this it parallels programmed instruction.

Thus since the effectiveness of given products can be engineered by practical procedures, there is little point to arguing whether information mapped programs are as effective as programs produced by other prescriptions. The information mapping approach, however, has certain unique advantages over other methods. Some of these are indicated on the next page.

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## SOME ADVANTAGES OF INFORMATION MAPPING

Multi-purpose	<p>Information mapping is a flexible multi-purpose system. Its base of classified information blocks permits it to be used:</p> <ul style="list-style-type: none"><li>· for book production</li><li>· for computer-based programs</li></ul>
Learning and Reference	<p>The separable labelled blocks can be drawn from the information base as needed and assembled into sequences suitable for:</p> <ul style="list-style-type: none"><li>· initial learning<ul style="list-style-type: none"><li>· for the naive student</li><li>· for the experienced student</li></ul></li><li>· relearning or review</li><li>· reference uses</li><li>· browsing or briefing</li></ul> <p>Where computer scopes are available, the information blocks may be presented with a variety of display options such as:</p> <ul style="list-style-type: none"><li>· static versus dynamic displays</li><li>· whole versus sequential display of parts</li></ul>
Updating	<p>The block-identified and cross-indexed information base can be easily modified; therefore, the task of updating the changes in a system is relatively simple.</p>
User Options	<p>The flexibility of the system would permit the user options that are not available with other methods. The user may custom-tailor his own program by calling up only those information blocks that he requires for his specific purpose.</p>
Correction	<p>Programs for initial learning have a built-in correction function: practice questions and answers monitor the effects of each map. Therefore it is easy to identify and modify the trouble spots.</p>
Retrieval	<p>Whether in book version or in computer-adapted form, the ease with which information can be retrieved is obvious: informative tables of contents, maps beginning on a new page, map titles, marginal labels, consistently located classes of information, related page numbers at end of maps, charts, summary tables, indexes -- all are designed for swift communication with the user.</p>

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## SOME ADVANTAGES OF INFORMATION MAPPING, continued

### Different Audiences

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The flexible block format enables one to adapt each learning or reference program to the special interests of student groups. For instance, the worked examples and feedback questions of our probability unit were geared to situations of interest to students of the behavioral sciences. The same probability text can be modified for medical students or business students by replacing the blocks of worked examples and the pages of practice questions.

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### Research Advantages

Research advantages of a system so organized are manifold. Since the content characteristics of the materials can be specified, variations in the make-up of learning materials can be systematically varied with relative ease. For example, the effects of varying the number of worked examples or of changing the amount of redundant information could be explored.

With computer capabilities, many questions concerning the optimal complexity of displays and the desirable degree of learner control over instructional sequencing can be researched more economically with a flexible, modular system.

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### Comment

It has been remarked that the venerable textbook with its two distinctly different functions as both learning medium and reference source may soon disappear and be replaced by programmed instruction plus "the well designed reference handbook" (Lumsdaine, 1963, p. 586).

It seems that a better solution may be in information mapping.

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# APPENDIX

## MAP CLASSIFICATION CHART

Types of Maps	Description	Information Blocks
Concepts	<p>A concept may be a</p> <ul style="list-style-type: none"> <li>• technical term</li> <li>• generalization sentence</li> <li>• property sentence</li> <li>• rule sentence</li> <li>• relationship sentence</li> </ul>	<ul style="list-style-type: none"> <li>• name of the concept</li> <li>• definition or description</li> <li>• criteria</li> <li>• generalization</li> <li>• formula</li> <li>• use (purpose or function, worth, value)</li> <li>• example</li> <li>• non-example</li> <li>• introduction</li> <li>• synonym</li> <li>• notation</li> <li>• diagram</li> <li>• comment</li> <li>• properties</li> <li>• analogy</li> </ul>
Structures	<p>A structure is:</p> <ul style="list-style-type: none"> <li>• a physical thing, or</li> <li>• something which can be divided into parts which have boundaries.</li> </ul>	<ul style="list-style-type: none"> <li>• name of structure</li> <li>• meaning</li> <li>• function</li> <li>• /all of the concept blocks/</li> <li>• parts and subparts</li> <li>• boundaries</li> <li>• diagram (or illustration, picture)</li> </ul>
Processes	<p>A process is some structure changing through time. The description of a process involves writing about what happens during successive stages of time.</p>	<ul style="list-style-type: none"> <li>• name of process</li> <li>• /all of concept blocks/</li> <li>• /all of structure blocks/</li> <li>• purpose of process</li> <li>• stage</li> <li>• function of the part</li> <li>• cycle</li> <li>• input</li> <li>• result (output)</li> <li>• occasion for starting</li> <li>• changes</li> <li>• time</li> <li>• state</li> </ul>

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MAP CLASSIFICATION CHART, continued

Types of Maps	Description	Information Blocks
(continued) Processes		<ul style="list-style-type: none"> <li>• condition</li> <li>• cause</li> <li>• effect</li> </ul>
Procedures	A procedure is a set of steps performed to obtain some specified outcome.	<ul style="list-style-type: none"> <li>• name of procedure</li> <li>• /all of concept blocks/</li> <li>• given</li> <li>• step/procedure</li> <li>• example</li> <li>• when to use</li> <li>• when to stop</li> <li>• decisions</li> </ul>
Classifications	Classification is the sorting of things by concepts into categories by the use of one or more sorting factors (criteria).	<ul style="list-style-type: none"> <li>• name</li> <li>• sorting factor</li> <li>• subclass names</li> <li>• purpose of sort</li> </ul>
Decisions	Decision tables display actions prescribed for different conditions.	<ul style="list-style-type: none"> <li>• name of decision</li> <li>• "if" parts (or conditions)</li> <li>• "then" parts (or actions)</li> <li>• example</li> </ul>
Facts	Facts are sentences containing arbitrary associations of such things as symbols, measurements, dates associated with events, experimental results. How a fact is presented depends on the context.	<ul style="list-style-type: none"> <li>• statement of fact</li> </ul>
Proofs	Proofs are generally used in mathematical subjects for more difficult theorems.	<ul style="list-style-type: none"> <li>• assumptions</li> <li>• to prove</li> <li>• statement</li> <li>• reason</li> <li>• example</li> </ul>

# TEST-A USED IN RESEARCH REPORTED IN CHAPTER 6

1. Match the notation on the left with the correct term on the right.

<u>      </u> $P(A \cap B)$	a. probability of the complement of an event
<u>      </u> $S$	b. empty event
<u>      </u> $P(A)$	c. sample space
<u>      </u> $P(A B)$	d. conditional probability of one event given another
	e. probability of the intersection of two events
	f. independent events

2. There are five balls in an urn. Three are black and are numbered from one to three, and two are white and are numbered four and five. We draw a ball at random from the urn.

A. Assign probabilities to the elementary events. \_\_\_\_\_

B. Find the probability that the ball drawn had an odd number and was black. \_\_\_\_\_

C. Find the probability of the complement of the event in question B. \_\_\_\_\_

D. What are the odds in favor of drawing a white ball? \_\_\_\_\_

E. What is the conditional probability that the ball is black given that the number on the ball is odd? \_\_\_\_\_

3. If event A and event B are mutually exclusive, find  $P(A \cap B)$ . \_\_\_\_\_

4. We have two urns. Urn I contains three white and two black balls, and Urn II contains six black and three green balls.

A. If we choose two balls at random from Urn I without replacement, what is the probability that they are both black? \_\_\_\_\_

B. If we choose two balls at random from Urn II with replacement, what is the probability that they are of different colors? \_\_\_\_\_

C. If we choose a ball at random from the first urn and then independently choose a ball at random from the second urn, what is the probability that neither ball is black? \_\_\_\_\_

TEST-A, continued

- D. We are going to choose two balls from the urns in the following way: Choose the first ball at random from Urn I. If this ball is white, replace it and choose the second ball at random from Urn I also. If the first ball is black, however, put it into Urn II and choose the second ball at random from Urn II. What is the probability that both balls are of the same color? \_\_\_\_\_
5. A card is drawn at random from a standard deck. What is the probability that the card is a heart or a picture card? (Jack, Queen and King of each suit are the only picture cards.) \_\_\_\_\_
6. If A and B are independent, and  $P(A) = .8$ ,  $P(B) = .3$ , find the probability that A or B occurs. \_\_\_\_\_
7. A coin is tossed five times, or until a head appears, whichever comes first. The probability of a head on any toss is  $1/2$  and the tosses are independent.
- A. List the points of the sample space. \_\_\_\_\_
- \_\_\_\_\_
- B. Assign probabilities to the elementary events. \_\_\_\_\_
- \_\_\_\_\_
- C. What is the probability that the coin is tossed less than five times? \_\_\_\_\_
- D. What is the conditional probability that the coin is tossed five times given that the first three tosses all result in tails? \_\_\_\_\_
- \_\_\_\_\_
8. A sample space contains 25 sample points, and the event A in the sample space contains 10 points. Find the probability of the complement of A, assuming all the outcomes are equally likely. \_\_\_\_\_
- \_\_\_\_\_
9. A fair coin is tossed five times. Find the probability of getting at least one head. \_\_\_\_\_

TEST-B USED IN RESEARCH REPORTED IN CHAPTER 6

1. Match the notation on the left with the correct term on the right.

<u>      </u> $\mathcal{S}$	a. probability of an elementary event
<u>      </u> $P(B A)$	b. empty event
<u>      </u> $P(\{0\})$	c. sample space
<u>      </u> $P(A \cup B)$	d. independent events
	e. probability of the union of two events
	f. conditional probability of one event given another

2. There are ten balls in an urn. Three are white and are numbered from one to three, and seven are black and are numbered from four to ten. We draw a ball at random from the urn.

A. Assign probabilities to the elementary events. \_\_\_\_\_

\_\_\_\_\_

B. Find the probability that the ball drawn had an odd number and was black. \_\_\_\_\_

C. Find the probability of the complement of the event in B. \_\_\_\_\_

\_\_\_\_\_

D. What are the odds in favor of drawing a white ball? \_\_\_\_\_

\_\_\_\_\_

E. What is the conditional probability that the ball is black given that the number on the ball is odd? \_\_\_\_\_

\_\_\_\_\_

3. If event A and event B are independent and each has probability  $1/4$ , find the probability of their intersection. \_\_\_\_\_

4. We have two urns. Urn I contains three white and seven black balls, and Urn II contains two black and two green balls.

A. If we choose two balls at random from Urn I without replacement, what is the probability that they are both black? \_\_\_\_\_

B. If we choose two balls at random from Urn II with replacement, what is the probability that they are of different colors? \_\_\_\_\_

C. If we choose a ball at random from the first urn and then independently choose a ball at random from the second urn, what is the probability that neither ball is black? \_\_\_\_\_

TEST-B, continued

- D. We are going to choose two balls from the urns in the following way: Choose the first ball at random from Urn I. If this ball is white, replace it and choose the second ball at random from Urn I also. If the first ball is black, however, put it into Urn II and choose the second ball at random from Urn II. What is the probability that both balls are of the same color? \_\_\_\_\_
5. A card is drawn at random from a standard deck. What is the probability that the card is a spade or an ace? \_\_\_\_\_
6. If  $P(A) = .7$ ,  $P(B) = .2$ , and  $P(A|B) = .5$ , find  $P(A \cap B)$ . \_\_\_\_\_
7. Cards are drawn at random from a standard deck until a black card appears, or until four cards have been drawn, whichever comes first. Each card is replaced before the next card is drawn, and each drawing is independent of others.
- A. List the points of the sample space. \_\_\_\_\_
- B. Assign probabilities to the elementary events. \_\_\_\_\_
- C. What is the probability that less than three cards are drawn? \_\_\_\_\_
- D. What is the conditional probability that four cards are drawn given that the first card is red. \_\_\_\_\_
8. A sample space contains 50 sample points, and the event A in the sample space contains 5 points. Find the probability of the complement of A, assuming all outcomes are equally likely. \_\_\_\_\_
9. A fair die is rolled twice. Find the probability of getting at least one six. \_\_\_\_\_

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13. ABSTRACT Information mapping is a method of organizing categories of information and of displaying them for both learning and reference purposes. The method may be applied to the production of self-instructional books or to the organization of data bases for computer-aided instruction and reference. This report is itself written in modified information map form. The procedures and rules for information mapping were derived from educational research and technology as well as from the communications world. The emphasis is on formats to communicate quickly and to facilitate scanning and retrieval. The research and development work reported here deals with the book form of a twelve-hour course on sets and probability; significant achievement scores and favorable attitude results were found in several evaluative series with college students. Because information maps are composed of separable labelled information blocks, they can serve as the data base for computer systems where both learning and reference needs must be met. Preliminary work with simulated computer displays explored the flexibility with which a system so organized can respond with a range of user options and display variations. Cost for instruction hour is competitive with that of other methods, but the method has additional advantages in its versatility and ease of updating.		

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