SCHOEN, Harold Leo, 1941-
A COMPARISON OF FOUR TYPES OF FEEDBACK TO
STUDENT RESPONSES IN A CAI UNIT DESIGNED
to Teach the Concept of Function to Pre-
Calculus College Students.

The Ohio State University, Ph.D., 1971
Education, scientific

University Microfilms, A XEROX Company, Ann Arbor, Michigan

Copyright by
Harold Leo Schoen
1971
A COMPARISON OF FOUR TYPES OF FEEDBACK TO STUDENT RESPONSES IN A CAI UNIT DESIGNED TO TEACH THE CONCEPT OF FUNCTION TO PRE-CALCULUS COLLEGE STUDENTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Harold Leo Schoen, B.S., M.S., M.S.

The Ohio State University
1971

Approved by

Adviser
College of Education
ACKNOWLEDGMENTS

I would like to thank my reading committee, Dr. Richard Shumway, Dr. Robert Fisher, and Dr. F. Joe Crosswhite, for helping to make this paper possible. Dr. Crosswhite, as my major adviser, deserves particular thanks for his generous giving of time and advice throughout my degree program. Finally, my heartfelt appreciation goes to my wife, Theresa, and my daughters, Mary and Jenny, who suffered through this time as much as I. I sincerely hope we will all feel that the result justifies the sacrifice.
VITA

May 7, 1941 • • • Born - Fort Recovery, Ohio

1963. . . . . . . • • • B.S., University of Dayton, Dayton, Ohio

1963-1967 . . . . • Mathematics Teacher, Chartrand High School, Indianapolis, Indiana

1966. . . . . . . • • • M.S., Indiana University, Bloomington, Indiana

1967-1969 . . . . • Mathematics Instructor, University of Dayton, Dayton, Ohio

1969. . . . . . . • • • M.S., University of Dayton, Dayton, Ohio

1969-1970 . . . . • NDEA Fellow in Mathematics Education, The Ohio State University, Columbus, Ohio

1970-1971 . . . . • Teaching Associate, Department of Mathematics, The Ohio State University, Columbus, Ohio

FIELDS OF STUDY

Major Field: Mathematics Education

Studies in Educational Research. Professor James Gunnell

Studies in Teacher Education. Professor Herbert Coon

Studies in Mathematics. Professor Robert Fisher
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>VITA</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF DIAGRAMS</td>
<td>vii</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Problem Statement</td>
<td></td>
</tr>
<tr>
<td>Hypotheses</td>
<td></td>
</tr>
<tr>
<td>Research Design and Analysis</td>
<td></td>
</tr>
<tr>
<td>Definition of Terms</td>
<td></td>
</tr>
<tr>
<td>Assumptions and Limitations of the Study</td>
<td></td>
</tr>
<tr>
<td>Overview of Succeeding Chapters</td>
<td></td>
</tr>
<tr>
<td>II. REVIEW OF LITERATURE</td>
<td>13</td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>Learning of Concepts</td>
<td></td>
</tr>
<tr>
<td>Individualization and Personalization</td>
<td></td>
</tr>
<tr>
<td>Concept Learning Via CAI</td>
<td></td>
</tr>
<tr>
<td>Feedback (CAI)</td>
<td></td>
</tr>
<tr>
<td>The Hawthorne Effect</td>
<td></td>
</tr>
<tr>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>III. DEVELOPMENT AND PILOT TESTING OF INSTRUCTIONAL PROGRAM</td>
<td>20</td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>First Pilot Study</td>
<td></td>
</tr>
<tr>
<td>Second Pilot Study</td>
<td></td>
</tr>
<tr>
<td>Instrument Development</td>
<td></td>
</tr>
<tr>
<td>IV. RESEARCH METHOD AND DATA ANALYSIS</td>
<td>49</td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>Research Method</td>
<td></td>
</tr>
<tr>
<td>Data Analysis</td>
<td></td>
</tr>
</tbody>
</table>
V. SUMMARY AND CONCLUSIONS .......... 76

Summary
Conclusions
Implications
Suggested Future Research

APPENDIX

A. .................................................. 87
B. .................................................. 96
C. .................................................. 126
D. .................................................. 137

BIBLIOGRAPHY ..................................... 141
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. First Pilot Scores</td>
<td>23</td>
</tr>
<tr>
<td>2. Pilot High School Scores</td>
<td>27</td>
</tr>
<tr>
<td>3. Math 151 Scores: Second Pilot Study</td>
<td>28</td>
</tr>
<tr>
<td>4. Math 150 Scores: Second Pilot Study</td>
<td>29</td>
</tr>
<tr>
<td>5. Attitude Scale: First Pilot Study</td>
<td>30</td>
</tr>
<tr>
<td>6. Pearson R: Second Pilot Study</td>
<td>31</td>
</tr>
<tr>
<td>7. Means, Standard Deviations, and Cell Sizes for O&lt;sup&gt;F&lt;/sup&gt;</td>
<td>61</td>
</tr>
<tr>
<td>8. Cell Means and Standard Deviations, Plot of Cell Means, and ANOVA of O&lt;sub&gt;1&lt;/sub&gt;</td>
<td>62</td>
</tr>
<tr>
<td>9. Cell Means and Standard Deviations, Plot of Cell Means, and ANOVA of O&lt;sub&gt;2&lt;/sub&gt;</td>
<td>64</td>
</tr>
<tr>
<td>11. Correlation Matrix of All Variables</td>
<td>69</td>
</tr>
<tr>
<td>12. Student On-line Time in Minutes Cell Means and Standard Deviations</td>
<td>70</td>
</tr>
<tr>
<td>13. Plot of Cell Means and ANOVA of Unit B On-line Time</td>
<td>71</td>
</tr>
<tr>
<td>14. Cell Medians - Unit B Time</td>
<td>72</td>
</tr>
<tr>
<td>15. Student Use of Alternate Feedback</td>
<td>74</td>
</tr>
<tr>
<td>16. Scores of Additions to Sample</td>
<td>75</td>
</tr>
</tbody>
</table>
LIST OF DIAGRAMS

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Experimental Cells</td>
<td>5</td>
</tr>
<tr>
<td>2. Learning Hierarchy for CAI Unit</td>
<td>37</td>
</tr>
<tr>
<td>3. Statistical Design</td>
<td>60</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

PROBLEM STATEMENT

Need for Study

There seems to be little doubt that computer involvement in instruction, in one form or another, will make a substantial impact on education during the next decade. In what form, or forms, and to what extent this impact will occur is open to discussion—and to research. The computer is now being used in some schools and universities as a problem-solving teaching aid. Recent interest has also developed in computer assisted instruction (CAI) in which the student and computer program interact in varying degrees. Many proponents of CAI including Stolurow, Gerard, and Bundy, see it as a means of individualizing instruction superior to programmed learning in capability. The potential of CAI as a "learning laboratory" is also emphasized by Bundy. He bases this on the capability of the computer for storing and manipulating data (Hatfield, 1969).

Gentile (1967) cites three problem areas in CAI development: 1) the technical (hardware) problems; 2) the need for computer languages designed for CAI.
instruction; and 3) the need to determine the best kinds of programs to write. Concerning these, he says,

The technical problem is virtually solved, languages which allow courses to be programmed relatively easily are being developed, but what kinds of programs to write in order to use the equipment effectively is nevertheless an almost untouched problem.

The purpose of this study is to compare the achievement of groups of students receiving different types of feedback on a CAI unit on the concept of function. The researcher's keen interest in the development of individualized mathematics units and the need for determining the best role the computer can play in that development are the chief motivations for the study.

A further, more localized motivation is the need of the Ohio State University Mathematics Department for CAI material at this level for use in their new experimental program, called Curriculum Revision and Instruction in Mathematics on the Elementary Level (Fisher and others, 1969). In this program, initiated in Autumn, 1970, the student is responsible to a great extent for his own pace and quality of learning through the use of pamphlets, workbooks, short topical television lessons, and computer assisted instruction. The materials developed for this study will be available to
this project in the future.

The concept of function was chosen for four reasons:

1) The investigator has had seven years of experience in high school and university teaching and tutoring in which function was a key concept.

2) The concept of function has been considered to be the basic unifying concept for all mathematics since the early 1900's (Osborne and Crosswhite, 1970).

3) Concept learning lends itself well to CAI tutorial instruction (Kersh, 1967).

4) The concept of function is taught in the first or second week of the pre-calculus (Math 150) course at The Ohio State University.

In summary, proponents of CAI point to its capability for individualizing instruction. However, in what ways individualization can be achieved is an open question. The quality and quantity of student-program interaction appear to be major factors, and the feedback to student responses is a major part of that interaction. There appears, therefore, to be a need for research in this area.
Conceptual Framework

The major problem investigated is to determine which of four types of feedback to student responses on a CAI unit yields greatest student achievement. The topic of the unit is the mathematical concept of function. It was written and revised by the researcher during the Spring, Summer, and Autumn quarters of 1970. The program is written in I.B.M. Coursewriter III language and is on one of The Ohio State University's I.B.M. 360/50 computer systems.

Two levels of each of two variables are crossed yielding four types of feedback. Call the variables I (individualization) and P (personalization) and define the levels as follows.

I' - the student, following an incorrect response, receives feedback which states why his answer is incorrect and the correct answer.

I" - the student, following an incorrect response, receives feedback which states the correct answer and why it is correct, but does not refer to the student's answer specifically.

Feedback is the same for the two levels of I on correct responses.

P' - the student's first name appears in some of the feedback (the frequency with which
the name appears is discussed in Chapter III.

P" - the student's first name never appears in the feedback.

While I' and P' may seem to be more desirable treatment levels the time required to program them is greater than I" and P", respectively. By comparison of the four group mean scores on achievement and attitude scales, the researcher is taking a step toward determining whether the additional programming time and expense yield positive results.

The four types of feedback are I'P', I'P", I"P', and I"P" as shown in Diagram 1.

**DIAGRAM 1**

**EXPERIMENTAL CELLS**

\[
\begin{array}{cc}
P' & P" \\
I' & I'P' & I'P" \\
I" & I"P' & I"P" \\
\end{array}
\]

Let I₁ represent the combined group I'P' and I'P", I₂ the combined group I"P' and I"P", P₁ the combined
group $I'^P$ and $I"^P$, and $P_2$ the combined group $I'^P$ and $I"^P$. Then $I_1$ is compared to $I_2$ and $P_1$ to $P_2$ with respect to

1) the mean number of correct responses on $O_1$,
2) the mean number of correct responses on $O_2$, and
3) the mean score on $O_3$.

$O_1$ and $O_2$ above are achievement tests developed by the investigator to test subunits 1 and 2, respectively, of the CAI unit. $O_3$ is an attitude scale designed to determine the student's general attitude toward CAI and his specific attitude toward this unit.

**HYPOTHESES**

$H_1$: There is no significant difference in mean number of correct responses on $O_1$ between $I_1$ and $I_2$.

$H_2$: There is no significant difference in mean number of correct responses on $O_1$ between $P_1$ and $P_2$.

$H_3$: There is no significant difference in mean number of correct responses on $O_2$ between $I_1$ and $I_2$.

$H_4$: There is no significant difference in mean number of correct responses on $O_2$ between $P_1$ and $P_2$.

$H_5$: There is no significant difference in mean scores on $O_3$ between $I_1$ and $I_2$.

$H_6$: There is no significant difference in mean scores on $O_3$ between $P_1$ and $P_2$. 
RESEARCH DESIGN AND ANALYSIS

The subjects were sixty college students enrolled in Math 150, pre-calculus mathematics, at The Ohio State University. They were the members of two sections of about thirty students each. The treatment occurred during the first full week in which the classes met as a group. The sixty students were assigned randomly in equal numbers to each of the four treatment groups.

The experiment was performed over nine consecutive days.

Days 1-4: Subjects were scheduled for an introductory CAI unit which included sets, ordered pairs, and graphs, followed by a posttest, $O^P$, administered at the terminal immediately after completion of the unit.

Days 5-9: Subjects were scheduled for the experimental treatment. This includes subunit 1, the definition of function, followed immediately by $O_1$, and subunit 2, graphs of functions and $f(x)$ notation, followed by $O_2$, all at the terminal.

Three days after the above treatment, $O_3$, an attitude scale, was administered off the terminal to all subjects.
The design may be diagrammed as follows:

\[
\begin{align*}
R_1 & \quad X^P \quad O^P \quad X_1^1 \quad O_1 \quad X_2^1 \quad O_2 \quad O_3 \\
R_2 & \quad X^P \quad O^P \quad X_2^2 \quad O_1 \quad X_2^2 \quad O_2 \quad O_3 \\
R_3 & \quad X^P \quad O^P \quad X_3^3 \quad O_1 \quad X_2^3 \quad O_2 \quad O_3 \\
R_4 & \quad X^P \quad O^P \quad X_4^4 \quad O_1 \quad X_2^4 \quad O_2 \quad O_3
\end{align*}
\]

where \( R_1 - R_4 \) are the four experimental groups, \( X^P \) is the introductory unit, \( O^P \) is the posttest on \( X^P \), \( X_1^1 - X_4^4 \) are the four treatments on subunit 1, \( X_2^1 - X_2^4 \) are the four treatments on subunit 2, and \( O_1 - O_3 \) are the posttests described earlier.

A two-way analysis of variance using \( O_1 \), \( O_2 \), and \( O_3 \) scores, respectively, as criterion measures was employed to test the hypotheses. Further analysis includes pairwise correlations of other variables with the above and with each other—for example, total time on the experimental unit, total time on the introductory unit, and time on a short test designed to measure typing ability.

**DEFINITION OF TERMS**

The technical terms employed in this report are defined at this point.

1) CAI tutorial system: a CAI system in which the program significantly assumes the responsibility for teaching. Though this could be in several forms, it is usually synonymous with materials written in
one of the interactive languages such as Coursewriter III in this study.

2) I.B.M. Coursewriter III: a conversational language designed by I.B.M. specifically for CAI systems. Coursewriter III is not bound by or committed to any particular teaching method but lets the author implement his own instructional techniques within the confines of the physical units that make up the Coursewriter III system (I.B.M., 1969).

3) Feedback: the message given a student by a CAI program following a student response.

4) First coordinate: the left element, or coordinate, of an ordered pair of numbers (for example, in (a,b), a is the first coordinate).

5) Function: a set of ordered pairs in which no two pairs have the same first coordinate.

6) On-line time: the number of minutes each student spends at the terminal while it is connected with the CAI system.

7) Loop: a set of statements in the CAI program consisting of possible student responses and corresponding feedback to each. The student is returned to the loop entry point if his answer does not match a correct answer as found in a program statement.
ASSUMPTIONS AND LIMITATIONS OF THE STUDY

Assumptions relating to this study are:

1) The use of CAI materials for teaching the function concept to college freshmen mathematics students is practical and valuable.

2) The type of feedback is an important variable in the development of CAI programs.

3) The variables chosen for comparison of achievement and attitude are relevant and important measures of concept acquisition and attitude, respectively.

4) The testing instruments actually measure the chosen variables.

5) Random assignment ensured that the effects of significant variables such as intelligence and mathematical inclination lie evenly distributed across treatment groups.

6) The study of the design of CAI programming for concept learning will make a valuable contribution to the development and refinement of the computer as an instructional and research tool.

Some limitations of the study follow:

1) The concept of function and prerequisite concepts are the only ones that are considered.

2) The sample is limited to 60 students enrolled in Math 150 (pre-calculus) at The Ohio State University.
in the Winter Quarter, 1971.

3) Due to practical limitations, the sample population is limited to those Math 150 students enrolled at eleven A.M. daily. There is no reason to believe that there are any systematic differences between these students and the set of all students enrolled in Math 150 during Winter, 1971.

4) The mode of CAI instruction is exclusively via an I.B.M. 2741 computer terminal utilizing Coursewriter III.

5) The objectives of the CAI unit are only those identified in Appendix A.

6) The feedback is designed to vary only on the two described dimensions, individualization and personalization.

7) No attitude pretest was administered since it was felt that most of the subjects would have had no previous experience using CAI and hence no basis for their attitudes.

OVERVIEW OF SUCCEEDING CHAPTERS

Related literature is reviewed in Chapter II. To provide a theoretical base for this study, research in the learning of concepts particularly concept learning via CAI is cited. The role of feedback to student responses, the problem of the "newness of working on
a machine" effect in CAI studies, and the application of this research to the conceptualization of the problem in this study complete Chapter II.

Chapter III consists of a report of the two pilot studies which preceded this experiment. The purpose of these studies was primarily developmental—the data were used to refine the CAI unit, testing instruments, and problem conceptualization.

The research methodology and data analysis are reported in Chapter IV, followed by a summary, conclusions, and interpretations of the results in Chapter V.
II. REVIEW OF LITERATURE

INTRODUCTION

The literature reviewed for this study is essentially of four types:

1) general CAI position papers usually describing CAI and its many applications;
2) articles concerned with the development of instructional sequences like the one developed in this CAI program;
3) publications dealing with methods of presenting mathematical concepts, particularly the concept of function; and
4) articles which deal specifically with the theoretical and problem conceptualization employed in this experiment.

In this chapter, comment has been restricted to those articles which fall in the fourth classification. Articles from the first three categories are not reviewed but are included as uncited references in the bibliography.

The literature review includes:

1) Learning of Concepts
2) Concept Learning via CAI
3) Individualization and Personalization in Instructional Sequences
4) Feedback (CAI)
5) The Hawthorne Effect
6) Discussion

An attempt is made to cite literature only in areas which are germane to the experimental study. So, for example, in the first section, the learning theory cited is that of Gagne and others doing research often like Gagne's or at least influenced by his theory of learning. Obviously other theories of learning exist but those have not specifically influenced this research, hence are not cited. Analagous limitations are placed on the contents of the other sections. It is felt that these limitations are necessary to achieve the purpose of this chapter; that is, to lay a theoretical foundation for the experimental study.

LEARNING OF CONCEPTS

Gagne (1965) states that two conditions are necessary prior to concept learning:
1) capabilities previously established by multiple discrimination and
2) a set of chains must have been acquired to representative stimulus situations that exhibit the characteristics of the class defining the concept and that
The concept is learned when a set of novel stimuli in novel positions is responded to correctly, thus demonstrating that the result is impossible on the basis of simpler learning. Although other theories of concept learning exist, the influence of Gagne is very strong in the area of individualization of instruction—particularly via programmed learning and computer assisted instruction (Heimer, 1969).

To what extent can and should a learning sequence be individualized? A guided discovery program in which specific examples of a concept were followed by a statement of a general rule supplied by the student was found to be more effective than an approach in which a rule was supplied by the program followed by specific examples (Gagne and Brown, 1961). Merrill (1965) found that learning was greater if the learning sequence was not strictly hierarchical. It is clear that even if Gagne's theory of concept learning is correct, its implications for sequencing learning material is not obvious (Glaser and Reynolds, 1964).

Much work has been done at Stanford using CAI in which questions like the above are being asked. As yet results are inconclusive but as research and
computer methods are refined, much of value should come from Stanford (Suppes and Groen, 1967; Suppes, 1966; Suppes, 1967; Suppes, 1968; Suppes, Jerman, and Brian, 1968).

INDIVIDUALIZATION AND PERSONALIZATION IN INSTRUCTIONAL SEQUENCES

In a programmed learning study some subjects were given review following an incorrect answer while others were only given the correct answer. No evidence of significant differences in achievement scores was found. The program was designed to teach an imaginary science (Merrill and Stolow, 1966).

Levels of personal treatment of students on a CAI unit were compared in another study (Sutter, 1967). He compared pretest-posttest achievement gain scores of a group of students who took a CAI unit alone at the terminal with a group who took the unit in pairs. No significant group differences were found, but the evidence indicated that students with certain personality traits scored higher in one treatment group than in the other.

CONCEPT LEARNING VIA CAI

The computer is a useful tool to help students learn concepts (Kersh, 1967). The problem of how it can best be utilized for this purpose has not been
solved, however (Gentile, 1967). Achievement scores for a group of high school students taught logic by a branched CAI program were significantly higher than those of an equivalent group taught by a fixed sequence program (Coulson, 1962). Other research involving concept learning via CAI can be cited (Dick, 1970; Fiedler, 1969; Gallagher, 1970; Majer, 1970; O'Neill, 1969). However, the results do not clearly indicate the best way to utilize CAI in concept learning.

**FEEDBACK (CAI)**

The relative effect of verbal definitions and numerical examples as corrective feedback in a computer assisted learning task for ninth graders was investigated. Results indicated that when the learner is in an erroneous state, providing correctional messages in the form of verbal definitions increases his probability of being removed from that state more than the use of numerical examples (Keats and Hansen, 1970).

Three other studies dealing specifically with feedback in a CAI unit were located. No differences in learning or retention were found among groups receiving five different types of feedback on a CAI unit teaching science concepts to university upperclassmen (Gilman, 1967; Gilman, 1969). No differences were found in a study comparing two modes of CAI feedback with a conventional classroom approach (Proctor, 1969).
THE HAWTHORNE EFFECT

The "newness of working on a machine" effect must be considered to be a significant variable in any study involving CAI. Typically a design similar to that used by Grubb and Sefridge (1963) has been employed (Hickey, 1968). CAI performance was compared with instruction via programmed text and lecture. Their criteria were mean instruction time, mean review time, and mean achievement scores. In a study sponsored by I.B.M. using a similar design, it was found that in 5.3 hours of instruction a group of students scored an achievement mean of 94.3%, compared to 58.4% by a group taught by a lecture method after 24 hours of instruction (Dick, 1965). Dick indicates that the Hawthorne effect was probably tremendous.

Grayson summarizes this problem in the following statement.

while many studies have been conducted ... In many of them, the Hawthorne effect of novelty may be the overwhelming factor (Grayson, 1970).

DISCUSSION

The investigations reviewed point to several conclusions.

1) While theories on concept learning exist, there is no clear evidence concerning the best approach to teaching a concept.
2) CAI can be used to aid in concept learning. However, how it can best be used is not known.

3) Evidence concerning types of feedback in a CAI unit is scarce and inconclusive.

4) The control of the Hawthorne effect of "newness of working on a machine" is a problem in many studies.

The question of what type of feedback is desirable in a CAI program designed to teach a concept is not answered, either by pure learning theoretical research or by CAI research. This study is a step toward answering that question.

The Hawthorne effect of novelty will be at least partially accounted for by the design. In addition to the random assignment of students to treatments, each student will take an introductory CAI unit no more than five days before receiving the experimental treatment (see the design in Chapter I).
Much of the researcher's initial effort was extended toward becoming familiar with the capabilities of the Ohio State CAI system and the I.B.M. Coursewriter III language. Once the topic--the concept of function--was chosen, a list of behavioral objectives was formulated. These are consistent with the recommendations of several authors (Bohien, 1968; Gagne, 1964; Gagne and others, 1965; Krathwohl, 1964; Lindvall, 1964; Mager, 1962; Tyler, 1964; Ullmer, 1967). The objectives are found in Appendix A.

Writing of the instructional unit was begun in April, 1970. The material was designed to lead the students to achieve the behavioral objectives, using a branched program format. In the original program a student, when asked a question, could not proceed until he had typed the correct answer. If he answered incorrectly he was given a hint and asked to try again. Each incorrect answer was followed by a more direct hint until, if necessary, the command, "Type CA" where CA is the correct response was given to the student. This format was revised following the
first pilot study (see Chapter III—Follow-up of Conclusions - First Pilot Study).

A diagnostic test (originally three questions) preceded each subunit. If the student answered all three questions correctly he was given the option of skipping that subunit. This was later changed to three of the four questions, and in the final study was used only in the introductory unit.

A summary section for each subunit was also written in the original unit. These were conceived as a supplement to the subunit which a student, upon completing the entire unit (all subunits), could use to review the contents of a subunit(s) of his choice. These proved to be of little value for this study and were not included as an option in the final treatment.

This chapter includes a detailed report of two pilot studies which preceded the experiment. Included are the purpose, design, results, conclusions, and revisions based on the conclusions of each pilot study. A primary purpose for these studies was the development and refinement of the instructional and evaluation instruments. The problem conceptualization and research design also underwent changes due at least partially to the results of the pilot studies. For example, the problem originally considered was a simple development and testing of the CAI unit. That is, does it reach
its objectives? A review of the literature indicated that CAI research is beyond that point (see Chapter II). However, the question of "does it teach?" was answered affirmatively by the pilot studies. The comparison of the CAI unit with a conventional form of instruction was also considered. Physical limitations and experimental control problems were major factors in eliminating that approach. The results of the pilot studies were partially responsible for this decision. Finally the development and refinement of the evaluation instruments used in this study are reported in the last section of this chapter. In short, Chapter III is a chronicle of the conceiving and refining of ideas and instruments which preceded the final experiment reported in the other chapters.

FIRST PILOT STUDY

Purpose and Design

A pilot study to obtain feedback for revision and refinement of the CAI program and the evaluation instruments was conducted by the researcher during the Summer Quarter, 1970. Twenty students in a Math 150 class volunteered to take the instructional program. Data were obtained from eleven of the original 20 students (the remainder failed to take the units).
In addition, six graduate students and/or faculty members in mathematics education and mathematics at The Ohio State University took all or part of the CAI program. Both numerical and verbal feedback were analyzed and utilized in the subsequent revision.

Analysis and Results

Data collected from Math 150 subjects include on-line time for each part of the unit, total time, time for tests, answers on tests, scores on pretest and posttest, and incorrect responses on unit items. An analysis of the incorrect responses on unit items pointed out the locations of needed revision. Appendix C contains extensive data from this pilot. Table 1 summarizes some of the most interesting data.

**TABLE 1**

<table>
<thead>
<tr>
<th>Table 1: First Pilot Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pretest</strong></td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>S.D.</td>
</tr>
</tbody>
</table>

*All times are in minutes

The pretest and posttest are identical ten item tests (see Appendix B). Some data are missing due to system problems. Specifically, if a student was on-line
when the system failed, all data for that student on that day were lost. However, using only the four subjects whose pretest scores are available, the null hypothesis of no difference in means from pretest to posttest is rejected with p less than .10 (using a one tail t-test, t=1.494, d.f.=6).

Partially due to a very small standard deviation (.99) it was found that the test's reliability, using the Kuder Richardson Formula 20 with ten items and fourteen subjects, was .013.

Conclusions

Based on the feedback, both verbal and written, the following observations were made.
1) As expected, revision was needed from the programming point of view.
2) The general reaction was positive, though suggestions for improvement were many.
3) The Math 150 students may have been too mathematically sophisticated as indicated by a mean 7.0 correct of 10 questions on a pretest. However, there was evidence to suggest that the summer population in Math 150 was better than during the academic year.
4) More explanatory frames for incorrect responses should be provided.
5) The limited pretest-posttest data suggested that the program led to improved student achievement.

6) The reliability of the measurement instrument must be greatly improved.

7) Revision should be done before the next pilot study, but with revision the program would be adequate for use in the study.

**Follow-up of Conclusions - First Pilot Study**

**Description of Revision**

The revision made following the first pilot study was extensive. Most of it was of the programming variety; for example, the addition of feedback for frequently occurring incorrect responses to many items, the correction of mechanical programming errors such as incorrect branch statements, and the improvement of the wording of questions and feedback found to be unclear. The decision was also made to allow a student to leave a loop even though he may not have given a correct answer in one or two tries. The failure to allow this had caused some student frustration when seemingly correct answers were not being accepted by the program.

It was also decided that students would be allowed to skip a subunit in the introductory unit if three of
four diagnostic questions were answered correctly, rather than three of three. Diagnostic questions were deleted from the experimental segment to ensure that all students would receive treatment except for the experimental variables.

Administration of Test to High School Groups

Due to conclusion 3 above, it was decided that the same pretest should be administered to other types of students to isolate a best population. For this purpose the test was administered to three groups of high school mathematics students, seniors enrolled in Math IV, seniors enrolled in honors math, and sophomores enrolled in geometry at Worthington High School, Ohio.

To better analyze the results, the ten item test was divided into those items which tested the material in the introductory segment of the program (items #1–#3) and those which tested the material in the experimental segment (the remaining seven items). The results are found in Table 2.

While the honor seniors scored very well, the geometry students were at guess level on the seven experimental items. The low KR-20 for the sophomores was probably due to frequent random responses. The Math IV seniors, a population felt to be similar to Math 150 students, scored at slightly less than 50%
TABLE 2
PILOT HIGH SCHOOL SCORES

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean #3-10</th>
<th>Total Mean</th>
<th>S.D.</th>
<th>KR-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry</td>
<td>30</td>
<td>1.70</td>
<td>3.67</td>
<td>1.40</td>
<td>.066</td>
</tr>
<tr>
<td>Math IV</td>
<td>45</td>
<td>3.31</td>
<td>5.96</td>
<td>1.71</td>
<td>.433</td>
</tr>
<tr>
<td>Honors Math</td>
<td>23</td>
<td>5.50</td>
<td>8.39</td>
<td>1.44</td>
<td>.495</td>
</tr>
</tbody>
</table>

on the experimental items. Based on these results, it was decided that the high pretest scores in the summer were the result of an exceptional sample, and, hence the Math 150 population could be used in the experiment.

SECOND PILOT STUDY

Purpose and Conceptual Framework

Following the revision of the unit indicated by the first pilot study, five evaluation instruments were developed. These include:

1) a posttest for the introductory unit, unit A,
2) a pretest for the experimental unit, unit B,
3) a posttest for subunit 1 of unit B,
4) a posttest for subunit 2 of unit B, and
5) a posttest for subunit 3 of unit B.

In Autumn Quarter, 1970, unit B and instruments 2 through 5 were administered to seven Math 151 (first quarter
calculus) students to determine how mathematically advanced students would perform.

Finally a sample of twenty students from the target population, Math 150, were administered units A and B including the tests. An attitude scale was also completed by most of the subjects.

Analysis and Results

The results from the Math 151 sample which was administered unit B only are summarized in Table 3. The mean of nearly 60% correct on the pretest (Test 2) indicates that students in this population are too advanced for the instructional unit.

<table>
<thead>
<tr>
<th></th>
<th>Test 2 Mean</th>
<th>Test 3 Mean</th>
<th>Test 4 Mean</th>
<th>Test 5 Mean</th>
<th>Total Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>11.86</td>
<td>7.86</td>
<td>4.57</td>
<td>5.80</td>
<td>18.80</td>
</tr>
</tbody>
</table>

In the above table, test 2 contains 20 items, test 3 contains 10, test 4 contains 5 items, and test 5 contains 8.

Twenty Math 150 students volunteered to be administered the entire treatment—units A and the tests. However, not all of them completed the treatment,
due primarily to limited CAI availability—specifically, until January 3, 1971, the CAI system at Ohio State was available for use from eight A.M. to five P.M. five days a week. In addition, only eight ports were available during those times. Hence, with several (about ten) other courses on the system, lines were often tied up or unavailable. After January, but before the final study, the CAI availability was expanded to sixteen ports and ninety-four hours per week. Thus no similar problem occurred during the final experiment. The results are summarized in Table 4.

**TABLE 4**

**MATH 150 SCORES: SECOND PILOT STUDY**

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Mean</td>
<td>16.1</td>
<td>8.80</td>
<td>7.73</td>
<td>4.27</td>
<td>5.77</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.12</td>
<td>3.33</td>
<td>1.81</td>
<td>0.77</td>
<td>1.62</td>
</tr>
<tr>
<td>KR-20</td>
<td>.54</td>
<td>.67</td>
<td>.58</td>
<td>.01</td>
<td>.60</td>
</tr>
</tbody>
</table>

Comparing mean percentage correct on the twenty item test 2 with the mean percentage correct on tests 3, 4, and 5 combined (twenty-three items) for the thirteen subjects who completed all tests yields $t=8.643$ ($p$ less than .001 with d.f. = 12). This indicates a very definite
gain from pretest to posttest. Mean time required for completion of the units in the second pilot study were 72.4 minutes for unit A and 122.6 minutes for unit B. The unit B time is substantially more than the hour and one half that was hoped for.

A ten item attitude scale (see Appendix B) was developed and distributed to the twenty Math 150 students. The students were to complete the scale and return it to the researcher. Ten students returned the scales but since there was practically no way to contact all the students, the others were not returned. A summary of the results is in Table 5. The student responses are coded so that the higher the score the more positive the attitude, as follows:

1) for items #1, 2, 5, 6, 7, 8, 9 - a=+2, b=+1, c=0, d=-1, e=-2, and
2) for items #3, 4, 10 - a=-2, b=-1, c=0, d=+1, e=+2.

TABLE 5
ATTITUDE SCALE: FIRST PILOT STUDY

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Grand Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>4</td>
<td>-.5</td>
</tr>
<tr>
<td>5</td>
<td>.5</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>.7</td>
</tr>
<tr>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>9</td>
<td>.6</td>
</tr>
<tr>
<td>10</td>
<td>.2</td>
</tr>
<tr>
<td>Means</td>
<td>+.58</td>
</tr>
</tbody>
</table>
Pairwise correlations between scores on all instruments were calculated. Of particular interest was the test 1 correlation with the posttests, tests 3, 4, and 5 since test 1 was considered as a potential covariate for the final study. The correlation matrix is in Table 6.

**TABLE 6**

**PEARSON R: SECOND PILOT STUDY**

<table>
<thead>
<tr>
<th>Test</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>3,4, &amp; 5</th>
<th>Att.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>--</td>
<td>--</td>
<td>.54</td>
<td>.51</td>
<td>.24</td>
<td>.35</td>
<td>.54</td>
</tr>
<tr>
<td>2</td>
<td>.54</td>
<td>--</td>
<td>.64</td>
<td>.38</td>
<td>.63</td>
<td>.71</td>
<td>.82</td>
</tr>
<tr>
<td>3</td>
<td>.51</td>
<td>.64</td>
<td>--</td>
<td>.48</td>
<td>.60</td>
<td>.68</td>
<td>.64</td>
</tr>
<tr>
<td>4</td>
<td>.24</td>
<td>.38</td>
<td>.48</td>
<td>--</td>
<td>.45</td>
<td>.66</td>
<td>.44</td>
</tr>
<tr>
<td>5</td>
<td>.35</td>
<td>.63</td>
<td>.60</td>
<td>.45</td>
<td>--</td>
<td>.79</td>
<td>.61</td>
</tr>
<tr>
<td>3,4, &amp; 5</td>
<td>.54</td>
<td>.71</td>
<td>.68</td>
<td>.66</td>
<td>.79</td>
<td>--</td>
<td>.70</td>
</tr>
<tr>
<td>Att.</td>
<td>.82</td>
<td>.82</td>
<td>.64</td>
<td>.44</td>
<td>.61</td>
<td>.70</td>
<td>--</td>
</tr>
</tbody>
</table>

**Conclusions**

Conclusions based on the results were:

1) Both units A and B are free from programming errors.

2) Students did learn from the program as indicated by an improvement from 45% on the pretest to 74% on the sum of the posttests in unit B (p less than .001).
3) The Math 150 population was well suited for the experiment.

4) Several specific aspects of certain concepts needed to be better explained.

5) Posttests 4 and 5 should be combined for statistical comparisons since test 4 was too short to be highly reliable.

6) The mean time and the results of item 4 on the attitude scale (mean of -.5) indicated that the experimental unit was too long. Some students also indicated that by the end of the unit they were tired of all the tests.

7) The tests, with refinement, would be reasonably reliable.

8) Student reaction was generally positive and students also reacted favorably to the program's use of their first names.

9) There was a fairly high correlation between test 1 scores and the sum of the posttest scores (r=.54). Thus test 1 could be used as a covariate.

10) The correlations between the attitude scores and the test 1 scores (.82) and between the attitude scores and the sum of tests 3, 4, and 5 scores (.70) were very high. The reason for this high correlation should be sought if it re-occurs in the final study.
In summary, the results of the pilot studies indicated that the CAI units, target population, and evaluation instruments were compatible for the study.

**Follow-up of Conclusions - Second Pilot Study**

Minor programming improvements were made following the second pilot study, although no program execution errors occurred during the study. Wording of some feedback was changed if it had been unclear. The revision of this type, however, was minor especially when compared to that following the first pilot study.

Based on conclusion 3, it was decided that the Math 150 population would be used in the study. Conclusions 5 and 6 led to the combining of tests 4 and 5 and the deletion of test 2, the pretest for Unit B.

This left the four tests indicated in Chapter I:

- $O^P$ - a twenty item posttest of unit A, the introductory unit. This test is a refinement of test 1.
- $O_1$ - a fifteen item posttest of subunit 1 of unit B, the experimental unit. This test is a refinement and extension of test 3.
- $O_2$ - a fifteen item posttest of subunit 2 of unit B. This test is a combination and refinement of tests 4 and 5.
- $O_3$ - a thirty item attitude scale. This scale is an extension of the scale used in the second pilot.
For a more detailed description of the development of the testing instruments, see the next section.

Through the first and second pilot studies only one type of feedback was given all the students. This feedback often contained the student's name and was directed to his specific answer. In other words, it was like that to be used in the I'P' treatment described in Chapter I. Following the second pilot study the alternate forms of feedback were written and programmed. This development is described in more detail in the next section.

INSTRUMENT DEVELOPMENT

Behavioral Objectives

Many authors consider the development of a set of behavioral objectives a necessary pre-requisite to writing an instructional sequence, especially when written in a programmed format (see Chapter III - Introduction). It is also a policy of The Ohio State University CAI division not to issue author numbers until objectives, at least in rough form, are written. Hence, development of behavioral objectives prior to writing the instructional unit seemed highly desirable, if not absolutely necessary.

Guidelines for the development came from several sources.
1) Articles and/or books written by experts in the area of learning sequence development, particularly Mager, 1962: (For others, see Chapter III - Introduction.) Influence from these sources convinced the researcher of the need for behavioral objectives and also were an aid in showing how to write good behavioral objectives.

2) Restrictions of the population used: Since the Math 150 population was to be used in the study, it was felt that the objectives should be consistent with those of the Math 150 course as taught at The Ohio State University. The textbook used in the course was particularly helpful (Fisher and Ziebur, 1967). Analysis of the exercises on the concept of function in the text made the objectives of the authors clear. These objectives as interpreted by the researcher were then followed as closely as possible.

3) Advice of experts: Throughout the development of all the instruments used in this study, expert advice was utilized. Faculty members from the Ohio State Mathematics Department, CAI office, and Mathematics Education Department were consulted periodically. All those consulted approved the behavioral objectives as written in Appendix A.
4) Time limitations: At the advice of Dr. R. G. Christopher, Ohio State University CAI coordinator, it was decided to limit the instruction time to about one hour per unit (later the one hour became one and a half hours for the experimental unit). It was felt that one hour is near the maximum desirable time for a student on the I.B.M. 2741 terminal at one sitting. Another type of time limitation was that of the researcher's time spent in the development of the units. Since it is estimated that it takes from 200 to 300 hours of author time to produce one hour of CAI tutorial instruction, two hours of instruction was set as a limit. Thus, in writing the behavioral objectives, these limitations were kept in mind. The pilot studies were very helpful in checking this two hour time goal.

CAI Unit Development

The teaching unit was developed directly from the behavioral objectives. The concepts taught and their interrelationships are shown in Diagram 2.

The revised course flow is diagrammed in Appendix A. This underwent some minor revision following each of the pilot studies. A "specific example to general rule" approach is used in each subunit. That is, prior to stating a definition the program asks the
DIAGRAM 2
LEARNING HIERARCHY FOR CAI UNIT

Recognize a function described analytically

Use $f(x)$ notation

Recognize the graph of function

State the domain and range of a function

Distinguish between first and second coordinates

Graph sets of ordered pairs

Recognize and write sets of ordered pairs

Recognize and use set builder and list notation
student a series of questions designed to motivate the definition. For example, preceding the statement of the definition of function the following line of questioning is taken:

In section II, we looked at a set, \( B = \{(22,8),(12,21),(14,10),(33,20),(44,23)\} \), which was a set of ordered pairs in which the first coordinate represented the uniform number of a starting player on a basketball team and the second coordinate represented that player's points per game average.

The player whose number is 12 averaged ____ points per game.
(Pause for student response)
(Feedback to student response)

Now suppose \( C = \{(14,16),(20,9),(32,17),(42,9),(44,21)\} \) is the same pairings for another basketball team.

The uniform number of the player who averaged 9 points per game is ____.
(Pause for student response)
(Feedback to student response emphasizing that both 20 and 42 are correct)

Is it possible for two different players to have the same points per game average?
(Pause for student response)
(Feedback to student response emphasizing yes)

Suppose a third team's pairings are \( D = \{(14,22),(24,38),(22,6),(42,5),(14,7)\} \).

Player number 14's points per game average is ____.
(Pause for student response)
(Feedback to student response emphasizing the ambiguity)

Note the difference between sets C and D. In set C, 9 appears as a second coordinate twice with no problem, while in set D, 14 appears twice as a first coordinate and the result was to say that the same player had two different points per game averages for the same team.

D is a perfectly good set of ordered pairs, but because of the meaning of the pairs it makes no sense to have first coordinates repeated in different pairs.

(Pause for student to read the above and then press the return key)

Can you think of other uses of ordered pairs in which repeating a first coordinate is nonsense?

(Pause for student response)

(Feedback to student response - examples are provided if the student response is no)

A set of ordered pairs, with this restriction, is called a function.

More specifically, a function is ...

Similar lines of questioning with the purpose of motivating a definition were used throughout the two units.

Following each subunit the number of correct answers and the number of wrong answers the student gave in that subunit were given him. It was hoped, and at least informally verified in the pilot studies, that this would tend to motivate the student to compete with his previous record.
An attempt was made to minimize the amount of text material the student was asked to read between questions. It was felt that this would keep the student interest at a maximum, as watching a message being typed at length is quite boring. With few exceptions, no more than three or four lines of explanation separate requests for student input.

Branching was done based on student responses. However, except for skipping entire subunits as a result of high diagnostic test scores in unit A, the branching was confined to skipping one or more explanation or question frames. That is, entirely separate "tracks" were not written—only some extra explanation and questions were skipped by students whose performance warranted it. Branching decisions were based on the researcher's judgment at first. This was improved upon using pilot study data.

Similarly, feedback following a student response was refined twice—once after each pilot study. All feedback was written originally in the I' form, as defined in Chapter I. That is, an attempt was made to anticipate frequent incorrect responses to each question and, following an incorrect response, to explain why the student's response was incorrect and what the correct answer was. Following the second pilot study
the I" feedback was written. This feedback does not deal specifically with a student's incorrect response, but responds with a statement that the given answer is incorrect, what the correct response is, and why it is correct. The use, or lack of it, of the student's first name did not require any re-writing. A simple addition of a few statements to the program eliminated the name based on the student's I.D. number. Sections containing the tests were added and revised before each pilot study and before the final study.

Test Development

First Pilot Test

The primary purpose of the first pilot study was to de-bug the original program. Testing student achievement was a secondary purpose. Thus it was felt that a ten item test administered via the computer terminal both before and after the student took the entire treatment would suffice as an indicator of student learning from the CAI treatment. The most basic ideas taught in the unit were tested. The items were developed directly from the behavioral objectives. Three items were written for the introductory unit and seven items for the experimental unit, although nearly all of the last seven do require knowledge of concepts taught in the introductory unit.
The test is found in Appendix B and the behavioral objectives are in Appendix A. For an example of the method of test development, consider test item #1.

(4 → represent braces—set symbols—and \( W = \{0,1,2,\ldots\} \)).

Which of the following sets equals \( \emptyset \)?

a. \( \{0\} \)
b. \( \{w: w \text{ is in } W, w \text{ is less than } 0\} \)
c. \( \{(y,z): y=z\} \)
d. \( \{x: x \text{ is between } 4 \text{ and } 5\} \)

This item tests concepts in the introductory unit.

In particular, objective #4,

Given two simple sets of numbers denoted by either listing or set builder notation, to state correctly whether or not they are equal sets. In particular, to state that two sets with the same elements listed in different orders are equal.

and objective #5,

To state what elements are in the empty set and that the symbol, \( \emptyset \), is used to denote it.

In addition, to understand choice a, objectives #1 and #2 must be at least partially reached. To understand choice b, objectives #3 and #4 must be reached. To understand choice c, objectives #3, #4, and #6 must be reached. To understand choice d, objectives #3 and #4 must be reached.

The choices for each item contain

1) the correct answer—in this case b,

2) a "distractor" or choice which is obviously incorrect to anyone with minimal knowledge of the material—in this case, a, and
3) two "discriminators" or choices which require some degree of depth of understanding to reject—in this case, c and d.

As a second example, consider item #7.

A function defined by $4y + 2 = 8x$ is
a. $\{(x,y): y = 2x - 1\}$
b. $\{(y,x): 4y + 2 = 8x\}$
c. $\{(x,y): y = 2x\}$
d. $\{(x,y): x = 2y + 4\}$

This item tests objective #4 of the experimental unit,

Given a simple (as defined in 2) rule, algebraic or not, which relates two variables, to state correctly whether or not the associated set of ordered pairs is a function.

and assumes skills at or beyond the level of #1 of the experimental unit and #3, #4, #7, and #8 of the introductory unit. More basic abilities are also needed, such as basic manipulative algebra skills. It is assumed that a student at this level possesses them. In this item, b is the correct choice, c is the distractor, and a and d are the discriminators.

This test was used in the summer pilot study with a Math 150 sample, and it was also administered to the high school samples described in Chapter III, First Pilot Study. The test was analyzed in an attempt to determine which were good items to be used in the achievement tests. The analysis included 1) computation of the KR-20 reliability estimate for each sample,
2) a discrimination index on each item was computed by subtracting the number of correct responses in the lower 27% of students from the corresponding number in the upper 27% of students,

3) item difficulties were tabulated, and

4) the actual response, a, b, c, or d, to each question was recorded for each item and each student.

Items with zero or negative discrimination indices were either dropped or re-written. Items which were either too easy or too difficult were analyzed and improved. If only one of two choices on an item was chosen by the great majority of students, a more appealing statement was written for one of the rarely used choices. In general, many of the ten items were used in one of the tests developed for the second pilot study, but most of those were revised prior to their inclusion. For details of the test analysis see Appendix C.

Second Pilot Tests

Following the same approach described in the preceding section five achievement tests were developed for use in the second pilot study. These include

1) Test 1, a twenty item posttest for unit A;
2) Test 2, a twenty item pretest for unit B;
3) Test 3, a ten item posttest for unit B, subunit 1;
4) Test 4, a five item posttest for unit B, subunit 2; and
5) Test 5, an eight item posttest for unit B, subunit 3. These tests were designed to be long enough to reliably test the units but short enough to fit in the desired time limits.

The tests were programmed to immediately follow (or precede in the case of Test 2) the units or subunits tested. The programming format was the same for each test. For example, the student copy for Test 3 is

Please answer the following questions over the material you just completed. Please do your best without referring to that material.

1. Which one of the following is not a function?
   a. \( y = 7x \)
   b. \( \{(x,y) : y = 3x + 1\} \)
   c. \( \{(2,3),(1,1)\} \)
   d. \( \{(x,y) : y = x^2\} \)

(Pause for student response)

(Following student response)

\( ca \) - a

2. The domain of ...

Hence, while the student was given the correct answer immediately following his response, no explanations were included in the test sections. At the end of each test, the student was told the number of correct answers he had given.

Data from these tests were analyzed in detail, as in the preceding section. For results of this analysis see Appendix C. Items were again often re-written
or eliminated based on the analysis. The decision was also made to eliminate Test 2 and combine Tests 4 and 5 for the final study. Reasons for this are given in Chapter III, Second Pilot Study.

A ten item attitude scale was also developed by the researcher and administered to subjects following the CAI treatment in the second pilot study (see Appendix B). The scale was designed to determine the student's attitude toward certain very specific aspects of the CAI treatment—not to test his attitude toward CAI, in general. For example, did he learn anything, was the course too long, was the feedback clear, were the tests good, and did he enjoy seeing his name being used. The results were used to determine needed improvement. However, due to surprisingly high correlations between the attitude scores and the pretest and posttest scores, it was decided that these items, with minor changes, would be used in the final study. The Pearson r correlations of .70 and .82 are phenomenally high when compared with correlations of at most .13 reported between achievement scores and various attitude measures in the International Association for the Evaluation of Educational Achievement Mathematics Study (Postlethwaite, 1971).
Instruments Used in the Final Study

For reasons previously stated, the decision was made to use three achievement tests. They are $O^p$, a twenty item posttest of unit A; $O_1$, a fifteen item posttest of unit B, subunit 1; and $O_2$, a fifteen item posttest of unit B, subunit 2 (including graphs of functions and $f(x)$ notation). $O^p$ is a refinement of Test 1 of the second pilot study. In fact, many items are the same and still others have been re-written slightly. $O_1$ and $O_2$ were, for the most part, constructed by choosing the "best" items from Tests 2, 3, 4, and 5 of the second pilot study. Which items were "best" was judged by the second pilot test analysis and the desire to test all the objectives for that subunit. The number of items, twenty, fifteen, and fifteen, respectively, were chosen in an attempt to reach the goals of high reliability and a one hour unit A and one and a half hour unit B time limit. Since KR-20 reliabilities ranging from .54 to .67 had been achieved on the first try with N's of 13 to 20 on often shorter tests, it was felt that fifteen items each on $O_1$ and $O_2$ should yield acceptable reliabilities. The question of test validity is answered by the "fitting" of the test items to the objectives of the unit.

For the attitude scale used in the final study,
the researcher is indebted to two people—Dr. R. G. Christopher, Ohio State University CAI coordinator, for suggesting the availability of a test of general attitude toward CAI developed in part by him and refined and used by Carlton P. Robardey, University of Michigan, whose permission was graciously granted for its use in this study. Mr. Robardey's scale contains twenty items. Using ninety subjects (prospective teachers and administrators) and Hoyt's reliability formula, he estimated the reliability of the instrument at .94. The scale used in this study (see Appendix B) consists of Mr. Robardey's scale with a slight variation of the ten item scale used in the second pilot.

In summary, while the use of experimenter developed testing instruments may be considered less desirable than using standardized tests, pilot data seem to give every indication that the tests used in the final study are reliable and valid measurement instruments.
IV. RESEARCH METHOD AND DATA ANALYSIS

INTRODUCTION

This chapter contains a detailed description of the research methodology and a complete analysis of the data. Included in the section on research method is the operational statement of the problem, a description of the experimental treatment, a statement of the hypotheses, a detailed description of the sampling procedure, the time table for the experiment, and the experimental and statistical design employed in the study.

Analysis of the data includes the results of the hypotheses tests. A two-way analysis of variance (no covariates) is employed. An analysis of correlations between pairs of variables is also included in the data analysis section.

RESEARCH METHOD

Operational Statement of the Problem

A CAI tutorial program consisting of unit A—Introduction to the Concept of Function—and unit B—The Concept of Function—was developed by the researcher prior to this study. The program consists of:
Unit A

1. Set Language
2. Sets of Ordered Pairs
3. Graphs of Ordered Pairs

Unit B

1. The Definition of Function
2. Graphs of Functions and f(x) Notation

The program is written in I.B.M. Coursewriter III language and is on one of The Ohio State University's I.B.M. 360/50 computer systems. For details of the development and content of the CAI program, see Chapter III. Herein unit A is referred to as the introductory unit and unit B as the experimental unit.

The major problem investigated in this study was to determine which of four types of feedback to incorrect student responses in unit B of the CAI program yields highest achievement and attitude scores. The target population was the set of Math 150 (pre-calculus mathematics) students enrolled at Ohio State during Winter Quarter, 1971. The four types of feedback were the result of crossing two levels of each of two variables—a 2x2 factorial design. The variables considered were I (individualization) and P (personalization). The levels were defined as follows.

I' - the student, following an incorrect response,
receives feedback which states why his answer is incorrect and the correct response.

I" - the student, following an incorrect response, receives feedback which states that the given answer is incorrect, what the correct answer is, and why it is correct, but the feedback does not refer specifically to the student's response.

Feedback to correct student responses was the same for the two levels of I. The lengths of the feedback statements for the two levels were as nearly equal as possible.

P' - the student's first name appears in some of the feedback to both correct and incorrect student responses. The frequency of use of the first name was decided by what seemed reasonable to the researcher. The only pattern followed for use of the first name was that if the name was used in feedback to one response to a given question it appeared in feedback to any response to that question. Hence, the student's error rate did not effect the frequency with which his first name appeared. To be exact, the name appears in feedback to 41 of the 56 questions in unit B.

P" - the student's first name never appears in the feedback.
The four types of feedback then were I'P', I"P", I"P', and I"P" which result from crossing the two levels of I with the two levels of P (see Diagram 1). As an example of the type of feedback for each group, suppose this question is asked the subject.

The set \( F=\{(2,7),(3,9),(2,7)\} \) is a function, even though 2 appears twice as a first coordinate. The reason for this is:

a. \((2,7)\) is in \( F \) so listing it twice does not really put two different pairs in \( F \).
b. the number 2 may be repeated as a first coordinate in a function.
c. \( F \) only contains three ordered pairs.
d. \(2+7=9\) so 2 may be repeated, since 9 is in a pair.

Then suppose a subject's response is b. If he is in I'P', feedback to him may be:

No number, including 2, may be repeated as a first coordinate in a function.
The correct answer is a, John.

If he is in I"P", the feedback is the same except "John" is eliminated. If he is in I"P', the feedback may be:

No, John, a is correct since the repetition of elements of a set does not change the set's contents.

If he is in I"P", the feedback is the same except "John" is eliminated. Further examples of feedback for each group are in Appendix A.

The main comparisons are made in the following ways. Let \( I_1 \) represent the combined group I'P' and
I'P", I_2 the combined group I"P' and I"P", P_1 the combined group I'P' and I"P', and P_2 the combined group I'P" and I"P". Let O_1 represent the achievement posttest for unit B, subunit 1; O_2 represent the achievement posttest for unit B, subunit 2; and O_3 represent the attitude scale. The construction of these testing instruments is described in Chapter III. Then I_1 is compared to I_2 and P_1 to P_2 with respect to 1) the mean number of correct responses on O_1, 2) the mean number of correct responses on O_2, and 3) the mean score on O_3.

Hypotheses

H_1: There is no significant difference in mean number of correct responses on O_1 between I_1 and I_2.

H_2: There is no significant difference in mean number of correct responses on O_1 between P_1 and P_2.

H_3: There is no significant difference in mean number of correct responses on O_2 between I_1 and I_2.

H_4: There is no significant difference in mean number of correct responses on O_2 between P_1 and P_2.

H_5: There is no significant difference in mean scores on O_3 between I_1 and I_2.

H_6: There is no significant difference in mean scores on O_3 between P_1 and P_2.
Schedule and Procedure

In Winter Quarter, 1971, the Math 150 course was taught by a television lecturer, Dr. Sandra Scheick, to recitation sections of approximately thirty students each. Each recitation section was led by an instructor, usually a graduate student in mathematics or mathematics education. The sections met daily with the first twenty minutes allotted to the recitation instructor, followed by a television lecture for the remaining twenty-eight minutes. There were a total of nineteen sections (about 570 students) meeting at one of three times, 11:00 A.M., 12:30 P.M., or 5:00 P.M.

Prior to the Winter Quarter, arrangements were made through Dr. Bert K. Waits of The Ohio State University Mathematics Department for authorization of the use of two of the Math 150 sections for this study. To facilitate direction of the study and to be compatible with the researcher's own schedule, it was decided that two sections meeting at 11:00 A.M. in adjacent rooms would comprise the sample. Dr. Waits then identified two recitation instructors whom he felt would be cooperative. These two, Mr. Charles Chittendon and Mr. Kirk Postier, were contacted by the researcher and proved to be as cooperative as predicted. Dr. Scheick, as course supervisor, also was kind enough to consent to the use of the sections for the experiment.
There is no reason to believe that prior to the Winter Quarter, the two sections chosen in this manner differed in any significant way from the entire Math 150 population for that quarter. This assertion is made since students are placed into sections randomly. No known scheduling conflicts existed which might cause systematic error.

The concept of function was scheduled to be taught beginning in the third week of the quarter. The experiment was planned so that it would terminate just prior to the introduction of the function concept in class. To reach this goal, the following schedule was developed.

Tuesday, January 5: first day of classes - the instructors announced that the CAI units would be part of the course.

Thursday, January 7: collected class lists from the two instructors and randomly placed students in equal numbers into the four treatment groups; had the instructors distribute a sheet explaining that there is a CAI unit available covering topics in this course and that each of them would be scheduled to take the unit in the next few days.

Friday, January 8: the researcher met with the two sections and explained what would be expected of the students; the students were asked to pick two time slots, one for unit A and one for unit B, in the next nine days; they were instructed to report to (I.B.M. 2741) computer
terminal at the times they chose; instruction sheets explaining the use and locations of the terminals were handed out; it was explained that the content of the CAI units was compatible with that in class.

Saturday, January 9 - Tuesday, January 12: unit A
Wednesday, January 13 - Sunday, January 17: unit B
Thursday, January 21: O3 completed by subjects in class

The procedure used for randomizing the treatment groups was as follows.

1) To construct a list of student computer identification numbers consisting of fifteen numbers between 2000 and 3000, fifteen between 3000 and 4000, fifteen between 4000 and 5000, and fifteen between 5000 and 6000.

2) To identify the 2000 to 3000 as the I'P' group, the 3000 to 4000 as the I'P" group, the 4000 to 5000 as the I"P' group, and the 5000 to 6000 as the I"P" group.

3) To randomly order these sixty numbers using a table of random numbers.

4) Using the class lists from the two Math 150 sections on which the students are listed alphabetically, to pair each student with the corresponding number from the list of randomly ordered CAI identification numbers.
The original class lists contained a total of sixty-two names. After the sixty numbers had been assigned, the remaining students were assigned randomly to one of the four groups (not both to the same group).

However, five students had already dropped the course or switched sections within the first few days of the quarter, and two students from foreign countries were dropped from the sample due to serious language problems. In addition, five students transferred into one of the sections just before, or during, the experiment. These new students were assigned to the cell which at that time contained the least number of subjects. In case two or more cells contained the minimum number, the assignment was made by flipping a coin.

The students were generally reliable in appearing for the CAI units at their scheduled times. This reliability was greatly improved by the researcher's presence each day before the 11:00 A.M. classes to re-schedule those who had missed the previous day. Nevertheless, not all the students did manage to complete the units within the nine day scheduled time. Actually, forty-five had finished—on schedule—by Sunday, January 17. By Thursday, January 21, fifty-seven had finished. Consequently, the attitude scale was not administered until Monday, January 25. By that time one student,
who had been absent for ten consecutive days, had still not completed the CAI unit. However, he returned to class, completed the CAI unit on Wednesday, January 27, and completed the attitude scale the next day. Thus sixty subjects, fifteen per group, completed the CAI units. However, between its completion and the administration of the attitude scale two of these students had dropped the course. So fifty-eight of the sixty subjects completed the attitude scale.

A certain amount of fluctuation, as described above, in the enrollment of a section is to be expected. The effect of students dropping and adding should be randomly distributed over the groups. The drops and adds by group are as follows.

I'P': dropped - 3, added - 2 (dropped one on O3)
I'P'': dropped - 2, added - 2
I"P': dropped - 1 (dropped one on O3)
I"P'': dropped - 1, added - 1

The concentration of drops and adds in groups I'P' and I'P'' is discussed in the analysis of data section.

Design

To summarize the preceding information concerning the problem conceptualization and sampling procedures, the experimental design may be diagrammed as follows.
Here $R_1 - R_4$ are the four treatment groups, $X^P$ is the introductory unit, $O^P$ is the posttest on $X^P$, $X_1^1 - X_1^4$ are the four treatments on subunit 1, $X_2^1 - X_2^4$ are the four treatments on subunit 2, and $O_1^1 - O_3^1$ are the posttests described earlier.

Diagram 3 shows the 2x2 factorial design employed in testing hypotheses 1 through 4. Let $m$ represent the grand mean, $a_1$ represent the $I'$ effect, $a_2$ represent the $I''$ effect, $b_1$ represent the $P'$ effect, $b_2$ represent the $P''$ effect, and $d_{ij}$ represent the $ij^{th}$ cell effect, where $i=1,2$ and $j=1,2$. Then if the expected value of $X_{rij}$ is $EX_{rij}$, the model used is

a) $EX_{rij} = m + a_1 + b_j + d_{ij},$

where it assumed that

b) $S_{i=1}^2(a_i) = S_{j=1}^2(b_j) = S_{i=1}^2(d_{ij}) = S_{j=1}^2(d_{ij}) = 0.$

(S represents summation).

Using b) it follows that $a_2 = -a_1$, $b_2 = -b_1$, $d_{11} = -d_{12}$, $d_{21} = -d_{22}$, and $d_{12} = -d_{22}$. Substituting into a) yields the following equations.

$EX_{r11} = m + a_1 + b_1 + d_{22}$, $r=1,\ldots,15$

$EX_{r12} = m + a_1 - b_1 - d_{22}$, $r=1,\ldots,15$
In testing hypotheses 5 and 6, in which the dependent variable is $O_3$, two scores are missing. The statistical model employed is the same as above, except that in the first and third cells $r=1,\ldots,14$ (Health Sciences Computing Facility, 1970).

**DATA ANALYSIS**

**Test of Hypotheses**

The Ohio State University computation center and the BMD05V program for testing general linear hypotheses were utilized in testing the hypotheses in this study. The possibility of using the $O^p$ scores
as a covariate was considered. However, since the 
$O^P$ means for the four cells were almost identical, 
the hypotheses were tested without a covariate. See 
Table 7 for the $O^P$ results. The results of testing 
the hypotheses follow.

TABLE 7
MEANS, STANDARD DEVIATIONS 
AND CELL SIZES FOR $O^P$

<table>
<thead>
<tr>
<th>Cell</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'P'</td>
<td>15</td>
<td>15.33</td>
<td>2.16</td>
</tr>
<tr>
<td>I'P''</td>
<td>15</td>
<td>15.13</td>
<td>2.42</td>
</tr>
<tr>
<td>I''P'</td>
<td>15</td>
<td>15.33</td>
<td>2.97</td>
</tr>
<tr>
<td>I''P''</td>
<td>15</td>
<td>15.13</td>
<td>2.85</td>
</tr>
</tbody>
</table>

Hypotheses 1 and 2

$H_1$: There is no significant difference in mean number 
of correct responses on $O_1$ between $I_1$ and $I_2$.

$H_2$: There is no significant difference in mean number 
of correct responses on $O_1$ between $P_1$ and $P_2$.

The results of the two-way analysis of variance 
using $O_1$ scores as the dependent variable follow. $O_1$ 
is a fifteen item posttest and with $N=60$, its estimated 
reliability is KR-20=.54.

Since the interaction, IxP, is not significant,
TABLE 8
CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS, AND ANOVA OF $O_1$

**Cell Statistics**

<table>
<thead>
<tr>
<th></th>
<th>$P'$</th>
<th>$P''$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I'$</td>
<td>$\bar{X}=9.87$</td>
<td>$\bar{X}=8.60$</td>
</tr>
<tr>
<td></td>
<td>S.D.=2.36</td>
<td>S.D.=2.59</td>
</tr>
<tr>
<td></td>
<td>N=15</td>
<td>N=15</td>
</tr>
<tr>
<td>$I''$</td>
<td>$\bar{X}=9.53$</td>
<td>$\bar{X}=8.80$</td>
</tr>
<tr>
<td></td>
<td>S.D.=2.03</td>
<td>S.D.=2.60</td>
</tr>
<tr>
<td></td>
<td>N=15</td>
<td>N=15</td>
</tr>
</tbody>
</table>

**Plot of Cell Means**

![Plot of Cell Means]

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sum of Sqs.</th>
<th>D.F.</th>
<th>F</th>
<th>Prob. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>323.54</td>
<td>1.56</td>
<td>0.011</td>
<td>.91</td>
</tr>
<tr>
<td>P</td>
<td>338.47</td>
<td>1.56</td>
<td>2.596</td>
<td>.11</td>
</tr>
<tr>
<td>IxP</td>
<td>324.54</td>
<td>1.56</td>
<td>0.184</td>
<td>.67</td>
</tr>
<tr>
<td>Total</td>
<td>5094.52</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
main effect I was employed to test \( H_1 \) and main effect \( P \) to test \( H_2 \). The results show that at the .05 level \( H_1 \) cannot be rejected, and \( H_2 \) cannot be rejected.

The I effect is clearly non-significant, but the P effect is significant with \( p \) less than .11. With the small \( N \) in each cell, this may be an indication of some differences in the levels of \( P \)—namely, that the \( P' \) group, those receiving feedback with student names included, tended to perform better than the \( P'' \) group on \( O_{1} \).

Hypotheses 3 and 4

\( H_3 \): There is no significant difference in mean number of correct responses on \( O_2 \) between \( I_1 \) and \( I_2 \).

\( H_4 \): There is no significant difference in mean number of correct responses on \( O_2 \) between \( P_1 \) and \( P_2 \).

The results of the analysis of variance using \( O_2 \) scores as the dependent variable follow. \( O_2 \) is a fifteen item posttest of unit B, subunit 2, and with \( N=60 \) its estimated reliability is KR-20=.70.

Table 9 shows that again the interaction, \( I \times P \), is not significant, so main effect I was used to test \( H_3 \) and main effect \( P \) to test \( H_4 \). The results show that at the .05 level
TABLE 9
CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS, AND ANOVA OF O₂

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th>P'</th>
<th>P''</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'</td>
<td>(\bar{X} = 9.20)</td>
<td>S.D. = 2.68</td>
</tr>
<tr>
<td></td>
<td>(\bar{X} = 7.73)</td>
<td>S.D. = 3.08</td>
</tr>
<tr>
<td>I''</td>
<td>(\bar{X} = 9.93)</td>
<td>S.D. = 2.76</td>
</tr>
<tr>
<td></td>
<td>(\bar{X} = 10.13)</td>
<td>S.D. = 2.90</td>
</tr>
</tbody>
</table>

Plot of Cell Means

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sums of Sqs.</th>
<th>D.F.</th>
<th>F</th>
<th>Prob. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>494.82</td>
<td>1,56</td>
<td>4.501</td>
<td>.04</td>
</tr>
<tr>
<td>P</td>
<td>464.02</td>
<td>1,56</td>
<td>0.736</td>
<td>.39</td>
</tr>
<tr>
<td>IxP</td>
<td>468.42</td>
<td>1,56</td>
<td>1.273</td>
<td>.26</td>
</tr>
<tr>
<td>Total</td>
<td>5645.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
H₃ can be rejected, but
H₄ cannot be rejected.

Students receiving the I", non-individualized treatment scored significantly higher on O₂ than those receiving the I' treatment. This is in contrast to nearly equal means on the O₁ scores for the two groups. Analyzing the P effect shows that the P' group, those receiving their names in feedback, scored higher than the P" group, though not significantly higher. The I'P" cell mean (7.73) is lowest among the cell means, while the I"P" and I"P' are nearly equal. It appears that on the achievement tests the I effect is over-shadowing the P effect. That is, the difference in scores attributed to I" over I' is greater than that attributed to P' over P".

Hypotheses 5 and 6
H₅: There is no significant difference in mean scores on O₃ between I₁ and I₂.
H₆: There is no significant difference in mean scores on O₃ between P₁ and P₂.

O₃ is a thirty item attitude scale, the first twenty of which concern general attitude toward CAI while the last ten deal with students' attitudes toward this specific program. The possibility of analyzing scores on the two parts individually was considered.
However, since the scores on the two parts correlated highly \( r=0.80 \) it was decided to analyze the total score on the thirty items. Student responses were coded from 0 to 4 with a higher score indicating a more positive attitude. The following results are based on student scores computed by taking the sum of the coded student response for each of the thirty items. Using correct to mean a 3 or 4 on an item and wrong to mean a 0, 1, or 2, the reliability of this instrument was estimated by KR-20=0.84 where \( N=58 \). Table 10 shows the results of the ANOVA using \( O_3 \) scores as the dependent variable.

The interaction, \( IxP \), is non-significant so the main effect \( I \) was used to test \( H_5 \) and the main effect \( P \) to test \( H_6 \). The results show that at the .05 level

\[ H_5 \text{ cannot be rejected, and} \]
\[ H_6 \text{ cannot be rejected.} \]

However, the attitude scores of students receiving the \( P' \) treatment are higher than those receiving the \( P'' \) treatment at the .07 probability level.

Correlation of Pertinent Variables

Data were collected on each student's performance on a number of variables in addition to \( O_1, O_2, \) and \( O_3 \) scores. They are listed below.
TABLE 10

CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS, AND ANOVA OF O3

| Cell Statistics |  |  
|-----------------|---|---
| **P'**          | **P''**      |
| **I'**          | **I''**      |
| \( \overline{X} = 79.50 \) | \( \overline{X} = 75.73 \)  
| S.D. = 14.86    | S.D. = 13.31 |
| N = 14          | N = 15       |
| \( \overline{X} = 84.43 \) | \( \overline{X} = 75.20 \)  
| S.D. = 6.99     | S.D. = 16.34 |
| N = 14          | N = 15       |

**Plot of Cell Means**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sums of Sqs.</th>
<th>D.F.</th>
<th>F</th>
<th>Prob. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>9794.38</td>
<td>1,54</td>
<td>0.389</td>
<td>.55</td>
</tr>
<tr>
<td>P</td>
<td>10335.81</td>
<td>1,54</td>
<td>3.395</td>
<td>.07</td>
</tr>
<tr>
<td>IxP</td>
<td>9832.50</td>
<td>1,54</td>
<td>0.600</td>
<td>.45</td>
</tr>
<tr>
<td>Total</td>
<td>368861.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1) $O^P$, the twenty item posttest of unit A,
2) the total time in minutes required for each student to complete unit A,
3) the time in minutes required for each student to complete a test designed to test the student's typing ability (see Appendix A), and
4) the total time in minutes required for each student to complete unit B.

Variables 2 and 3, the unit A time and typing test time, were considered as possible covariates but low correlations with achievement and attitude scores caused this idea to be rejected. Table 11 shows the Pearson correlation coefficients.

Several things may be pointed out from analyzing Table 11. First, the high correlation between attitude scores and achievement scores in the second pilot study does not appear again. The typing ability as measured in this study does not correlate highly with achievement or with attitude. Correlations between time on unit A and $O_1$ scores ($-.20$) and time on unit A and $O_2$ scores ($-.25$) also are worth consideration. The possibility of skipping one or more of the subunits of unit A based on diagnostic scores probably accounts for these correlations. The students who already knew the material in unit A went through it more rapidly. Since unit A
TABLE 11
CORRELATION MATRIX OF ALL VARIABLES

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Typing Test</td>
<td>Unit A Time</td>
<td>Unit B Time</td>
<td>0 1</td>
<td>0 2</td>
<td>0 3</td>
</tr>
<tr>
<td>1</td>
<td>---</td>
<td>.07</td>
<td>-.08</td>
<td>.02</td>
<td>.45**</td>
<td>.26*</td>
<td>-.07</td>
</tr>
<tr>
<td>2</td>
<td>.07</td>
<td>---</td>
<td>-.05</td>
<td>.14</td>
<td>.07</td>
<td>.07</td>
<td>.06</td>
</tr>
<tr>
<td>3</td>
<td>-.08</td>
<td>-.05</td>
<td>---</td>
<td>.18</td>
<td>-.20</td>
<td>-.25*</td>
<td>.05</td>
</tr>
<tr>
<td>4</td>
<td>.02</td>
<td>.14</td>
<td>.18</td>
<td>---</td>
<td>.24*</td>
<td>-.03</td>
<td>.23*</td>
</tr>
<tr>
<td>5</td>
<td>.45**</td>
<td>.07</td>
<td>-.20</td>
<td>.24*</td>
<td>---</td>
<td>.37**</td>
<td>.08</td>
</tr>
<tr>
<td>6</td>
<td>.26*</td>
<td>.07</td>
<td>-.25*</td>
<td>-.03</td>
<td>.37**</td>
<td>---</td>
<td>.16</td>
</tr>
<tr>
<td>7</td>
<td>-.07</td>
<td>.06</td>
<td>.05</td>
<td>.23*</td>
<td>.08</td>
<td>.16</td>
<td>---</td>
</tr>
</tbody>
</table>

* significant at the .05 level
** significant at the .01 level

contained pre-requisite material for unit B these same students were better prepared for unit B. The only variable that correlated highly with $O_3$, the attitude score, was unit B time. Perhaps students who enjoyed the CAI treatment were content to take their time in completing it, while those who did not enjoy it tended to hurry through. The correlation of .24 between unit B time and $O_1$ scores might tend to support this conjecture. The correlation between $O_1$ and $O_2$ scores (.37), while significant at the .01 level, is low enough to indicate that different dimensions
are being tested. Thus the scores on these instruments
should be analyzed separately—as they were.

Miscellaneous Analysis

Student Time for CAI Units

The goal of one hour for unit A and one and a
half hours for unit B was set. Table 12 shows that
this goal was nearly met in both cases.

<table>
<thead>
<tr>
<th>TABLE 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUDENT ON-LINE TIME IN MINUTES</td>
</tr>
<tr>
<td>CELL MEANS AND STANDARD DEVIATIONS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Unit A Mean</th>
<th>Unit A S.D.</th>
<th>Unit B Mean</th>
<th>Unit B S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'P</td>
<td>77.62</td>
<td>17.21</td>
<td>101.53</td>
<td>22.11</td>
</tr>
<tr>
<td>I'P&quot;</td>
<td>70.67</td>
<td>14.76</td>
<td>94.20</td>
<td>10.86</td>
</tr>
<tr>
<td>I&quot;P</td>
<td>71.60</td>
<td>14.76</td>
<td>90.33</td>
<td>13.46</td>
</tr>
<tr>
<td>I&quot;P&quot;</td>
<td>72.54</td>
<td>16.26</td>
<td>105.76</td>
<td>31.63</td>
</tr>
</tbody>
</table>

Another goal was to ensure that the treatment
did not effect student time in unit B. To test this,
the hypotheses,

H': there is no significant difference in student
time in unit B between I₁ and I₂, and

H": there is no significant difference in student
time in unit B between P₁ and P₂
were posed. The results of a two-way analysis of variance using student time in minutes on unit B as the dependent variable are shown in Table 13.

**TABLE 13**

**PLOT OF CELL MEANS AND ANOVA OF UNIT B ON-LINE TIME**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Sums of SQS.</th>
<th>D.F.</th>
<th>F</th>
<th>Prob. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>25040.94</td>
<td>1,56</td>
<td>0.001</td>
<td>.98</td>
</tr>
<tr>
<td>P</td>
<td>25245.88</td>
<td>1,56</td>
<td>0.459</td>
<td>.50</td>
</tr>
<tr>
<td>IxP</td>
<td>26866.50</td>
<td>1,56</td>
<td>4.083</td>
<td>.05</td>
</tr>
<tr>
<td>Total</td>
<td>600767.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Neither of the main effects yields a significant F, so

H' cannot be rejected, and

H" cannot be rejected.
There is a significant interaction which cannot be explained by the treatment. A further analysis of the raw times does explain it, however. The two cells with highest means, I'P' and I"P", also have much higher standard deviations than the other two cells. This indicates that there are more extreme times in the cells with higher means. This is the case. For example, one student in the I"P" group had a unit B time of 202 minutes, while the next highest time in any cell was 136 minutes. This student has a serious sight problem which made it necessary for him to be within two inches of the printout to read it. This obviously increased his time spent on the unit. With the presence of such extreme cases, a comparison of median time may be helpful. The results are in Table 14.

**TABLE 14**

**CELL MEDIANs - UNIT B TIME**

<table>
<thead>
<tr>
<th>Group</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'P'</td>
<td>94.0</td>
<td>66</td>
</tr>
<tr>
<td>I'P&quot;</td>
<td>92.8</td>
<td>37</td>
</tr>
<tr>
<td>I&quot;P'</td>
<td>92.0</td>
<td>59</td>
</tr>
<tr>
<td>I&quot;P&quot;</td>
<td>98.0</td>
<td>131</td>
</tr>
</tbody>
</table>
Using a median test the medians differed only at the .20 probability level \( \chi^2 = 2.678 \) with d.f. = 3. It seems obvious that much of the apparent difference can be attributed to a few extreme times. Thus there is no reason to believe that student time differed due to treatment.

Extent of Treatment Differences on the I Variable

Since the differences on the two I treatments, I' and I", only occurred when students made incorrect responses, it is conceivable that a capable student could complete unit B with few incorrect responses. In that case, he would rarely be exposed to the feedback peculiar to his I level. The extent of the actual difference between the I' and I" treatments is summarized here.

Not every question in the text of unit B was programmed with alternate forms of feedback. For example, on two choice questions where a right or wrong situation existed, it was impossible not to refer to the student's specific wrong answer. Furthermore, if a question was written with alternate feedback, correct answers by students were still treated the same at both I levels. A summary of the actual differences in the I' and I" levels is in Table 15.
TABLE 15
STUDENT USE OF ALTERNATE FEEDBACK

<table>
<thead>
<tr>
<th>Subunit of Unit B</th>
<th>Total Questions*</th>
<th>Quest. with Alt. F. B.</th>
<th>Mean No. of Stu. Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>11</td>
<td>3.73</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
<td>16</td>
<td>5.27</td>
</tr>
</tbody>
</table>

* This varies according to student performance.

This table indicates that on the average a student in an I" treatment cell received I" feedback less than four times in subunit 1 and over five times in subunit 2. This difference may help explain why there was no significant I effect on O₁, but significant differences did occur on the I effect in subunit 2. The means of student use differed at the .01 level (t=2.66, d.f.=58).

A further explanation of why differences on the I variable were found on O₂ but not on O₁ could lie in the type of skills required of a student in subunit 1 and O₁, as compared to subunit 2 and O₂. For the most part simple recognition was required on O₁, but algebraic manipulation was required in many items in O₂. The purpose of this study was not to isolate levels of knowledge, but further research along these lines is desirable.
Sample Fluctuation

As described earlier, after the original groups were formed a total of seven students dropped, or were dropped, from the sample. Five were added when they registered late for the class. The scores of the five adds are in Table 16. The means indicate that the adds did not differ significantly from the entire sample.

TABLE 16

<table>
<thead>
<tr>
<th></th>
<th>0&lt;sub&gt;1&lt;/sub&gt;</th>
<th>0&lt;sub&gt;2&lt;/sub&gt;</th>
<th>0&lt;sub&gt;3&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>I'P'</td>
<td>14</td>
<td>10</td>
<td>79</td>
</tr>
<tr>
<td>I'P'</td>
<td>7</td>
<td>6</td>
<td>77</td>
</tr>
<tr>
<td>I&quot;P&quot;</td>
<td>6</td>
<td>12</td>
<td>98</td>
</tr>
<tr>
<td>I&quot;P&quot;</td>
<td>6</td>
<td>6</td>
<td>75</td>
</tr>
<tr>
<td>I&quot;P&quot;</td>
<td>14</td>
<td>12</td>
<td>82</td>
</tr>
</tbody>
</table>

\[ \bar{X} = 9.40 \quad 9.20 \quad 82.20 \]

Grand Means 9.20 9.25 78.72

Instructor Variable

Since the subjects were randomly assigned to one of the four cells, the effect of an instructor variable is evenly distributed over cells. Hence, it is not considered in the statistical analysis.
V. SUMMARY AND CONCLUSIONS

SUMMARY

Two CAI units designed to teach the concept of function were developed by the researcher. Unit A includes pre-requisite topics—sets, ordered pairs, and graphs. Unit B includes the definition of function, graphs of functions, and functional notation. Sixty pre-calculus college students were randomly placed in equal numbers into four treatment groups. The treatments differed in the type of feedback the student receives to his responses in unit B.

The treatment groups were the result of crossing two levels of each of two variables, I, individualization, and P, personalization. The levels of I were defined by:

I' - the student, following an incorrect response, receives feedback which states why his answer is incorrect and what the correct answer is.
I" - the student, following an incorrect response, receives feedback which states the correct answer and why it is correct, but does not refer to the student's answer specifically.

Feedback was the same for the two levels of I on correct responses. The levels of P are defined as follows.
P' - the student's first name appeared in some of the feedback (as often as was determined to be reasonable by the investigator).

P'' - the student's first name never appeared in the feedback.

The resulting cells then are I'P', I'P'', I''P', and I''P'' (see Diagram 1).

The sixty students took unit A, all receiving the same treatment. Taking unit A should have greatly reduced the novelty effect of the computer prior to the subject's taking unit B, the experimental unit.

Three achievement tests and an attitude test were developed:

O^P - a twenty item posttest of unit A,

O_1 - a fifteen item posttest of unit B, subunit 1,

O_2 - a fifteen item posttest of unit B, subunit 2, and

O_3 - a thirty item attitude scale.

O^P, O_1, and O_2 were administered via the I.B.M. 2741 terminal immediately following the material each was designed to test. O_3 was administered using pencil and paper within a week after the majority of the subjects had completed the two units.

A two-way analysis of variance was employed to test the null hypotheses of no differences on O_1, O_2, and O_3 scores between the levels of the I and P
variables. $O^p$ scores were to be used as a covariate but nearly identical cell means prompted the decision not to use them. Achievement results show that on $O_1$ there was no significant I effect but $O_2$ did yield a significant difference ($p$ less than .04) in favor of I". There was no significant main P effect on $O_1$ or $O_2$, but in both instances the P' treatment groups performed better than the P" (0.11 level on $O_1$ and 0.39 level on $O_2$). Attitude results showed no significant I effect on $O_3$ but the P' scores were better than the P" ($p$ less than .07).

Further findings were non-significant correlation between attitude and achievement, a usual result in educational research, little correlation between typing ability and achievement or attitude, and small positive correlation between total time and attitude scores. Conclusions and implications of the results of the study follow in this chapter.

CONCLUSIONS

From the data analysis certain conclusions seem clear.

1) The CAI program used in this study did improve student achievement as tested by the behavioral objective based tests. This conclusion is based primarily on the results of the pilot studies.
2) Feedback as employed in the I" treatment level yielded greater student achievement than the I' treatment. This is true at least on unit B, subunit 2 (p less than .04).

3) The attitude of students toward CAI appears to be better after a treatment in which their first name appears in feedback than after one in which the name does not appear (p less than .07).

4) There is some indication that the use of the student name in feedback improves achievement.

5) There is no significant correlation between achievement and attitude scores.

6) There is small negative correlation between unit A time and achievement (−.20 with $O_1$ and −.25 with $O_2$). This can be explained by the diagnostic testing in unit A which allowed the best students to skip one or more of the three parts of unit A.

7) There is no significant correlation between typing ability as measured in this study and achievement or attitude.

8) There is small positive correlation between student time and attitude ($r=.23$) on unit B.

9) The correlation among the achievement tests, $O^p$, $O_1$, and $O_2$, is fairly high (.45 between $O^p$ and $O_1$, .26 between $O^p$ and $O_2$, and .37 between $O_1$ and $O_2$).
10) The evidence did not show that differences in feedback treatment significantly affect the time taken for subjects to complete unit B.

11) The mean number of times students received different feedback on the I variable was greater in subunit 2 than in subunit 1 of unit B. This may help account for conclusion 2.

IMPLICATIONS

The individualization variable considered in this study is one in which all developers of CAI should be interested. One of the major claims of proponents of CAI as an instructional tool is that it can individualize instruction. Certainly directing feedback to a student's specific response would be part of this individualization. The development of a CAI program which includes much individualized feedback is very time consuming, however. The primary reason is that to individualize, it is necessary for the author to anticipate a wide range of student responses in a variety of forms. No matter how experienced or clever an author is he will not anticipate some responses. Thus testing and revision are needed. This takes time—author time, student time, and computer time.

On the other hand, to write a CAI program which treats every incorrect response to a question in the
same way is a much simpler task. The author's job is greatly simplified since he only needs to concern himself with variable forms of correct responses. The program length is greatly reduced also since space is needed for only one form of feedback to incorrect responses to each item. This time and length reduction certainly will be followed by a reduction in cost, an all too important factor to consider.

If CAI developers cannot demonstrate that the extra time and money expended to "individualize" result in student improvement of some sort, then it seems that the extra money should not be spent. As yet this has not been demonstrated and perhaps that is because developers have not found the best way to individualize feedback (Gentile, 1967).

The results of this study do not suggest that the type of individualized feedback written for this program yields better student achievement or attitude scores than non-individualized feedback. In fact, on one achievement test, scores were significantly higher in the non-individualized group, while no significant differences were found in the other achievement test scores or the attitude scores. At the very least these results should be viewed as an indication that if individualization of feedback in CAI tutorial programs is to be justified, then more work on how best to
accomplish it is needed. Research in which varying types of individualized and non-individualized feedback are tested and compared should be done. Perhaps combinations of elements of the two levels of individualized feedback compared in this study would yield better results than either of them.

The levels of feedback on the I variable were defined as:
I' - on an incorrect response the student receives feedback which says his response is incorrect, why it is incorrect, and what the correct response is.
I" - on an incorrect response the student receives feedback which says his response is incorrect, what the correct response is, and why it is correct.

Perhaps the key difference between I' and I" is not that I' speaks to the student's response and I" does not. A more important difference may be that the I' feedback tells why the student answer is incorrect but only states the correct answer, while the I" feedback tells why the correct answer is correct. It may be more important for the student to know what the correct answer is and why, than for him to understand why his answer is not correct. A replication of this study could help decide that question. A variation of this study in which the difference described above is a
variable and compared with other forms of feedback would also be valuable.

The P variable, personalization, seems to be a more clear cut question. First, it is not as difficult to program a student name into feedback as it is to anticipate a wide variety of student responses. In I.B.M. Coursewriter III, for example, to include a name in a line of feedback to a student requires three lines in the program. So while including the name does increase the length of the program and does require more time, the amount of extra time and space is not great and it is known.

The results of this study imply that the time taken to include the name is worth it. On both achievement tests the P' group which had their names included in feedback tended to do better than the P'' group, though in neither case did the difference reach the .10 level. However, student attitude toward CAI following the P' treatment was better than the P'' group (p less than .07). Such a significant attitude difference seems to warrant the extra programming time. Further research should be done comparing use of feedback with and without first names in other types of CAI programs with different levels of subjects.

The non-significant correlations between achievement scores and attitude scores found in this study
support the results of many previous studies (Postlethwaite, 1971). The typing ability of students did not correlate significantly with achievement or attitude scores. However, the measurement of typing ability was rather gross—time in minutes on a very short test. Further investigation of the typing ability versus achievement in CAI question is needed.

The possibilities of CAI as an instructional tool are exciting, but perhaps as exciting is its potential as a research tool. The ease with which large amounts of data can be collected and the experimental control which can be gained using CAI are great research assets. The results of this study, for example, are easily explainable due to the absence of confounding variables.

The extent to which results of studies such as this one can be generalized is an open question. Developers of CAI tutorial material in mathematics for the college freshman level student should certainly take notice. To say the same results will hold in other disciplines and with other age and ability level students may be questionable. Here again more research should be done with other programs and populations.

It is also quite conceivable that the results of this study may say something to classroom teachers concerning feedback to student responses in class,
on tests, or on homework papers. It seems more important to state why a correct answer is correct than to simply point out why a student's answer is wrong. This is not always done as there is a tendency among teachers to continue to something else once the correct response is stated.

The results of the personalization effect may also imply that students, as probably all human beings, do respond positively to being referred to by name. This is not a surprising result, though in the classroom and in CAI programs it is not always put into practice.

SUGGESTED FUTURE RESEARCH

The significantly different performances of the treatment groups suggest the need for further research in this area. First, CAI studies in which feedback is varied using the same treatment levels defined in this study and combinations of them should be done. For example, one level of feedback could include explanation of the student's error, the correct answer, and why it is correct.

Students at different levels of mathematical maturity may respond differently also, so similar studies with different populations would be desirable. It is very likely that the nature of the content of the feedback and of the CAI unit were major factors effecting
the outcome of this study. CAI units teaching different concepts, not necessarily mathematical, could be used in research studies similar to this one.

The possibility of generalizing this study's results to the classroom situation suggests some very interesting ideas for research. A study could be designed using the four treatment levels of this study, but in which the teacher's verbal and/or written feedback to student homework replaces the CAI feedback. Several teachers should be involved to control for teacher differences. The possible effect of the teacher's use of student's first names on achievement and attitude could be easily researched in a classroom setting. Teachers in one treatment level could make a conscious effort to use names while the reverse would be true at the other level.

If results of this type of classroom research tend to support this study's outcomes on the individualization variable, a major change in teacher education may be in order. If students acquire concepts better when they are simply told correct answers with explanation then the present trend to individualize instruction may be off base. The outcome of this study should not lead one to make such a conclusion. While much more evidence is required, this study does suggest the need for research relative to the conclusion.
BEHAVIORAL OBJECTIVES

Introductory Unit

1. Given the elements or description of a set, to use the listing method to symbolize the set.

2. Given a set denoted by the listing method, to state whether or not given objects are elements of the set.

3. Given a set denoted in set builder (descriptive) notation, to state whether or not certain objects are elements of the set. This assumes the descriptive expression contains words and symbols with which the student is familiar.

4. Given two simple sets of numbers denoted by either listing or set builder notation, to state correctly whether or not they are equal sets. In particular, to state that two sets with the same elements listed in different orders are equal.

5. To state what elements are in the empty set and that the symbol, $\emptyset$, is used to denote it.

6. To use the proper symbols to write "the ordered pair $a, b$," where $a$ and $b$ are any objects or symbols.

7. Given an ordered pair of numbers, to state correctly which of the coordinates is the first coordinate.

8. Given two ordered pairs of numbers, to state correctly whether or not they are equal. In particular, does $(a, b) = (b, a)$?
9. Given a set of ordered pairs in either listing or set builder notation, to state correctly whether or not indicated objects are elements of the set.

10. Given a set of ordered pairs, to state correctly the set of first coordinates and the set of second coordinates.

11. Given a set of coordinate axes, to state which coordinate of the ordered pair is plotted on the horizontal (x) axis and which on the vertical (y) axis.

12. Given a vertical line (or horizontal line), to indicate that each point satisfies \( x=h \) (or \( y=k \)) where \( h \) and \( k \) are constants.

13. Given a point in the cartesian plane, to state its coordinates correctly.

14. Given an ordered pair of numbers, to describe the location of its graph in terms of the intersection of a horizontal and a vertical line.

15. Given a discrete set of points in the plane, to denote the corresponding set of ordered pairs.

16. Given a finite set of ordered pairs, to identify its graph.

**Experimental Unit**

1. Given a set of ordered pairs either in listing or set builder notation, to state correctly whether or not it is a function.
2. Given a simple function, to state correctly its (understood) domain and/or range. "Simple" means that the function is either a discrete set of ordered pairs or is described by a statement involving no mathematics beyond polynomials. For example, \( f(x, y) = \log \sin x \) would not be considered a simple function.

3. Given a graph, to state correctly whether or not it is the graph of a function.

4. Given a simple (as defined in 2) rule, algebraic or not, which relates two variables, to state correctly whether or not the associated set of ordered pairs is a function.

5. Given a function as a finite set of ordered pairs, and a particular \( x \) in its domain, to state the number \( f(x) \).

6. Given a rule which defines a function, or a function as a set in set builder notation, and an \( x \) in its domain, to state the number \( f(x) \).

7. Given a function \( f \), to state the set of \( x \) for which \( f(x) \) is defined. In particular, to state that \( f(x) \) only makes sense if \( x \) is in the domain of \( f \).
Unit A

Begin

Diag Test 1 (4)

not 3 corr

Subunit 1
Sets

Diag Test 2 (4)

not 3 corr

Subunit 2
Ordered Pairs

Diag Test 3 (4)

not 3 corr

Subunit 3
Graphs

End

Posttest
Unit B

Begin

Subunit 1
Definition of Function

Posttest

Subunit 2
Graphs of Functions, f(x) Notation

Posttest

End
SAMPLES OF ALTERNATE FEEDBACK

Sample 1

So in the previous question, \( S = \{(x,y) : y = 2x + 3 \text{ and } x = 1, 2, 3 \} \) is a function

a. whose domain is \( \{9, 7, 5\} \) and whose range is \( \{1, 2, 3\} \).

b. whose domain is \( \{1, 2, 3\} \) and whose range is \( \{5, 7, 9\} \).

c. whose domain is \( x \) and whose range is \( y = 2x + 3 \).

d. none of the above.

(Student response - c)

I'P' f. b. - \( x \) is only a symbol representing the values in the domain and \( y \), those in the range.
The correct answer is b, Alice.

I'P'' f. b. - \( x \) is only a symbol representing the values in the domain and \( y \), those in the range.
The correct answer is b.

I''P' f. b. - No, the domain is the set of values \( x \) (or the first coordinate) may take, so the domain is \( \{1, 2, 3\} \). The range is the set of \( y \) values so \( y = 2x + 3 \) has values \( 2(1) + 3 = 5 \), \( 2(2) + 3 = 7 \), and \( 2(3) + 3 = 9 \). The correct answer is b, Alice.

I''P'' f. b. - No, the domain is the set of values \( x \) (or the first coordinate) may take, so the domain is \( \{1, 2, 3\} \). The range is the set of \( y \) values so \( y = 2x + 3 \) has values
\[2(1) + 3 = 5, \quad 2(2) + 3 = 7, \quad \text{and} \quad 2(3) + 3 = 9. \] The correct answer is \(b\).

Feedback for the last two groups is the same for any incorrect response; that is, \(c, a, \text{or} \ d\).

**Sample 2**

The domain of \(d(s,t): \ t = (\sqrt{s}) \) is understood to be all real numbers whose square root is also a real number.

In other words, all _________ real numbers.

(Student response - positive)

I'P' f. b. - That's close, Reginald. However, the square root of 0 is 0, a real number.

The correct answer is nonnegative.

I'P" f. b. - That's close. However, the square root of 0 is 0, a real number. The correct answer is nonnegative.

I"P' f. b. - The square root of a negative number is not in \(R\). So nonnegative is the correct answer, Reginald.

I"P" f. b. - The square root of a negative number is not in \(R\). So nonnegative is the correct answer.

**Sample 3**

Suppose \(t = 4(x, x+4) \). Then \(t(3) = \_\).

(Student response - 1)
I'P' f. b. - Roy, you seem to have blown it! \( t(3) = 3 + 4 \), not 3-4 or 4-3. The correct answer is 7.

I'P" f. b. - You seem to have blown it! \( t(3) = 3 + 4 \), not 3-4 or 4-3. The correct answer is 7.

I"P' f. b. - I don't recognize your answer, Roy. The correct answer is 7 since \( t(3) = 3 + 4 = 7 \).

I"P" f. b. - I don't recognize your answer. The correct answer is 7 since \( t(3) = 3 + 4 = 7 \).

Feedback on correct responses is the same for all four groups except that the first name never appears in the I'P" and I"P" feedback.
TEST IN FIRST PILOT STUDY

1. Which of the following sets equals $\emptyset$?
   a. $\{0\}$
   b. $\{w: w \text{ is in } W, w \text{ less than } 0\}$
   c. $\{(y,z): y=z\}$
   d. $\{x: x \text{ is between } 4 \text{ and } 5\}$

2. Which of the following sets equals $\{(a,b): b=2a, a \text{ is an even whole number}\}$?
   a. $\emptyset$
   b. $\{0, 2, 4, \ldots\}$
   c. $\{(0,2), (2,4), (4,6), (6,8), \ldots\}$
   d. $\{(0,0), (2,4), (4,8), (6,12), \ldots\}$

3. Refer to diagram 9. The graph of $\{(x,y): y=2\}$ is
   (a/b/c/d)

4. Which of the following is not a function?
   a. $\{(2,0)\}$
   b. $\{(x,y): y=x^2\}$
   c. $\{(0,1), (1,1), (2,1), (3,1), \ldots\}$
   d. $\{(x,y): y \text{ less than } x, x \text{ and } y \text{ in } W\}$

5. A set, $S$, of points in the coordinate plane is the graph of a function if and only if
   a. no two points of $S$ are on the y-axis.
   b. no two points of $S$ are on the x-axis.
   c. no two points of $S$ are in the same vertical line.
   d. no two points of $S$ are in the same horizontal line.
6. Which of the following does not define a function?
   a. y=2x-x   b. f(s)=3   c. y less than 2x   d. 2+2x=3y

7. A function defined by 4y+2=8x is
   a. 4(x,y): y=2x-1
   b. 4(y,x): 4y+2=8x
   c. 4(x,y): y=2x
   d. 4(x,y): x=2y+\frac{1}{2}

8. If f is a function, then f(x) is best described as
   a. a function with x in its defining rule.
   b. an element of the domain of f corresponding to x in the range of f.
   c. the element of the range of f which corresponds to x, an element of the domain of f.
   d. f(x) and f are the same function.

9. The domain of the function defined by f(x)=1/(x-2)^2 is understood to be
   a. R
   b. all of R except 1
   c. all of R except 1 and -2
   d. all of R except -1 and 2

10. Suppose f=4(0,3),(1,5) and g=4(r,s): s=2r-1.
    Then 2f(0)-g(2)=_. Type a letter only.
    a. 3   b. -2   c. 2   d. -3
TESTS IN SECOND PILOT STUDY

Test 1

1. \( (x,y): y=5, \ x \in W, \ x \leq \) is equal to which of the following?
   a. \( (0,5),(1,5),(2,5),(3,5),(4,5),(5,5) \)
   b. \( (5,0),(5,1),(5,2),(5,3),(5,4) \)
   c. \( (0,0),(1,1),(2,2),(3,3),(4,4),(5,5) \)
   d. \( (0,5),(1,5),(2,5),(3,5),(4,5) \)

2. Let \( E=\{0,2,4,\ldots\} \). Which one of the following is not an element of \( E \)?
   a. 21  b. 138  c. 10  d. None of the above

3. Let \( S=\{r,s): s=(r/2), \ r \in W \} \). Which one of the following is in \( S \)?
   a. 10  b. \((-4,-2)\)  c. \((15,7.5)\)  d. \((6,12)\)

4. Which one of the following is not a true statement?
   a. \( \{x: x \lessdot 4, \ x \in W\} = \{4,5,6,\ldots\} \)
   b. \( \{x,y): y=x, \ x \in W\} = \{0,0),(1,1),(2,2),\ldots\} \)
   c. \( \{x: x \lessdot 0, \ x \in W\} = \{4,5,6,\ldots\} \)
   d. \( \{8,3,2\} = \{42,3,8\} \)

5. Which of the following sets is equal to \( \{x,y): y=2x, \ x \in Q\} \)?
   a. \( \{x,y): y=2x\} \)
   b. \( \{r,s): r \in Q, \ s=2r\} \)
   c. \( \{r,s): r \in Q\} \)
   d. \( \emptyset \)
6. Suppose \( M = \{(2,8), (-7,1)\} \). The set of first coordinates of pairs in \( M \) is
a. \( \{2,8\} \)
   b. \( \{-7\} \)
   c. \( \{-7,1\} \)
   d. None of the above

7. Which of the following is **not** a true statement?
   a. \((2,5) = (5,2)\)
   b. \((2,5) = (5,2)\)
   c. \((2,5), (3,4) \neq (3,4), (2,5)\)
   d. \(\emptyset\)

8. Refer to diagram 9. The graph of \( f(x,y): y = 2 \) is
   a/b/c/d)

9. The point corresponding to \((2,-5)\) is located
   a. 2 units above the x-axis and 5 units to the left of the y-axis.
   b. 2 units above the y-axis and 5 units to the left of the x-axis.
   c. 2 units above the x-axis and 5 units to the right of the y-axis.
   d. 2 units to the right of the y-axis and 5 units below the x-axis.

10. The graph of \((-2,-1)\) is the point of intersection of the lines,
    a. \(x = -1\) and \(y = -2\)
    b. \(x = -2\) and \(y = -1\)
    c. Neither of the above
    d. Both of the above
11. Refer to diagram 10. Which of the graphs is the graph of 4(2,-1),(3,0),(-4,2)? (a/b/c/d)

12. Suppose a, b is a pair of non-zero whole numbers. In which of the following is the order of the two not important?
   a. a/b   b. a+b   c. a-b   d. None of the above

13. The set of second coordinates of 4(x,y): y=2x, x in W is
   a. 40,1,2,3,...
   b. 40,2,4,...
   c. 42
   d. ∅

14. Which of the following is not a set containing four elements?
   a. 4x: x in Q, x between 1 and 6
   b. 40,1,2,3,4,3
   c. 4x: x in W, x between 1 and 6
   d. 4(0,1),(2,5),(-1,3),(1,7)

15. The best way to denote the set of rational numbers between 0 and 1 among the following is
   a. 40,1/2,1/3,1/4,...
   b. 40,1
   c. 4x: x in Q, x between 0 and 1
   d. 4x: x between 0 and 1
16. Which one of the following is a true statement?
   a. \( \emptyset = 4r: r \text{ between } 0 \text{ and } 0 \)
   b. \( 47 \subseteq 4x: x \text{ between } 6 \text{ and } 8 \)
   c. \( 4(x, y): y = 2x, x \text{ in } W, x \text{ between } 0 \text{ and } 3 \)
      \( (1, 2), (2, 4) \)
   d. \( 4x: 2x + 3 = 7 \)

17. The coordinates of the point of intersection of
    the line \( x = \frac{1}{2} \) and the line \( y = -0.3 \) are
   a. \( (\frac{1}{2}, 0.3) \)
   b. \( (-0.3, \frac{1}{2}) \)
   c. \( (0.5, -\frac{3}{10}) \)
   d. \( (.5, -3/10) \)

18. The name usually given to the point corresponding
    to \((0,0)\) is
   a. origin  b. x-axis   c. y-axis   d. empty set

19. The graph of \( 4(x, y): y = 7 \) is
   a. a vertical line 7 units to the right of the y-axis
   b. a horizontal line 7 units above the x-axis
   c. a circle with radius 7
   d. a horizontal line 7 units to the right of the
      y-axis

20. If \( S = 4(\text{Jim}, 180), (\text{John}, 153), (\text{Jerry}, 180) \) represents
    three men paired with their weights, then which of
    the following is not a true statement?
   a. \( 4153, 180 \) is the set of second coordinates of
      pairs in \( S \).
   b. Jerry weighs 180 pounds.
   c. Jeff's weight is not found in \( S \).
   d. Jim weighs less than either John or Jerry.
Test 2

1. Which of the following is not a function?
   a. \((2,0)\)
   b. \((x,y): y=x^2\)
   c. \((0,1),(1,1),(2,1),(3,1),...\)
   d. \((x,y): y \text{ less than } x, x \text{ and } y \text{ in } W\)

2. A set, \(S\), of points in the coordinate plane is the graph of a function if and only if
   a. No two points of \(S\) are on the \(y\)-axis.
   b. No two points of \(S\) are on the \(x\)-axis.
   c. No two points of \(S\) are in the same vertical line.
   d. No two points of \(S\) are in the same horizontal line.

3. Which of the following does not define a function?
   a. \(y=2x-x\)
   b. \(f(s)=3\)
   c. \(y \text{ less than } 2x\)
   d. \(2+2x=3y\)

4. A function defined by \(4y+2=8x\) is
   a. \((x,y): y=2x-1\)
   b. \((y,x): 2y+1=4x\)
   c. \((x,y): y=2x\)
   d. \((x,y): x=2y+1\)

5. If \(f\) is a function, then \(f(x)\) is best described as
   a. a function with \(x\) in its defining rule.
   b. an element of the domain of \(f\) corresponding to \(x\) in the range of \(f\).
   c. the element of the range of \(f\) which corresponds to \(x\), an element of the domain of \(f\).
   d. \(f(x)\) and \(f\) are the same function.
6. The domain of the function defined by \( f(x) = \frac{1}{(x-2)(x+1)} \) is understood to be
   a. \( \mathbb{R} \), the set of real numbers.
   b. all of \( \mathbb{R} \) except 1 and -2.
   c. all of \( \mathbb{R} \) except -1 and 2.
   d. none of the above.

7. Suppose \( f = \{ (0,3), (1,5) \} \) and \( g = \{ (r,s) : s = 2r - 1 \} \). Then \( 2f(0) - g(2) = \)
   a. 3  b. -2  c. 2  d. -3

8. If \( f = \{ (0,3), (0,5), (2,3) \} \), then
   a. \( f \) is a function whose domain is \( \{ 0, 2 \} \) and whose range is \( \{ 3, 5 \} \).
   b. \( f \) is a function whose domain is \( \{ 3, 5 \} \) and whose range is \( \{ 3, 5 \} \).
   c. \( f \) is not a function because 0 is repeated.
   d. \( f \) is not a function because 3 is repeated.

9. If \( s = \{ (x,y) : y = \sqrt{\frac{1}{x}} \} \), then \( s \) is a function whose domain is understood to be
   a. \( \mathbb{R} \), the set of real numbers.
   b. the set of positive real numbers.
   c. the set of nonnegative real numbers.
   d. None of the above.

10. If \( s \) is defined as in #9, the range of \( s \) is
    a. \( \mathbb{R} \), the set of real numbers.
    b. the set of nonnegative real numbers.
c. the set of negative real numbers.
d. None of the above is true.

11. According to the strict definition of function, $y=3x$
a. is a function whose domain is $\mathbb{R}$.
b. is not a function, but $f(x,y): y=3x$ is.
c. is a function whose range is $40, 3, 6, \ldots$.
d. None of the above is true.

12. Refer to diagram 12. Which of the graphs is the graph of a function? (a/b/c/d)

13. Refer to diagram 11. Which of the graphs is not the graph of a function? (a/b/c/d)

14. Suppose $T=\{(x,y): y=x+3\}$ and $F=\{(x,y): y=2x\}$. Then $T(F(x))$ is
a. $2(x+3)$
b. $y$
c. $3x+3$
d. $2x+3$

15. If $T$ and $F$ are defined as in #14, then $2T(2)-F(1)=$
a. $4$
b. $3$
c. $3x+3$
d. $2x+3$

16. If $P=\{(s,t): s \text{ in } \mathbb{W}, t=2s\}$, then $P(\frac{1}{2})=$
a. $1$
b. $-1$
c. $\frac{1}{4}$
d. None of the above

17. If $g=\{(2,3),(4,3),(2,3)\}$, then
a. $g$ is a function.
b. $g$ is not a function because 3 is repeated.
c. $g$ is not a function because 2 is repeated.
d. None of the above is true.
18. Which one of the following defines a function?
   a. \( f(x) = x^2 \)
   b. \( 2y < 3x \)
   c. \( y < 7x + 1 \)
   d. \( y^2 = x^2 \)

19. If the domain of \( f = 4(x, y) : y = 2x + 2 \) is \( \{3, 4, 5\} \), then the range of \( f \) is
   a. \( f(x) = 2x + 2 \)
   b. \( 8, 10, \) and \( 12 \)
   c. \( 48, 10, 12 \)
   d. Both a and c

20. Which of the following defines a function?
   a. \( g(x) = x^2 \)
   b. \( p = 7q \)
   c. \( y = 4x^2 + 3 \)
   d. All of the above

**Test 3**

1. Which one of the following is not a function?
   a. \( y = 7x \)
   b. \( f(x, y) : y = 3x + 1 \)
   c. \( f(2, 3), (1, 1) \)
   d. \( f(x, y) : y = x^2 \)

2. The domain of the function defined by \( y = 2x/(x-3) \)
   is understood to be
   a. \( R \), the set of real numbers.
b. all of R except 0 and 3.
c. all of R except 3.
d. all of R except 0.

3. Which one of the following is a function?
   a. \(4(2,3), (3,1), (2,4)\)
   b. \(4(2,3), (3,1), (2,3)\)
   c. \(4(x,y): y \text{ less than } x\)
   d. None of the above.

4. If the domain of \(f=4(x,y): y=7\) is \(41,2,3\), then the range of \(f\) is
   a. \(48,9,10\)
   b. \(47\)
   c. \(47,14,21\)
   d. \(\emptyset\)

5. If the range of \(g=4(r,s): s=2r+1\) is \(45,7,9\), then the domain of \(g\) is
   a. \(42,3,4\)
   b. \(43,4,5\)
   c. \(411,15,19\)
   d. None of the above.

6. According to the strict definition of function, \(y\text{ less than } 5x\)
   a. is a function whose domain is \(R\).
   b. is a function whose range is \(45\).
   c. is not a function, but \(4(x,y): y \text{ less than } 5x\) is.
   d. is not a function, nor is \(4(x,y): y \text{ less than } 5x\).
7. A function defined by $y=x+1$ is
   a. $4(x,y): y=x-1$
   b. $4(x,y): x-1=y$
   c. $4(y,x): y+x=1$
   d. None of the above.

8. A function is
   a. a relationship between two variables.
   b. a set of ordered pairs in which no second coordinate is repeated.
   c. a set of ordered pairs in which no first coordinate is repeated.
   d. None of the above.

9. $4(x,y): y=4$ is a function whose range is
   a. $y=4$  b. $4y$  c. 4  d. $R$, the set of real numbers

10. If $S=4(x,y): y=2x+1$, $x$ is in $W$, then which one of the following numbers is in the range of $S$?
    Remember that $W=\{0,1,2,3,\ldots\}$.
    a. 31  b. 28  c. 14  d. all of the preceding

Test 4

1. A set, $S$, of points in the coordinate plane is the graph of a function if and only if
   a. no two points of $S$ are on the $y$-axis.
   b. no two points of $S$ are on the $x$-axis.
   c. no two points of $S$ are in the same vertical line.
   d. no two points of $S$ are in the same horizontal line.
2. Suppose $S=\{(2,5), (-2,1), (-2,5)\}$. Then
   a. two points of the graph of $S$ lie on the same horizontal line.
   b. two points of the graph of $S$ lie on the same vertical line.
   c. $S$ is not a function.
   d. All of the above are true.

3. Refer to diagram 13. Which one of the graphs is not the graph of a function? (a/b/c/d)

4. Refer to diagram 14. Which one of the graphs is the graph of a function? (a/b/c/d)

5. The graph of $S=\{(x,y): x=3\}$ is
   a. a circle, hence $S$ is not a function.
   b. a horizontal line, hence $S$ is a function.
   c. a point, hence $S$ is a function.
   d. a vertical line, hence $S$ is not a function.

**Test 5**

1. If $f$ is a function, then $f(x)$ is best described as
   a. a function with $x$ in its defining rule.
   b. an element of the domain of $f$ corresponding to $x$ in the range of $f$.
   c. the element of the range of $f$ which corresponds to $x$, an element of the domain of $f$.
   d. $f(x)$ and $f$ are the same function.
2. Suppose \( f(x) = 3x \) and the domain of \( f \) is \( W \). Then
\[
f\left(\frac{1}{3}\right) =
\]
a. \( \frac{1}{9} \)  b. 0  c. 1  d. None of the preceding

3. Suppose \( f = \{(0,3), (1,5)\} \) and \( g = \{(r,s) : s = 2r - 1\} \).
Then \( 2f(0) - g(2) = \)
\[
a. 3  
b. -2  
c. 2  
d. -3
\]

4. Suppose \( g(x) = \frac{1}{x} \), then \( g(0) = \)
\[
a. g(0) \) is not defined because 0 is not in the domain of \( g \\
b. 0 \\
c. g(0) \) is not defined because 0 is not in the range of \( g \\
d. 10
\]

5. Suppose \( g = \{(x, 2x)\} \) and \( f = \{(x, f(x)) : f(x) = 3x\} \).
Then \( f(g(2)) = \)
\[
a. 6x  
b. 4  
c. 12  
d. 3
\]

6. With \( g \) and \( f \) defined as in #5, \( g(f(8)) = \)
\[
a. 3  
b. 6  
c. 48  
d. 16
\]

7. Suppose \( f(x) = 2x \) and \( g(x) = \frac{1}{2}x \). Then \( f(3)g(2) = \)
\[
a. 4  
b. 7  
c. 2x  
d. 6
\]

8. With \( f \) and \( g \) defined as in #7, \( f(4)/g(4) = \)
\[
a. \frac{1}{4}  
b. 10  
c. 4  
d. 6
\]

**Attitude Scale**

Please circle the response which best describes your feelings about this computer experience.
a. strongly agree  b. agree  c. undecided  d. disagree  
e. strongly disagree
1. I felt I learned a lot about functions.  a b c d e
2. The course kept my interest.  a b c d e
3. I felt I already knew most of the material in the course before taking it.  a b c d e
4. I was interested at first, but then became bored later on.  a b c d e
5. I understood nearly all of the explanations.  a b c d e
6. I would be interested in learning more.  a b c d e
7. I thought the tests did test what I learned very well.  a b c d e
8. I enjoyed the computer's use of my name in comments.  a b c d e
9. I felt there should have been more explanations in the course.  a b c d e
10. I felt I learned more on the computer than I would have in two days of classes on the same material.

Please comment on anything you feel was not covered above. Use the other side of this sheet if needed.

TESTS IN FINAL STUDY

$C^P$, Posttest on Unit A
1. $\{ (x,y) : y=5, x \text{ in } W, x \text{ less than 5} \}$ equals which of the following?
2. Let \( E = \{10, 2, 4, \ldots\} \). Which one of the following is not an element of \( E \)?
   a. 21  b. 138  c. 10  d. None of the above.
3. Let \( S = \{(r, s) : s = r/2, \ r \in \mathbb{W}\} \). Which one of the following is in \( S \)?
   a. 10  b. \((-4, -2)\)  c. \((15, 7.5)\)  d. \((6, 12)\)
4. Which one of the following is not a true statement?
   a. \( \{x : x \text{ greater than } 4, \ x \in \mathbb{W}\} = \{4, 5, 6, \ldots\} \)
   b. \( \{(x, y) : y = x, \ x \in \mathbb{W}\} = \{(0, 0), (1, 1), (2, 2), \ldots\} \)
   c. \( \{x : x \text{ less than } 0, \ x \in \mathbb{W}\} = \emptyset \)
   d. \( \{8, 3, 2\} = \{2, 3, 8\} \)
5. Which of the following sets equals \( P = \{(x, y) : y = 2x, \ x \in \mathbb{Q}\} \)?
   a. \( \{(x, y) : y = 2x\} \)
   b. \( \{(r, s) : r \in \mathbb{Q}, s = 2r\} \)
   c. \( \{(r, s) : r \in \mathbb{Q}\} \)
   d. \( \emptyset \)
6. Suppose \( M = \{(2, 8), (-7, 1)\} \). The set of first coordinates of pairs in \( M \) is
   a. \( \{2, 8\} \)  b. \( \{2, -7\} \)  c. \( \{-7, 1\} \)  d. None of the above.
7. Which of the following is not a true statement?
   a. \((2,5) = (5,2)\)
   b. \(42,5 \neq 45,2\)
   c. \(4(2,5), (3,4) \neq 4(3,4), (2,5)\)
   d. \(4 \neq \emptyset\)

8. Refer to diagram 9. The graph of \(4(x,y): y=2\) is (a/b/c/d)

9. The point corresponding to \((2,-5)\) is located
   a. 2 units above the x-axis and 5 units to the left of the y-axis.
   b. 2 units above the y-axis and 5 units to the left of the x-axis.
   c. 2 units above the x-axis and 5 units to the right of the y-axis.
   d. 2 units to the right of the y-axis and 5 units below the x-axis.

10. The graph of \((-2,-1)\) is the point of intersection of the lines,
    a. \(x=-1\) and \(y=-2\)
    b. \(x=-2\) and \(y=-1\)
    c. neither of the above
    d. both of the above

11. Refer to diagram 10. Which of the graphs is the graph of \(4(2,-1),(3,0),(-4,2)\)? (a/b/c/d)
12. Suppose \( a, b \) is a pair of non-zero whole numbers. In which of the following is the order of the two important?
   a. \( a/b \) b. \( a+b \) c. \( a-b \) d. none of the above.

13. The set of second coordinates of \( 4(x,y): y=2x, x \text{ in } \mathbb{W} \) is
   a. \( \{0,1,2,3,\ldots\} \)
   b. \( \{0,2,4,\ldots\} \)
   c. \( \{2\} \)
   d. \( \emptyset \)

14. Which of the following is not a set containing 4 elements?
   a. \( \{x: x \text{ in } \mathbb{Q}, x \text{ between } 1 \text{ and } 6\} \)
   b. \( \{0,1,2,3,2\} \)
   c. \( \{x: x \text{ in } \mathbb{W}, x \text{ between } 1 \text{ and } 6\} \)
   d. \( \{(0,1),(2,5),(-1,3),(1,7)\} \)

15. The best way to denote the set of rational numbers between 0 and 1 among the following is
   a. \( \{0,\frac{1}{2},\frac{1}{3},\frac{1}{4},\ldots\} \)
   b. \( \{0,1\} \)
   c. \( \{x: x \text{ between } 0 \text{ and } 1\} \)
   d. \( \{x: x \text{ in } \mathbb{Q}, x \text{ between } 0 \text{ and } 1\} \)

16. Which one of the following is a true statement?
   a. \( \emptyset = \{x: r \text{ between } 0 \text{ and } 1\} \)
   b. \( \{7\} = \{x: x \text{ between } 6 \text{ and } 8\} \)
c. \( f(x,y) : y = 2x, x \text{ in } W, x \text{ between } 0 \text{ and } 3 \) = \( f(1,2), (2,4) \)

d. \( g(x) : 2x+3 = 3 \)

17. The coordinates of the point of intersection of the line \( x = \frac{3}{2} \) and the line \( y = -0.3 \) are
   a. \( (\frac{3}{2}, 0.3) \)  b. \( (-0.3, \frac{3}{2}) \)  c. \( (.5, -\frac{3}{2}) \)  d. \( (.5, -3/10) \)

18. The name usually given to the point corresponding to \( (0,0) \) is
   a. origin
   b. x-axis
   c. y-axis
   d. empty set

19. The graph of \( f(x,y) : y = 7 \) is
   a. a vertical line 7 units to the right of the y-axis.
   b. a horizontal line 7 units above the x-axis.
   c. a circle with radius 7.
   d. a horizontal line 7 units to the right of the y-axis.

20. If \( S = \{ (\text{Jim}, 180), (\text{John}, 153), (\text{Jerry}, 180) \} \) represents three men paired with their weights, then which of the following is not a true statement?
   a. \( \{153, 180\} \) is the set of second coordinates of pairs in \( S \).
   b. Jerry weighs 180 pounds.
c. Jeff's weight is not found in S.
d. Jim weighs less than either John or Jerry.

O_1, Posttest on Unit B, Subunit 1

1. Which of the following is not a function?
   a. \( f(2,0) \)
   b. \( f(x,y): y=x^2 \)
   c. \( (0,1),(1,1),(2,1),(3,1),... \)
   d. \( f(x,y): y \text{ less than } x, x \text{ and } y \text{ in } W \)

2. The domain of the function defined by \( y=\frac{2x}{x-3} \) is understood to be
   a. \( \mathbb{R} \), the set of real numbers.
   b. all of \( \mathbb{R} \) except 0 and 3.
   c. all of \( \mathbb{R} \) except 3.
   d. all of \( \mathbb{R} \) except 0.

3. Which one of the following is a function?
   a. \( (2,3),(3,1),(2,4) \)
   b. \( (2,3),(3,1),(2,3) \)
   c. \( f(x,y): y \text{ less than } x \)

4. If the domain of \( f=(x,y):y=7 \) is \( \{1,2,3\} \), then the range of \( f \) is
   a. \( \{8,9,10\} \)
   b. \( \{7\} \)
   c. \( \{7,14,21\} \)
   d. \( \emptyset \)
5. If the range of \( g = 4(r, s) : s = 2r + 1 \) is \( \{5, 7, 9\} \), then the domain of \( g \) is
   a. \( \{2, 3, 4\} \)
   b. \( \{3, 4, 5\} \)
   c. \( \{11, 15, 19\} \)
   d. None of the above.

6. According to the strict definition of function, \( y < 5x \)
   a. is a function whose domain is \( \mathbb{R} \).
   b. is not a function, but \( y = 5x \) is.
   c. is not a function, but \( f(x, y) : y < 5x \) is.
   d. is not a function, nor is \( f(x, y) : y < 5x \).

7. A function defined by \( y = x + 1 \) is
   a. \( f(x, y) : y = x - 1 \)
   b. \( f(x, y) : y - 1 = x \)
   c. \( f(y, x) : y + x = 1 \)
   d. None of the above.

8. A function is
   a. a relationship between two variables.
   b. a set of ordered pairs in which no second coordinate is repeated.
   c. a set of ordered pairs in which no first coordinate is repeated.
   d. None of the above.

9. \( f(x, y) : y = 4 \) is a function whose range is
   a. \( y = 4 \)  b. \( \{4\} \)  c. 4  d. \( \mathbb{R} \), the set of real numbers
10. If $S=\{(x,y): y=2x+1, x \in W\}$, then which one of the following numbers is in the range of $S$?
   a. 31   b. 0   c. -3   d. all of the preceding

11. If $S=\{(x,y): y=\sqrt{1/x}\}$, then $S$ is a function whose domain is understood to be
   a. $\mathbb{R}$, the set of real numbers.
   b. the set of positive real numbers.
   c. the set of nonnegative real numbers.
   d. all of $\mathbb{R}$ except 0.

12. If $S$ is defined as in #11, the range of $S$ is
   a. $\mathbb{R}$, the set of real numbers.
   b. the set of nonnegative real numbers.
   c. the set of negative real numbers.
   d. None of the above is true.

13. If $g=\{(2,3),(4,3),(2,3)\}$, then
   a. $g$ is a function.
   b. $g$ is not a function because 3 is repeated.
   c. $g$ is not a function because 2 is repeated.
   d. None of the above is true.

14. If the domain of $f=\{(x,y): y=2x-2\}$ is $\{3,4,5\}$, then the range of $f$ is
   a. $y=2x-2$
   b. 4, 6, and 8
   c. 4, 8, 4
   d. both a and c
15. Which one of the following defines a function?
   a. \( y = x^2 \)
   b. \( p = 7q \)
   c. \( y = 4x^2 + 3 \)
   d. all of the above

**Posttest on Unit B, Subunit 2**

1. A set, \( S \), of points in the coordinate plane is the graph of a function if and only if
   a. No two points of \( S \) are on the \( y \)-axis.
   b. No two points of \( S \) are on the \( x \)-axis.
   c. No two points of \( S \) are in the same horizontal line.
   d. None of the above.

2. Suppose \( S = \{ (2,5), (-2,1), (-2,5) \} \). Then
   a. two points of the graph of \( S \) lie on the same horizontal line.
   b. two points of the graph of \( S \) lie on the same vertical line.
   c. \( S \) is not a function.
   d. all of the above are true.

3. Refer to diagram 13. Which one of the graphs is not the graph of a function? (a/b/c/d)

4. Refer to diagram 14. Which one of the graphs is the graph of a function? (a/b/c/d)

5. The graph of \( S = \{ (x,y) : x = 3 \} \) is
   a. a circle, hence \( S \) is not a function.
b. a horizontal line, hence $S$ is a function.
c. a point, hence $S$ is a function.
d. a vertical line, hence $S$ is not a function.

6. Refer to diagram 11. Which of the graphs is not the graph of a function? (a/b/c/d)

7. Refer to diagram 12. Which of the graphs is the graph of a function? (a/b/c/d)

8. If $f$ is a function, then $f(x)$ is best described as
   a. a function with $x$ in its defining rule.
   b. an element of the domain of $f$ corresponding to $x$ in the range of $f$.
   c. the element of the range of $f$ which corresponds to $x$, an element of the domain of $f$.
   d. $f(x)$ and $f$ are the same function.

9. Suppose $f(x) = 3x$ and the domain of $f$ is $W = \{0, 1, 2, \ldots\}$.
   Then $f(\frac{1}{3}) =$
   a. $\frac{1}{9}$
   b. $0$
   c. $1$
   d. None of the above.

10. Suppose $f = \{(0, 3), (1, 5)\}$ and $g = \{(r, s) : s = 2r - 1\}$.
    Then $2f(0) - g(2) =$
    a. $3$
    b. $-2$
    c. $2$
    d. $-3$

11. Suppose $g(x) = \frac{1}{x}$, then $g(0) =$
    a. $g(0)$ is not defined because $0$ is not in the domain of $g$.
    b. $0$
    c. $g(0)$ is not defined because $0$ is not in the range
12. Suppose \( g = \{(x, 2x)\} \) and \( f = \{(x, f(x))\} : f(x) = 3x \). Then \( f(g(2)) = \)
   a. 6x   b. 4   c. 12   d. 3

13. With \( g \) and \( f \) defined as in #12, \( g(f(8)) = \)
   a. 3   b. 6   c. 48   d. 16

14. Suppose \( T = \{(x, y) : y = x + 3\} \) and \( F = \{(x, y) : y = 2x\} \). Then \( T(F(x)) = \)
   a. 2(x+3)   b. y   c. 3x+3   d. 2x+3

15. If \( p = \{(s, t) : s \text{ in } W, t = 2s\} \), then \( p(\frac{1}{2}) = \)
   a. 1   b. -1   c. \( \frac{1}{4} \)   d. None of the above

O3, Attitude Scale

In this Attitude Scale, the term "computer assisted instruction" refers to the method of instruction employed in the computer units you have recently taken on the concept of function. There are 20 statements about computer assisted instruction, in general, and 10 more about the course "The Concept of Function," in particular. Consider each statement separately and indicate the extent to which you agree or disagree with it by circling the appropriate symbol to the right of the statement. The symbols used are: SA - Strongly agree; A - Agree; N - No opinion; D - Disagree; and SD - Strongly disagree. All responses will be treated confidentially.
1. I am very interested in learning about computer assisted instruction.

2. Teaching machines can individualize instruction more effectively than other methods.

3. Computer assisted instruction is an impersonal teaching approach.

4. Computer assisted instruction will improve instruction programs.

5. Computer assisted instruction challenges the student to do his best.

6. I would prefer to take a course by computer rather than by conventional instruction.

7. Use of teaching machines causes students to feel isolated.

8. Use of the computer for data processing activities is more important than use of the computer for instruction.

9. Computer assisted instruction is based on the same principles as good classroom teaching.

10. I am uneasy about the use of computers for teaching youth.

11. Computer assisted instruction can develop problem-solving techniques.
12. Teaching machines are inflexible media.
13. Most elementary students would be adversely affected by computerized instruction.
14. I would prefer to take a course by conventional instruction rather than computer assisted instruction.
15. Teaching by machine will tend to dehumanize the curriculum.
16. The advocates for computer assisted instruction should press harder for its adoption.
17. By using computer assisted instruction, a teacher will probably become a better teacher.
18. Computer assisted instruction threatens the teacher's role.
19. Educators will find computer assisted instruction techniques successful.
20. Computer assisted instruction hinders the social development of the student.
21. I felt I learned a lot about functions.
22. The course kept my interest.
23. The computer's explanations following my incorrect answers were very helpful.
24. I was interested at first, but then  became bored later on.
25. I understood nearly all of the explanations.
26. I would be interested in learning more mathematical concepts by using the computer.
27. I thought the tests did test what I learned very well.
28. I enjoyed the computer's use of my name in comments.
29. I felt I learned more on the computer than I would have in two days of classes on the same material.
30. I felt there should have been more explanations in the course.

Please comment on anything you feel was not covered above. Use the other side of this sheet if needed.

**Typing Test**

Please type the following information for me.

Type your full name.

(Student response)

Type the name of this university.

(Student response)

Type your class rank, that is, freshman, sophomore, etc.
Type your home town and state.

Type the date of your birth.
### RAW SCORES

#### First Pilot Study

**Math 150 Students**

<table>
<thead>
<tr>
<th>Student Number</th>
<th>Pretest Time</th>
<th>Unit A Time</th>
<th>Total Time</th>
<th>Pretest Score</th>
<th>Posttest Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>2300</td>
<td>--</td>
<td>--</td>
<td>95</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2270</td>
<td>--</td>
<td>75</td>
<td>91</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>2280</td>
<td>--</td>
<td>103</td>
<td>151</td>
<td>--</td>
<td>9</td>
</tr>
<tr>
<td>2080</td>
<td>14</td>
<td>58</td>
<td>100</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>2200</td>
<td>22</td>
<td>91</td>
<td>120</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>2030</td>
<td>--</td>
<td>90</td>
<td>126</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>2250</td>
<td>--</td>
<td>68</td>
<td>119</td>
<td>--</td>
<td>9</td>
</tr>
<tr>
<td>2020</td>
<td>--</td>
<td>119</td>
<td>138</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>2240</td>
<td>18</td>
<td>104</td>
<td>136</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>2040</td>
<td>14</td>
<td>64</td>
<td>96</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2290</td>
<td>--</td>
<td>90</td>
<td>164</td>
<td>--</td>
<td>6</td>
</tr>
</tbody>
</table>

#### Senior Honor Math Students

<table>
<thead>
<tr>
<th>Student Number</th>
<th>Total Correct on #4-10</th>
<th>Student Number</th>
<th>Total Correct on #4-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Student Number</td>
<td>Total Correct</td>
<td>No. Corr.</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Math IV Students

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>17</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>21</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>22</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>23</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>27</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>28</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Student Number</td>
<td>Total Correct on #4-10</td>
<td>No. Corr.</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>29</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>30</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>31</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>32</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>34</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>35</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>36</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>37</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Geometry Students

<table>
<thead>
<tr>
<th>Number</th>
<th>Total Correct on #4-10</th>
<th>No. Corr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>21</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Student Number</td>
<td>Total No. Corr. Correct on #4-10</td>
<td>Student Number</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>26</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Second Pilot Study**

**Math 151 Students**

<table>
<thead>
<tr>
<th>Student Number</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
<th>Unit B Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>97</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>94</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>-</td>
<td>--</td>
</tr>
</tbody>
</table>

**Math 150 Students**

<table>
<thead>
<tr>
<th>Student Number</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
<th>Att. Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>15</td>
<td>13</td>
<td>9</td>
<td>5</td>
<td>8</td>
<td>---</td>
</tr>
<tr>
<td>2060</td>
<td>12</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>+0.3</td>
</tr>
<tr>
<td>2250</td>
<td>17</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>---</td>
</tr>
<tr>
<td>2260</td>
<td>16</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>---</td>
</tr>
<tr>
<td>2320</td>
<td>15</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>---</td>
</tr>
<tr>
<td>Student Number</td>
<td>Test 1</td>
<td>Test 2</td>
<td>Test 3</td>
<td>Test 4</td>
<td>Test 5</td>
<td>Att. Score</td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>2030</td>
<td>19</td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>----</td>
</tr>
<tr>
<td>2230</td>
<td>15</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>+0.3</td>
</tr>
<tr>
<td>2020</td>
<td>17</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>7</td>
<td>+1.0</td>
</tr>
<tr>
<td>2080</td>
<td>19</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td></td>
<td>-0.1</td>
</tr>
<tr>
<td>2jc</td>
<td>14</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>-0.5</td>
</tr>
<tr>
<td>21n</td>
<td>--</td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>+1.0</td>
</tr>
<tr>
<td>2db</td>
<td>16</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>----</td>
</tr>
<tr>
<td>2020a</td>
<td>17</td>
<td>11</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>+0.6</td>
</tr>
<tr>
<td>2ce</td>
<td>19</td>
<td>15</td>
<td>9</td>
<td>5</td>
<td>7</td>
<td>+1.4</td>
</tr>
<tr>
<td>2020m</td>
<td>16</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td></td>
<td>----</td>
</tr>
<tr>
<td>2040</td>
<td>19</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>----</td>
</tr>
<tr>
<td>2240</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>+0.3</td>
</tr>
<tr>
<td>2050</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>----</td>
</tr>
<tr>
<td>2070</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>----</td>
</tr>
<tr>
<td>2ts</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>----</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Final Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Number</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>2002</td>
</tr>
<tr>
<td>2003</td>
</tr>
<tr>
<td>2004</td>
</tr>
<tr>
<td>2005</td>
</tr>
<tr>
<td>2006</td>
</tr>
<tr>
<td>Student Number</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>2008</td>
</tr>
<tr>
<td>2009</td>
</tr>
<tr>
<td>2023</td>
</tr>
<tr>
<td>2024</td>
</tr>
<tr>
<td>2025</td>
</tr>
<tr>
<td>2026</td>
</tr>
<tr>
<td>2028</td>
</tr>
<tr>
<td>2029</td>
</tr>
<tr>
<td>2032</td>
</tr>
<tr>
<td>2033</td>
</tr>
<tr>
<td>3002</td>
</tr>
<tr>
<td>3003</td>
</tr>
<tr>
<td>3004</td>
</tr>
<tr>
<td>3005</td>
</tr>
<tr>
<td>3006</td>
</tr>
<tr>
<td>3007</td>
</tr>
<tr>
<td>3008</td>
</tr>
<tr>
<td>3009</td>
</tr>
<tr>
<td>3023</td>
</tr>
<tr>
<td>3025</td>
</tr>
<tr>
<td>3026</td>
</tr>
<tr>
<td>3028</td>
</tr>
<tr>
<td>3029</td>
</tr>
<tr>
<td>3030</td>
</tr>
<tr>
<td>Student Number</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>3032</td>
</tr>
<tr>
<td>4002</td>
</tr>
<tr>
<td>4003</td>
</tr>
<tr>
<td>4004</td>
</tr>
<tr>
<td>4005</td>
</tr>
<tr>
<td>4006</td>
</tr>
<tr>
<td>4007</td>
</tr>
<tr>
<td>4008</td>
</tr>
<tr>
<td>4009</td>
</tr>
<tr>
<td>4023</td>
</tr>
<tr>
<td>4024</td>
</tr>
<tr>
<td>4025</td>
</tr>
<tr>
<td>4027</td>
</tr>
<tr>
<td>4028</td>
</tr>
<tr>
<td>4029</td>
</tr>
<tr>
<td>4030</td>
</tr>
<tr>
<td>5002</td>
</tr>
<tr>
<td>5003</td>
</tr>
<tr>
<td>5004</td>
</tr>
<tr>
<td>5005</td>
</tr>
<tr>
<td>5008</td>
</tr>
<tr>
<td>5009</td>
</tr>
<tr>
<td>5022</td>
</tr>
<tr>
<td>5024</td>
</tr>
</tbody>
</table>
Student Number*  Inst.*  O
Type  Unit A  Unit B  O
Test  Time  Time  O

<table>
<thead>
<tr>
<th>Student Number</th>
<th>Inst.</th>
<th>O</th>
<th>Type</th>
<th>Unit A</th>
<th>Unit B</th>
<th>O1</th>
<th>O2</th>
<th>O3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5025</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>76</td>
<td>89</td>
<td>7</td>
<td>12</td>
<td>110</td>
</tr>
<tr>
<td>5026</td>
<td>1</td>
<td>16</td>
<td>2</td>
<td>57</td>
<td>96</td>
<td>8</td>
<td>14</td>
<td>68</td>
</tr>
<tr>
<td>5027</td>
<td>1</td>
<td>11</td>
<td>4</td>
<td>89</td>
<td>108</td>
<td>6</td>
<td>6</td>
<td>63</td>
</tr>
<tr>
<td>5028</td>
<td>1</td>
<td>14</td>
<td>2</td>
<td>100</td>
<td>114</td>
<td>9</td>
<td>5</td>
<td>66</td>
</tr>
<tr>
<td>5029</td>
<td>1</td>
<td>13</td>
<td>3</td>
<td>66</td>
<td>72</td>
<td>7</td>
<td>5</td>
<td>74</td>
</tr>
<tr>
<td>5030</td>
<td>2</td>
<td>17</td>
<td>3</td>
<td>54</td>
<td>93</td>
<td>11</td>
<td>14</td>
<td>88</td>
</tr>
<tr>
<td>5023</td>
<td>1</td>
<td>19</td>
<td>3</td>
<td>85</td>
<td>98</td>
<td>14</td>
<td>12</td>
<td>82</td>
</tr>
</tbody>
</table>

* I'P' Cell: 200-3000; I'P'' Cell: 3000-4000;
  I''P' Cell: 4000-5000; I''P'' Cell: 5000-6000.
** 1 - Postier; 2 - Chittenden

TEST ANALYSES

O, Posttest of Unit A

Item Diff. - percent of students answering the item correctly.

Discrimination - number of students in the top 27% who answered the item correctly minus the number in the lowest 27% who answered it correctly divided by the total number in each 27% group.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item Diff.</th>
<th>Discrim. Index</th>
<th>Item Number</th>
<th>Item Diff.</th>
<th>Discrim. Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.2</td>
<td>.25</td>
<td>7</td>
<td>90.9</td>
<td>.17</td>
</tr>
<tr>
<td>2</td>
<td>84.1</td>
<td>.42</td>
<td>8</td>
<td>59.1</td>
<td>.42</td>
</tr>
<tr>
<td>3</td>
<td>45.5</td>
<td>.50</td>
<td>9</td>
<td>81.8</td>
<td>.33</td>
</tr>
<tr>
<td>4</td>
<td>68.2</td>
<td>.58</td>
<td>10</td>
<td>79.5</td>
<td>.33</td>
</tr>
<tr>
<td>5</td>
<td>79.5</td>
<td>.33</td>
<td>11</td>
<td>72.7</td>
<td>.25</td>
</tr>
<tr>
<td>6</td>
<td>86.4</td>
<td>.08</td>
<td>12</td>
<td>70.5</td>
<td>.33</td>
</tr>
<tr>
<td>Item Number</td>
<td>Item Number</td>
<td>Item Number</td>
<td>Item Number</td>
<td>Item Number</td>
<td>Item Number</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>13</td>
<td>86.4</td>
<td>.33</td>
<td>17</td>
<td>59.1</td>
<td>.50</td>
</tr>
<tr>
<td>14</td>
<td>52.3</td>
<td>.33</td>
<td>18</td>
<td>100.0</td>
<td>.00</td>
</tr>
<tr>
<td>15</td>
<td>79.5</td>
<td>.50</td>
<td>19</td>
<td>95.5</td>
<td>.08</td>
</tr>
<tr>
<td>16</td>
<td>38.6</td>
<td>.42</td>
<td>20</td>
<td>79.5</td>
<td>.42</td>
</tr>
</tbody>
</table>

_O₁, Posttest of Unit B, Subunit 1_

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51.7</td>
<td>.63</td>
<td>9</td>
<td>85.0</td>
<td>.00</td>
</tr>
<tr>
<td>2</td>
<td>65.0</td>
<td>.50</td>
<td>10</td>
<td>73.3</td>
<td>.44</td>
</tr>
<tr>
<td>3</td>
<td>45.0</td>
<td>.13</td>
<td>11</td>
<td>23.3</td>
<td>.56</td>
</tr>
<tr>
<td>4</td>
<td>81.7</td>
<td>.44</td>
<td>12</td>
<td>26.7</td>
<td>.31</td>
</tr>
<tr>
<td>5</td>
<td>73.3</td>
<td>.50</td>
<td>13</td>
<td>80.0</td>
<td>.19</td>
</tr>
<tr>
<td>6</td>
<td>35.0</td>
<td>.88</td>
<td>14</td>
<td>36.7</td>
<td>.50</td>
</tr>
<tr>
<td>7</td>
<td>78.3</td>
<td>.25</td>
<td>15</td>
<td>75.0</td>
<td>.50</td>
</tr>
<tr>
<td>8</td>
<td>91.7</td>
<td>.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

_O₂, Posttest of Unit B, Subunit 2_

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
<th>Item Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68.3</td>
<td>.63</td>
<td>7</td>
<td>86.7</td>
<td>.44</td>
</tr>
<tr>
<td>2</td>
<td>65.0</td>
<td>.50</td>
<td>8</td>
<td>68.3</td>
<td>.19</td>
</tr>
<tr>
<td>3</td>
<td>95.0</td>
<td>.19</td>
<td>9</td>
<td>41.7</td>
<td>.38</td>
</tr>
<tr>
<td>4</td>
<td>78.3</td>
<td>.31</td>
<td>10</td>
<td>65.0</td>
<td>.50</td>
</tr>
<tr>
<td>5</td>
<td>65.0</td>
<td>.63</td>
<td>11</td>
<td>48.3</td>
<td>.56</td>
</tr>
<tr>
<td>6</td>
<td>88.3</td>
<td>.31</td>
<td>12</td>
<td>28.3</td>
<td>.63</td>
</tr>
<tr>
<td>Item Number</td>
<td>Item Diff.</td>
<td>Discr. Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
<td>--------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>36.7</td>
<td>.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>40.0</td>
<td>.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item Number</td>
<td>Item Diff.</td>
<td>Discr. Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>46.7</td>
<td>.82</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Terminal locations: Arps 196
Main library (undergraduate reading room)

Further directions

I prefer that you use Arps 196. I will be there as much as possible, so if you have any technical difficulties, I'll help you out. My schedule will be:

Sat., Jan. 9 and 16
Sun., Jan. 10 and 17
M-F, Jan. 11 thru 15
Arps 196 8-5.
Arps 196 2-6
Arps 196 8-11 a.m.
Class 11-1 p.m.
Arps 196 1-3 p.m.
Class 3-5 p.m.
Arps 196 5-10 p.m.

I will also stop by at the beginning of your math class to get your reactions as we go.

If you wish to, you may use the main library terminals. To do so, go there and sign up for the times you want. Sign up for two blocks of time, the first one hour, the second one and a half hours. Then simply go there at those times and follow the directions on the attached sheet. Be sure to get a copy of the book of diagrams that accompanies the course to take with you.

If you must leave before you finish a unit, just type sign off and press the return key. Return to a terminal at another time. Sign on as usual and you will automatically be returned to the point at which you signed off. There is no way that you can mess up the computer program, so don't worry about that. You needn't worry about being embarrassed for being stupid either. The computer couldn't care less. So relax, but do your best, and enjoy the experience.

If you need help at times other than those I have listed, call my home (268-7863) of the CAI office (2-9821).

Hal Schoen

Times Scheduled:

Unit A ___________________________ Unit B ___________________________
INSTRUCTIONS FOR CAI SYSTEM USE

1. Turn on typewriter terminal.

2. Be sure switch on lower left of table is on COM.

3. Using the DATA Phone:
   a. Press the TALK button.
   b. Dial 2-3600.
   c. When you hear a high-pitched tone, press DATA button
   d. Replace the telephone receiver.

4. Using the typewriter:
   a. Type: s / (Then press the 'Return' key)
   b. When asked for the terminal ID:
      1. Enter what is below the space bar, eg. AP02
      2. If no terminal ID is available, enter the name of the building you are in.
   c. Press the 'Return' key.

5. When you finish your CAI session, turn off the typewriter terminal, the cover light, and the slide projector, if used.

6. Report difficulties to the local CAI aide
   or
   Call 2-9821 (use another phone, not your DATA phone, if possible).

Special Note:
You may take a non-credit 20 minute CAI program by typing

s2/demo ('Return' key)

or

s8/tour ('Return' key) You need slides for this program. Local CAI aide has them.
Dear Harold:

Please forgive me for not answering you sooner but I have just returned from Texas after spending two weeks there over the Christmas holidays. By all means use any or all of the attitude items that Ron may have supplied to you! I am enclosing the entire questionnaire that I will use in my study. I hope it will be of some use to you.

The reliability of the attitude instrument was computed using Hoyt's reliability, which is a form of the analysis of variance, at .9365. This was using 90 subjects who were either teachers or administrators or prospective teachers and administrators, who were students at Michigan State University. The standard error was 3.2420. If you should desire I will send you the entire set of statistics, response patterns, item weights, etc. Also in a few weeks I hope to have the validity statistics completed on the attitude scale and I will be happy to supply these to you if you're interested. If you decide to use any of these instruments please let me know of the results. Give Ron Christopher my best regards and tell him it looks like June before I will graduate. Keep plugging away at your program and I'll do the same. If there is anything else that I can do to help you please let me know.

Best wishes for your successful completion of the program.

Carlton (Robardey)
BIBLIOGRAPHY

CITED REFERENCES


18. Health Sciences Computing Facility, UCLA. BMD05V-General linear hypothesis.


REFERENCES NOT CITED


