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The Ohio State University, Ph.D., 1977
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A COMPARATIVE STUDY OF THE EFFECTIVENESS OF FOUR TYPES OF FEEDBACK IN A CAI UNIT ON ACHIEVEMENT IN MATHEMATICS OF ELEMENTARY EDUCATION MAJORS

DISSERTATION

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

by

Gary Eugene Thompson, B.S., M.A.

The Ohio State University
1977

Reading Committee:
Dr. Edwin Novak
Dr. Richard Shumway
Dr. Loren Stull

Approved by
Edwin J. Novak
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ACKNOWLEDGEMENTS

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FIELDS OF STUDY

Studies in Educational Research, Statistics, Experimental Design, Computer Applications to Education

Studies in Educational Psychology, Measurement, Learning

Studies in Mathematics Education, Curriculum Design, Instructional Methods, Research Methods
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</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 FIGURES</td>
<td>vili</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Rationale for the Study</td>
<td>1</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>6</td>
</tr>
<tr>
<td>Hypotheses</td>
<td>7</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>9</td>
</tr>
<tr>
<td>Assumptions and Limitations</td>
<td>10</td>
</tr>
<tr>
<td>of the Study</td>
<td></td>
</tr>
<tr>
<td>Overview of Succeeding</td>
<td>11</td>
</tr>
<tr>
<td>Chapters</td>
<td></td>
</tr>
<tr>
<td>II. REVIEW OF THE LITERATURE</td>
<td>13</td>
</tr>
<tr>
<td>Introduction</td>
<td>13</td>
</tr>
<tr>
<td>Proposed Preparation Levels</td>
<td>13</td>
</tr>
<tr>
<td>Professional Preparation Levels</td>
<td>18</td>
</tr>
<tr>
<td>Feedback Effects</td>
<td>22</td>
</tr>
<tr>
<td>CAI Programs for Elementary Mathematics</td>
<td>28</td>
</tr>
<tr>
<td>III. DEVELOPMENT OF THE INSTRUCTIONAL SYSTEM</td>
<td>30</td>
</tr>
<tr>
<td>Introduction</td>
<td>30</td>
</tr>
<tr>
<td>Requirements</td>
<td>30</td>
</tr>
<tr>
<td>Design</td>
<td>33</td>
</tr>
<tr>
<td>Management Subsystem Design</td>
<td>37</td>
</tr>
<tr>
<td>Evaluation Subsystem Design</td>
<td>39</td>
</tr>
<tr>
<td>Support Subsystem Design</td>
<td>40</td>
</tr>
</tbody>
</table>

iv
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of Semester Hours of Mathematics Required of Elementary Education Majors for Graduation by American Colleges</td>
<td>22</td>
</tr>
<tr>
<td>2. Changes in the Number of Semester Hours of Mathematics Required by Colleges of Elementary Education Majors for Graduation Over the Period 1962-66</td>
<td>22</td>
</tr>
<tr>
<td>3. A Summary of the Objectives of Each Instructional Module by Objective Number Used in Appendix B.</td>
<td>43</td>
</tr>
<tr>
<td>4. Summary of Bartlett's Test of Homogeneity of Variance for Original and Transformed Variables.</td>
<td>56</td>
</tr>
<tr>
<td>5. Summary of a Multivariate Analysis of Covariance of Posttest and Final with Pretest as a Covariate.</td>
<td>58</td>
</tr>
<tr>
<td>6. Plot of Transformed Posttest and Transformed Final Adjusted for the Covariate of Transformed Pretest</td>
<td>59</td>
</tr>
<tr>
<td>7. Means, Standard Deviations, and Number of Observations for Cells and Marginals of the Design to Test Hypotheses One Through Three for Pretest, Posttest and Final Raw Scores</td>
<td>60</td>
</tr>
<tr>
<td>8. Means, Standard Deviations, and Sample Size for Pretest Scores of All Students Tested and of Students Included in the Analysis</td>
<td>62</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>9. Summary of the Data Utilized to Test Hypothesis Four</td>
<td>66</td>
</tr>
<tr>
<td>10. Correlation Matrix of All Variables</td>
<td>68</td>
</tr>
<tr>
<td>11. Analysis of Variance and Plot of Cell Means for Online Time</td>
<td>70</td>
</tr>
<tr>
<td>12. Mean and Standard Deviations of Student Online Time by Group</td>
<td>71</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Graphic Representation of the Instructional System and Subsystems</td>
<td>34</td>
</tr>
<tr>
<td>2. Flowchart of the Instructional System</td>
<td>36</td>
</tr>
<tr>
<td>3. General Framework for Instructional Dialogue</td>
<td>45</td>
</tr>
<tr>
<td>4. A Representation of the Design to Study the Effects of Individualization and Personalization</td>
<td>54</td>
</tr>
<tr>
<td>5. A Representation of the Design to Compare the Scores of Students Receiving the CAI Approach with the Scores of Students Receiving the Traditional Program</td>
<td>64</td>
</tr>
</tbody>
</table>
CHAPTER I
PROBLEM STATEMENT

Rationale for the Study

The professional preparation of elementary teachers in mathematics content and mathematics teaching methodology has been a topic of discussion among educators and mathematicians from the turn of the century to the present. At the turn of the century the normal schools were responsible for the preparation of the majority of the elementary teachers. Little or no preparation in mathematics or teaching methodology was included in the curriculum. Throughout the century requirements for certification have been upgraded in terms of mathematics content and pedagogy. The certification requirements have not, in general, been upgraded to the levels recommended by mathematicians and educators.

A review of the mathematics education literature from 1900 to the present revealed a sequence of studies on the level of professional preparation of elementary teachers. Included were surveys of the requirements
for certification across institutions, comparative studies of levels of preparation as recommended by educators and mathematicians with the levels of preparation of practicing teachers and new graduates of colleges, and surveys of supervisory ratings of the competencies of practicing teachers. Willoughby (1969) has summarized the literature of the previous two decades on the mathematics preparation of elementary teachers. The general consensus from the literature is that elementary teachers in the United States are poorly prepared in mathematics in comparison to the rest of the college population and in comparison to their counterparts in many other countries.

Combining the literature on the desired preparation level in mathematics of elementary teachers with studies of the abilities of the graduates of teacher training institutions establishes that teacher training institutions are not graduating students with the desired capabilities in mathematics.

The elementary mathematics educator is in the center of this dilemma. Given a candidate who does not fully understand basic mathematics concepts included in the elementary school curriculum, the educator must produce a teacher who understands the
mathematics concepts to be developed in the elementary school and a teacher who is an expert on the methods for teaching those concepts to students. The educator is forced to utilize instructional time available for discussion of teaching methods to teach mathematics concepts.

Computer assisted instruction (CAI) is one possible solution to the problem confronting the mathematics educator. Gerard (1965) points out CAI has a number of benefits over the more traditional classroom approach, and among these the greatest is the potential of personalized tutoring. The computer has the capability of assisting each student in developing mathematical skills to a sufficient level of understanding to permit discussion of teaching methods for those skills. If a CAI program is utilized to develop the mathematical skills of each student, the mathematics educator can devote all of his instructional time to the discussion of teaching methods. The expected product of the approach utilizing CAI is a student who achieves better than a student in a conventional program on measures of mathematics content and knowledge of teaching methods.
A more localized concern is the proportion of instructional time spent in Education 502 classes at the Ohio State University teaching basic mathematics concepts to students in comparison to the proportion of instructional time spent on the discussion of teaching methods.

According to Gentile (1967) the three problem areas in CAI development are the technical (hardware) problems, the need for computer languages designed for CAI, and the need to determine the best kinds of programs to write. Concerning these three problem areas, he said:

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 (Gentile, 1967).

At least five areas of research on the development of CAI can be distinguished. They include: 1) investigation of step size; 2) the effects of cueing techniques; 3) the effects knowledge of results of feedback; 4) analysis of frame difficulty; and 5) organization of a programmed sequence according to a set of theoretical constructs. All of these areas have been investigated in research related to the recognized predecessor of CAI, programmed instruction.
However, in comparison to the other four areas only limited research has been conducted on the effects of different strategies of feedback in CAI.

At least one study (Schoen, 1971) has shown significant differences among groups of students utilizing the same CAI program with different feedback strategies. Schoen considered two feedback variables each with two levels yielding four combinations of feedback in a CAI program for college mathematics. The two levels of the first variable, personalization, are simply the presence or the absence of the student's name in feedback statements.

The second variable, individualization, involved the information provided the student following an incorrect response. Under the first level the student, following an incorrect response received feedback which states why his answer is incorrect and the correct answer. Under the second level of individualization the student following an incorrect response, received feedback which stated the correct answer and why it was correct, but did not refer to the student's answer specifically. The feedback for both levels of the individualization variable was identical following a correct response. As Schoen points out perhaps the important distinction between the two levels is
the information on why the correct response is correct. That is, the reasons why the correct answer is correct has more utility to the student than does an explanation of why his response is incorrect.

Schoen's findings have sufficient implications for the development of CAI programs to warrant replication with some refinement of the individualization variable on subjects of a different level of mathematical sophistication.

Development of CAI materials for all of the mathematical topics covered in Education 502 was considered to be beyond the scope of this study. The topic of rational numbers was selected based on the need for individualized tutoring in the content area as expressed by mathematics educators, the representativeness of the selected topic of the overall content of Education 502, and an appraisal of the anticipated effectiveness of CAI for the topic.

Purpose of the Study

The first purpose of this study was to compare the level of achievement in mathematics content of students receiving a combination of instruction in mathematics by CAI and classroom instruction devoted to teaching methods to the achievement of students receiving the traditional program.
The second purpose of the study was to investigate the effects of two levels of individualization and two levels of personalization in a CAI instructional unit upon the achievement of students in mathematics content and teaching methods. The two levels of the personalization variable was simply the presence or absence of the student's name in computer feedback. Under the first level of individualization following an incorrect response, a student received feedback that the response was incorrect and the correct response. Under the second level of individualization a student received feedback that the response was incorrect, the correct response, and the correct response, and the reasons why the correct response is correct.

Hypotheses

Four hypotheses were investigated in this study. In view of the conflicting findings from similar research reported in Chapter II, sufficient information did not exist to permit the author to state directional hypotheses for the current study. The hypotheses are stated in the null form.
The four hypotheses tested by the study were:

H₁: There is no significant difference in the level of achievement in mathematics content (posttest) and knowledge of teaching methods (final examination) between the two levels of personalization.

H₂: There is no significant difference in the level of achievement in mathematics content (posttest) and knowledge of teaching methods (final examination) between the two levels of individualization.

H₃: There are no significant differences in the level of achievement in mathematics content (posttest) and knowledge of teaching methods (final examination) among the four combinations of individualization and personalization.

H₄: There is no significant difference in the level of achievement in mathematics (posttest) between students receiving the traditional program and students receiving the CAI approach.
Definition of Terms

The terms used in this study were defined as follows:

Traditional program: The teaching of the content of Education 502 at the Ohio State University by lecture and question and answer during regularly scheduled class sessions.

CAI approach: The teaching of the content of Education 502 at the Ohio State University by lecture and question and answer during regularly scheduled class sessions and by instruction on mathematics content by CAI.

CAI module: A set of computer instructions designed to provide instruction relative to a set of behavioral objectives utilizing a computer terminal.

Feedback: The message given a student by a CAI module following a student response.

Instructional system: A set of materials and equipment organized to provide instruction for students in a behaviorally defined domain.

Rational number: A number of the form a/b where a and b are integers and b is not zero.
Disaffirmative feedback: Feedback indicating that the response given by a student is either incorrect or inappropriate.

Affirmative feedback: Feedback indicating that the response given by a student is either correct or appropriate.

Assumptions and Limitations of the Study

Assumptions relating to the study were:

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

2. The use of CAI materials to teach mathematics concepts to elementary education majors is practical and useful.

3. Random assignment of students to the four treatment groups insures that the effects of variables not controlled for in the study are distributed evenly across all four groups.

Some Limitations of the Study were:

1. The content of the CAI was limited to specified behavioral objectives regarding operations with rational numbers.
2. The sample was limited to students enrolled in Education 502 at the Ohio State University during Spring Quarter of 1974.

3. The study was designed to control only the personalization and individualization dimensions of feedback.

Overview of Succeeding Chapters

The review of literature relating to the study is summarized in Chapter II. The summary includes reports of the desired and actual professional preparation levels of elementary teachers. Selected literature relating to the development of a theory of instruction for CAI is included with particular emphasis on reports dealing with the effects of feedback. Finally, reports concerning CAI programs similar to the program developed for this study are summarized.

Chapter III contains a description of the processes involved in producing the CAI instructional system. The chapter is organized according to the four phases of requirements, design, production, and evaluation as defined by Rosove (1968).
The research methodology and analysis of results are reported in Chapter IV. Chapter V includes the interpretation of results, statement of conclusions, and suggestions for further research.
CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The literature reviewed in this section covers four topics:

1) the papers presenting proposed content requirement for the preparation of elementary teachers in mathematics

2) the literature on the level of professional preparation in mathematics of elementary teachers

3) the research reported on the effects of feedback in CAI programs upon achievement of students

4) the literature on the development of CAI programs similar in content to the program developed as part of this study.

Proposed Preparation Levels

At the turn of the century a large portion of the elementary school teachers were trained in normal schools where preparation in mathematics was not
emphasized. The liberal arts colleges were also becoming involved in the training of teachers at this time. Both institutions, however, were actively involved in supplying faculty for the newly developing and expanding high schools, and little attention was directed towards elementary teacher preparation.

During the first twenty years of the century:

There had evolved a point of view concerning the type of education needed by elementary teachers which had a definite effect on the amount of arithmetic or arithmetic methods in the teacher-education curriculum. This philosophy prescribed that primary teachers needed no special training in arithmetic and methods of teaching arithmetic, intermediate grade teachers needed some work in subject matter and in methods, particularly verbal problems and percentages, and teachers of upper elementary grades (those forming the junior high school) need some academic training in mathematics (Gibb, Karnes, & Wren, 1970).

In 1916 the Mathematical Association of America (MAA) appointed a committee on mathematical requirements to make recommendations for the mathematics program of the secondary schools. The report issued by the committee in 1923 did not regard the preparation (Gibb, et al., 1970) of arithmetic teachers as a recognizable function of a department of mathematics.

During the period from 1923 to 1945 some teacher training institutions began requiring six semester hours of content in mathematics and three semester
hours in methods. In 1944 the Commission on Post-War Plans of the National Council of Teachers of Mathematics (1944) issued a report in the form of thirty-four theses for the improvement of mathematics education. These 24 and 25 dealt specifically with the training of elementary teachers:

Thesis 24. All students who are likely to teach mathematics in grades 1-8 should, as a minimum, demonstrate competence over the whole range of subject matter which may be taught in these grades.

(For each teacher in grades 1-6 this criterion should be satisfied individually, if necessary, without course credit. An acceptable score on some acceptable standard examination would indicate competence. This criterion is not enough for teachers of grades 7 and 8. The teacher in these grades needs work beyond the elements of algebra, geometry, and trigonometry.)

Thesis 25. Teachers of mathematics in grades 1-8 should have special course work relating to subject matter (that he is going to teach) as well as to the teaching process.

The so called "new math" which evolved near the end of the fifties undoubtedly had an effect upon the proposed level of mathematics preparation of elementary teachers. Topics which were formerly restricted to high school or college were moved downward into the elementary school curriculum and many teachers were unprepared to teach the topics. In-service programs were originated to assist teachers in developing the
necessary skills, but the need for improved training of elementary teachers was becoming evident.

In 1961 the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America (1966) released its first recommendations for the preparation of teachers of elementary school mathematics. The text of the CUPM recommendations are reported below:

RECOMMENDATIONS FOR LEVEL 1

(Teachers of elementary school mathematics)

As a prerequisite for the college training of elementary school teachers, we recommend at least two years of college preparatory mathematics, consisting of a year of algebra and a year of geometry, or the same material in integrated courses. It must also be assured that these teachers are competent in the basic techniques of arithmetic. The exact length of the training program will depend on the strength of their preparation. For their college training, we recommend the equivalent of the following courses:

(A) A two-course sequence devoted to the structure of the real number system and its subsystems.
(B) A course devoted to the basic concepts of algebra.
(C) A course in informal geometry.

The material in these courses might, in a sense, duplicate materials studied in high school by the prospective teacher, but we urge that this material be covered again, this time from a more sophisticated, college-level point of view.

Whether the material suggested in (A) above can be covered in one or two courses will clearly depend upon the previous preparation of the student.

We strongly recommend that at least 20 percent of the Level I teachers in each school have stronger preparation in mathematics, comparable to Level II preparation but not necessarily including calculus. Such teachers would clearly strengthen the elementary program
by their very presence within the school faculty. This additional preparation is certainly required for elementary teachers who are called upon to teach an introduction to algebra or geometry.

The recommendations of the Cambridge Conference on Teacher Training (Education Development Center, 1967) as published represent an upgrading of the CUPM recommendations. The recommended sequence of courses for elementary teachers coming out of the Cambridge Conference parallel quite closely the CUPM Level II recommendations for teachers of the elements of algebra and geometry.

In 1971, CUPM published an entirely new set of guidelines for the mathematics content to be included in a teacher preparation program. Major changes in the elementary teacher preparation program are summarized by the Conference Board of the Mathematical Sciences National Advisory Committee on Mathematical Education (1975):

(1) to stress the integration and interrelationship of concepts and the unifying ideas of mathematics, design the recommended courses in a spiral organization with gradual development from informal to formal, concrete to abstract; (2) expand and modify the informal geometry to incorporate considerable treatment of transformational geometry and coordinate geometry; (3) include some (nearly 20% of the detailed guides) probability and statistics; and (4) stress applications (p.35).
In 1973 the Commission on Education of Teachers of Mathematics (CETM) of the National Council of Teachers of Mathematics (1973) published a set of guidelines for the pre-service preparation of teachers of mathematics. An analysis of the 1971 CUPM recommendations and the 1973 CETM guidelines (Board of the Mathematical Sciences National Advisory Committee on Mathematical Education, 1975) indicates that there are no major conflicts between the two sets of guidelines. The 1971 CUPM guidelines may entail more mathematical content than the CETM guidelines. The CUPM guidelines place more emphasis upon the unifying mathematical concepts while the CETM guidelines give greater emphasis to the practical use of instruments.

Within a period of fifty to sixty years the proposed levels of preparation in mathematics of elementary teachers has grown from no requirements at all to a level of preparation that rivals or exceeds the level of preparation of most secondary mathematics teachers at the turn of the century.

Professional Preparation Levels

As early as 1905 researchers were investigating the levels of preparation of the elementary teachers
in the area of mathematics. Smith (1905) suggested that the preparation of elementary teachers was a major problem since eighty percent of the elementary teachers were women who stayed in teaching only a short period of time. He was particularly critical of preparation in the area of mathematics.

Layton (1949) reported that only one-fourth of the 85 higher education institutions that he surveyed required mathematics for admission to a teacher-education curriculum. In addition the mean number of semester hours for a four year program in elementary education was 4.3 hours.

Grossnickle (1951) reported that more than three-fourths of the colleges responding to his questionnaire did not have any entrance requirements in mathematics for prospective elementary teachers and fewer than fifty percent required mathematics courses for teachers in the upper elementary grades. Of the 62 liberal art schools sampled only one college provided a course in mathematics for elementary teachers.

Ruddell, Dutton, and Reckzeh (1960) reported that although requirements for certification of elementary teachers had increased significantly, little change had occurred in the number of hours of mathematics required. Approximately two-thirds of the schools
surveyed did not require high school mathematics preparation of candidates for admissions. The average training in mathematics of the graduates of these institutions was equivalent to two years of high school mathematics, three semester credits in general mathematics, and two semester credits in teaching methods for mathematics.

Stipanowich (1957) concluded from a study of the opinions of 70 mathematics-educators at 66 institutions that many institutions were not providing adequate preparation in mathematics subject matter for students enrolled in elementary teacher education programs.

Carroll (1964) reported that elementary teachers score at about the eighth grade level on a standardized test of mathematics achievement. About the same time Brown and Abell (1965) reported that elementary teachers have poorer preparation in mathematics than the rest of the college population.

Young (1966) reported that 19 of a sample of 22 leading mathematics educators ranked teacher training as the most crucial problem currently facing the profession.
The Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America investigated the mathematics training requirements of over seven hundred colleges in 1962 and in 1966 (Committee, 1966). The results of the CUPM survey are presented in Table 1 and Table 2. At the time of the survey CUPM was proposing a twelve hour sequence in mathematics. It is a program which matched the CUPM recommendations with respect to number of hours of course work. However, the members of CUPM were encouraged by the growth from 1962 to 1966 in number of hours required as depicted in Table 2.

Combining the literature on the desired preparation level in mathematics of elementary teachers with studies of the elementary teacher preparation programs and studies of graduate of teacher training institutions establishes that teacher training institutions are not graduating students with the desired capabilities in mathematics.
TABLE 1

Number of Semester Hours of Mathematics Required of Elementary Education Majors For Graduation by American Colleges

<table>
<thead>
<tr>
<th>Hours</th>
<th>Number of Colleges 1962</th>
<th>Number of Colleges 1966</th>
<th>Percentage of Colleges 1962</th>
<th>Percentage of Colleges 1966</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>173</td>
<td>75</td>
<td>22.7</td>
<td>8.3</td>
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<tr>
<td>1-2</td>
<td>39</td>
<td>29</td>
<td>5.1</td>
<td>3.2</td>
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<tr>
<td>3-4</td>
<td>308</td>
<td>345</td>
<td>40.4</td>
<td>38.3</td>
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<td>5-6</td>
<td>209</td>
<td>339</td>
<td>27.4</td>
<td>37.6</td>
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<td>7-8</td>
<td>17</td>
<td>63</td>
<td>2.2</td>
<td>7.0</td>
</tr>
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<td>9-10</td>
<td>11</td>
<td>40</td>
<td>1.4</td>
<td>4.4</td>
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<tr>
<td>11-12</td>
<td>5</td>
<td>10</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Total</td>
<td>762</td>
<td>901</td>
<td>99.9</td>
<td>99.9</td>
</tr>
</tbody>
</table>

TABLE 2

Changes in the Number of Semester Hours of Mathematics Required by Colleges of Elementary Education Majors For Graduation Over the Period 1962-1966

<table>
<thead>
<tr>
<th>Change in Less Than</th>
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<tbody>
<tr>
<td>Hours</td>
</tr>
<tr>
<td>+12</td>
</tr>
<tr>
<td>+10</td>
</tr>
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<td>+8</td>
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<td>+7</td>
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</tr>
<tr>
<td>Number of Colleges</td>
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<td>3</td>
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<td>34</td>
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<td>61</td>
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</table>

Feedback Effects

A number of studies were identified which dealt specifically with the effects of feedback in a CAI instructional unit. Keats and Hansen (1970) investigated the relative effects of verbal definitions and numerical examples as modes of feedback to an incorrect response
in a CAI task for ninth grade students. They concluded:

......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).

Gilman (1969) studied the effects of five levels of feedback upon the rate of original learning and immediate retention. The rate of original learning was based upon the degree-of-certainty estimates given by subjects for responses to program questions. Retention was established from degree-of-certainty estimates to posttest items administered to subjects. The five feedback modes considered were: 1) no feedback, 2) feedback of "correct" or "wrong", 3) feedback of the correct response choice, 4) feedback appropriate to the subject's response, and 5) a combination of modes of 2, 3, and 4 above. The subjects in groups 3, 4, and 5 scored significantly higher than subjects in groups 1 and 2 on the mean degree-of-certainty estimates for a second iteration of the program.

Majer (1968) studied the effects of five feedback conditions upon the achievement of subjects in a CAI learning task. The five conditions he defined were common reinforcement, high reinforcement, low
reinforcement, knowledge of results, and state reinforcement. Following an incorrect response the subjects under each condition received: 1) a hint, 2) the correct answer, or 3) a rule, usually preceded by the word "incorrect". Majer concluded that there was a significant advantage in verbal reinforcement over simple knowledge of results in reducing the terminal time required by subjects to learn a set of materials.

Goss (1965), based on a study with paired associate learning, reports that as the response integration and associative strength between stimulus and response items increases, the correct response becomes less necessary for the maintenance of correct responses by the subject. This finding would suggest that provision of the correct response to a question is of minimal value if the subject has responded correctly to a number of similar items.

Rothkopf (1968) studied the effects of providing the correct answer after each response to questions on a five thousand word passage which students read. Based on a sample of 159 college students, Rothkopf found no significant difference in the number of questions answered correctly between the students who received the correct answer after each question and those who did not.
Majer, Hansen, and Dick (1971) found that students receiving verbal praise feedback took significantly less time to complete a CAI unit than did those who received no verbal praise.

Lublin (1965) studied the effects of four levels of reinforcement on achievement among students in a psychology course. The four schedules of reinforcement considered were continuous, fixed-ratio fifty percent, variable-ratio fifty percent, and no reinforcement. The no reinforcement and variable-ratio fifty percent reinforcement groups scored significantly higher on achievement measured than the continuous reinforcement groups.

Anderson (1970) found that students who received immediate knowledge of a correct response learned significantly more than either students who were not provided with knowledge of a correct answer before responding. Students who received feedback after wrong responses only performed slightly better than students who received feedback only after right answers on measures of the content being taught.

Schoen (1971) investigated the effects of two feedback variables each with two levels yielding four combinations of feedback strategies in a mathematics course for college freshmen. The two levels of the
first variable, personalization, consisted simply of the presence or absence of the student's name in feedback. The two levels of the second variable, individualization, were defined as: 1) the student, following an incorrect response, receives feedback which states why his answer is incorrect and the correct answer, and 2) 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. The feedback to correct response was identical for both levels of individualization variables. Schoen found that students receiving the second level of individualization achieved significantly higher \((p < .04)\) on posttest than did students receiving the first level of individualization. No significant differences were found among the treatment groups on attitude towards CAI and the particular CAI unit of instruction.

Craig (1972) replicated Schoen's study with high school freshmen and found significantly higher attitudes toward CAI among students who received the first type of individualized feedback. No other significant differences were observed. In comparison with Schoen's findings, it appears that different age groups of students or students with different levels of mathematical
training respond differently to the four levels of feedback.

Keats and Hansen (1972) found that providing correctional feedback in the form of a verbal definition is of more benefit to the learner than using a numerical example for CAI presentations of mathematical proofs. However, no significant differences were found between the two forms of feedback with respect to acquisition and retention of knowledge as measured by a posttest.

Kaufman (1973) investigated the effects of three types of feedback to incorrect responses in a CAI unit on calculus. The three levels were defined by varying the information content of the feedback. The levels were response-sensitive, response-insensitive, and no correctional feedback. Students who received response-insensitive feedback exhibited significantly fewer errors in responding to items within the CAI unit than did students who received no correctional feedback.

Schoen and Kreye (1974) found that students receiving feedback on homework directed specifically to an incorrect response scored significantly higher on a test of retention than did students who received feedback which provided a general explanation of the
correct answer. The two forms of feedback utilized are the same as in an earlier CAI study by Schoen (1971).

In summary, under certain conditions the use of verbal feedback in a CAI program has a positive effect upon student learning. Several studies have concluded that feedback of the correct response has the most utility for the learner following an incorrect response. Beyond this limited base of knowledge, information regarding the effects of characteristics of feedback on learner outcomes are not reported in the literature reviewed.

CAI Programs for Elementary Mathematics

Three computer-assisted instruction programs developed for use in elementary teacher education programs in mathematics were identified. Riedesel and Suydam (1969) developed a set of fourteen tutorial, adaptive modules each of one hour duration. The results of the development process were reported, but a study of the relationship of the programs to student achievement was not completed.

Lund and Rothbart (1969) developed a tutorial computer-assisted instruction program to reinforce selected mathematical concepts among students in an
elementary mathematics education class. The program, written in TUTOR, requires both a keyboard terminal and television display. No published results regarding utilization of the program are available.

Hall (1974) found that the achievement level in mathematics of elementary teachers improved when teachers used a CAI course on mathematics methods and content. The course was designed to provide inservice for practicing teachers, and the supporting computer was housed in a mobile laboratory.

Based on a review of published research Jamison, Dean, and Supps (1974) concluded that at the secondary school and college level CAI is about as effective as traditional instruction when it is used as a replacement. Frequently CAI results in substantial savings of student time. As the relative cost of technology decreases in comparison to the cost of labor, the use of CAI will become more prevalent.
CHAPTER III
DEVELOPMENT OF THE INSTRUCTIONAL SYSTEM

Introduction

The purpose of this chapter is to describe the processes in the development of the instructional system. The processes are discussed within the framework of the phases of development of requirements, design, production, and evaluation as defined by Rosove (1968).

Requirements

The instructional system must provide for the evaluation of student achievement of the instructional objectives through criterion-referenced testing. The student should be tested prior to each instructional module to determine if he needs to complete the module and at the completion of a module to determine if he has achieved the criterion level.

The instructional system must provide control over the progress of each student through the system and schedule the instructional modules the student is to receive.
The instructional system must provide information to each student concerning their progress. The student should be provided feedback on the criterion-referenced tests administered prior to and after each module of instruction. In addition, the student should be able to initiate a summary of the number of objectives completed, the number of objectives remaining to be completed, and if requested, a listing of objectives completed or remaining to be completed.

The instructional system must provide the course instructor with information regarding the progress of each student. Specifically, the instructor must be able to request a report on an individual student which includes name, student identification number, a list of objectives completed, the number of hours of instruction received, and the date of the last instruction.

The instructor should be able to set the number of items per objective in the criterion-referenced tests and the criterion level for each test.

The instructional system should be compatible with IBM 2741 terminals and Hazeltine 2000 terminals utilized at the Ohio State University. The system should be developed utilizing a computer language supported by an appropriate computer facility at the Ohio State University.
The system must provide computer assisted instruction relative to a finite number of behavioral objectives through instructional modules. The author and Dr. Loren Stull went through a three step process in defining the requirements of the CAI instructional modules. First, a description of the mathematics content necessary for Education 502 was developed in topical outline form. The outline is included in Appendix A.

The development of a complete set of CAI modules for the entire course content was determined to be beyond the scope of this study. However, the area of operations on rational numbers was chosen based upon the need for individual tutoring in the content area as expressed by mathematics educators, the representativeness of the selected content area of the overall content outline, and an appraisal of the anticipated effectiveness of CAI for the content area.

In the final step of defining the instructional requirements of the CAI unit, behavioral objectives for the area of rationals were developed jointly by Dr. Stull and the author. The twenty-nine objectives are included in Appendix B.
Design

The instructional system which was developed may be considered to be comprised of four subsystems as depicted in Figure 1. The four subsystems were the instructional, support, evaluation, and management subsystems. Each subsystem was comprised of one or more modules. All the subsystems and constituent modules were designed to meet one or more of the specified requirements of the instructional system.

The instructional subsystem provided students with teletype dialogue organized to develop achievement of specified behavioral objectives at the criterion level. Each instructional module within the subsystem provided instruction relative to a set of logically related behavioral objectives.

The evaluation subsystem provided criterion-referenced measurement of a student's achievement prior to and following the completion of an instructional module. The subsystem presented items to students, evaluated responses, compared student achievement levels to criterion levels, and provided information on criterion achievement to the student and to the management subsystem.

The management subsystem scheduled student involvement in the other subsystems and provided
FIGURE 1

GRAPHIC REPRESENTATION OF THE INSTRUCTIONAL SYSTEM AND SUBSYSTEMS
information to the instructor regarding student activities in the instructional system. For example, the management subsystem directed the student to the next instructional module the student was to complete based upon the modules the student had completed. The subsystem also permitted the instructor to monitor the objectives the student had achieved, or the amount of time the student had been on the system.

The support subsystem was comprised of modules which facilitated the student in completing the instructional module. A student could also initiate a list of objectives of an instructional module through the instructional support subsystem. Finally, the support subsystem contained modules to provide instruction which was prerequisite to successful completion of an instructional module but was not specified in the behavioral objectives of the instructional module.

A flowchart of the system is presented in Figure 2. The students received introductory information about the instructional system prior to being scheduled into the first module. The program established the criterion level and number of items per objective from instructor input or assumed default values. Test items were presented to students from an item pool.
FIGURE 2

FLOWCHART OF THE INSTRUCTIONAL SYSTEM
If the criterion level was achieved, the student had the alternative of receiving instruction on the module or taking the criterion-referenced test for the next instructional module. If the criterion level was not achieved, the student was scheduled into the appropriate instructional module. Upon completion of the module, the student was retested. If the criterion level was achieved, the student was scheduled into the test for the next module. If the criterion level was not achieved, the student was provided with a set of suggested study activities, directed to see the instructor, scheduled for the criterion-referenced test for the module, and signed off the system.

A computer language for developing the system was chosen based on the criteria that the language could be utilized to meet the requirements of the instructional system and that the computer language was supported by an appropriate Ohio State University computer facility. Based on the two criteria COURSEWRITER III was chosen as the language for the system.

Management Subsystem Design

The management subsystem was designed to meet the following requirements of the instructional system:
1. to provide control over the progress of each student through the instructional activities.

2. to provide the course instructor with information regarding the progress of each student.

3. to provide the course instructor with the ability to set the number of items per objective and the criterion level for each criterion-referenced test.

The management subsystem was developed by modifying Computer Managed Instruction (CMI), a COURSE-WRITER III program developed by the computer-assisted instruction department of the Ohio State University (Allen, Meleca, & Myers, 1972). The program was modified to branch from the management subsystem to modules of the instructional subsystem under two conditions. A student who did not complete the criterion-referenced test for an instructional module at the criterion level is branched to the appropriate instructional module. A student who completed the criterion-referenced test for an instructional module at or above the criterion level was provided the option of completing the instructional module. Upon completion of any instructional module, control was returned to the management subsystem.
Reports required for the course instructor were a part of CMI. The instructor could enter the number of items per objective and the criterion level for each criterion-referenced test by inserting appropriate COURSEWRITER III coding at the proper place within the management subsystem.

The modified version of CMI had additional capabilities not specified as requirements of the instructional system. The instructor could specify the order in which instructional modules were to be taken, modules which were prerequisites for other modules, modules which were required of students, and modules which were optional for students.

Evaluation Subsystem Design

The evaluation subsystem was designed to present criterion-referenced items selected randomly from a pool of items, to evaluate the responses of students to each item, and to compare the performance of each student to the criterion level of performance.

Test items for each instructional objective were chosen randomly without replacement from a pool of items designed to measure the objective. In addition, the subsystem provided for the evaluation of each objective at any or all of three cognitive levels as
specified by the instructor. The three cognitive levels were condensed from Bloom's Taxonomic Criteria (1965) as follows: level A items included knowledge and comprehension measurements; level B items included application and analysis items; and level C included synthesis and evaluation measurements (Allen, et al., 1972).

The instructor could set the number of objectives in the module, the number of items of each cognitive level to be administered for each objective, and the criterion performance level for the module. The test items were entered by the instructor utilizing a generalizable COURSEWRITER III coding scheme. The scheme required the instructor to enter multiple choice items with three or four alternatives and the correct alternative.

The subsystem evaluated the responses of students to each item and created a record of the response on disk for subsequent batch processing of item responses utilizing classical item analysis procedures.

Support Subsystem Design

The support subsystem was designed to facilitate student completion of instructional modules. The subsystem permitted each student to initiate a request for a list of objectives he had not mastered, to obtain
an explanation of any objective, and to obtain a summary of his current status in terms of modules completed.

The support subsystem included a glossary of terms used in the CAI modules. A student could refer to the glossary at any polling point in a CAI module. The coding in the glossary module permitted the student to request the definition of any word and searched the glossary entries for that word or its phonetic equivalent (Allen, 1973). If the word was contained in the glossary, the student was provided the definition and given the option of requesting the definition of another word or returning to the CAI module. If the word was not contained in the glossary, the student was informed that the word was not in the glossary and was given the option of requesting the definition of another word or returning to the CAI module. A record was written to disk of words not found in the glossary for subsequent retrieval and consideration for inclusion in the glossary.

The support subsystem also included instructional support modules which were designed to provide instruction relative to objectives which were prerequisites of objectives contained in an instructional module. The instructional support modules were designed to be
entered from any point in a CAI instructional module and to return control to that point when the instructional support module was completed. For example, finding the least common denominator (LCD) for two fractions has as a prerequisite the skill of decomposing a composite number into its prime factorization. If in the CAI instructional module on finding the LCD, it was determined that the student could not decompose a composite number into its prime factorization, control was branched to the instructional support module on prime decomposition. Upon completion of instruction on prime decomposition, control was returned to the CAI module at the point at which instruction on finding the LCD was initiated.

The support subsystem contained two instructional support modules. The modules provided instruction relative to finding the least common denominator and reducing a fraction to lowest terms.

Design of the Instructional Subsystem

The instructional subsystem was comprised of instructional modules which were designed to provide computer assisted instruction for students relative to a finite number of behavioral objectives. The
twenty-nine objectives defined for rational numbers were partitioned into four modules based upon either the arithmetic operation included in the objective or based on the objective being a prerequisite for performing the operation. The four modules, in the order students were to complete them, were addition of rationals, subtraction of rationals, multiplication of rationals, and division of rationals.

Table 3 shows the objectives included in each module.

**TABLE 3**

**A Summary of the Objectives of Each Instructional Module by Objective Number Used in Appendix B**

<table>
<thead>
<tr>
<th>Instructional Module</th>
<th>Objective Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition to Rationals</td>
<td>1, 2, 3, 4, 5, 18, 19, 20, 29</td>
</tr>
<tr>
<td>Subtraction of Rationals</td>
<td>6, 7, 8, 9, 21, 22, 23, 24</td>
</tr>
<tr>
<td>Multiplication of Rationals</td>
<td>10, 11, 12, 13, 25, 26</td>
</tr>
<tr>
<td>Division of Rationals</td>
<td>14, 15, 16, 17, 27, 28</td>
</tr>
</tbody>
</table>

Within each module the objectives were analyzed for interdependencies, and objectives were organized in order of prerequisites to permit a logical development of instructional dialogue relative to the objectives.
Figure 3 illustrates the logic employed within the dialogue developed for a specific behavioral objective. Two of the thirty-two COURSEWRITER III switches for each student were designated to indicate the levels of the personalization and the individualization variable which the student was to receive. If switch thirty was "off", the name of the student was to appear in feedback; otherwise, it was not. If switch twenty-nine was "off", the student was to receive disaffirmative feedback and the correct answer following an incorrect response to a question. If switch twenty-nine was "on", the student was also provided with reasons why the correct answer is correct. Following a correct response to a question, the student received either personalized affirmative feedback or affirmative feedback dependent upon the status of switch thirty.

The affirmative and disaffirmative feedback phrases were chosen at random with replacement from an appropriate set of feedback phrases. If a student was to receive personalized feedback, the student's first name was concatenated with the randomly chosen feedback phrase. All affirmative and disaffirmative feedback processing was performed by a COURSEWRITER III subroutine.
FIGURE 3
GENERAL FRAMEWORK FOR INSTRUCTIONAL DIALOGUE
The following frame illustrates feedback given a student receiving the first level of individualization after an incorrect response.

**PROBLEM:** \( \frac{1}{2} + \frac{1}{4} = ? \)

(student response)

Sorry, your answer is incorrect.
The correct answer is \( \frac{3}{4} \)

Under the second level of individualization an incorrect to the same frame would result in the following feedback:

**PROBLEM:** \( \frac{1}{2} + \frac{1}{4} = ? \)

(student response)

Sorry, your answer is incorrect.
The correct answer is \( \frac{3}{4} \).

When adding fractions with unlike denominators, we first change both fractions to the lowest common denominator \( \frac{2}{4} + \frac{1}{4} = \frac{3}{4} \) and then add the numerators.

**Production**

The evaluation subsystem and management subsystem were developed by modifying CMI (Allen, et al., 1973). The required modifications to CMI were completed first since the evaluation subsystem could be pilot tested and debugged as soon as the modifications were made and since only a few hours were necessary to make the modifications.

The instructional support modules and instructional modules were all developed by the same process. Instructional dialogue was coded to achieve each instructional objective within the general framework designed
for dialogue described previously. Dialogue was coded to provide transition between instruction relative to each objective.

Within the dialogue relating to a specific objective, information was maintained on the number of correct and incorrect responses to questions by each student. The percent of correct responses was utilized to make the decision to branch a student to the instruction for the next objective, to branch a student to additional instruction relative to the current objective, or to branch a student to an instructional support module. The level of percent of correct responses which was accepted as an indicator of mastery of the concept measured by a set of questions varied from seventy-five to ninety percent throughout the instructional modules. The highest levels of performance were required on questions concerning concepts of which mastery was mandatory for successful completion of the module as judged by the author of the module.

The glossary module of the instructional support subsystem was coded according to the specified design. The author, based on his teaching experience, selected the initial terms to include in the glossary.
Evaluation

After the coding for a module had been entered through a computer terminal, the author completed each module as a student and made necessary corrections to the coding so that the module functioned properly.

Each module was then completed by three judges, one at a time. Corrections and modifications suggested by each judge were made and checked by the author before the next judge completed the module. The mathematics background and classroom experience of the three judges were varied. One judge was a junior high school student, the second was a high school student who had completed three years of high school mathematics, and the third was a practicing elementary school teacher.

When the corrections and modifications suggested by all three judges had been incorporated into a module, the module was considered to be ready for the experimental study of the effects of individualization and personalization (Meredith, 1971).
CHAPTER IV
RESEARCH METHOD AND DATA ANALYSIS

Introduction
This chapter is organized into two sections. The first section contains a description of the methodology, the research design, statements of all the hypotheses to be tested by the design, and descriptions of the measurement instruments employed. The second section discusses the data analysis which includes the test of all the stated hypotheses of the study along with an analysis of other data collected.

Method
One of the purposes of this study was to investigate the effects of two levels of individualization and two levels of personalization in a CAI instructional unit upon the achievement of students in mathematics content and teaching methods. The two levels of the personalization variable were simply the presence (P1) or the absence (P2) of the student's name in feedback. Under the first level of individualization (II) following an incorrect response, the student
received feedback that the response was incorrect and the correct response. Under the second level of individualization (I2) following an incorrect response, the student received feedback that the response was incorrect, the correct response, and the reasons why the correct response is correct. Examples of the two levels of individualization were provided in Chapter III.

The other purpose of this study was to compare the level of achievement in mathematics content of students receiving a combination of instruction in mathematics by CAI and classroom instruction devoted to teaching methods to the level of achievement of students receiving only classroom instruction.

To investigate the effects of the individualization and personalization variables, the author developed a computer-based instructional system which included four instructional modules. Each of the four instructional modules can incorporate any combination of the two levels of personalization and two levels of individualization in feedback to students completing the modules. Crossing the two levels of individualization with the two levels of personalization yields four feedback treatment strategies. The particular combination of personalization and
individualization which a student received was determined by the area number assigned to the student during the registration process for COURSEWRITER III. Students enrolled in two sections of Education 502 at the Ohio State University during the Spring Quarter of 1974 were randomly assigned one of four consecutive area numbers. The feedback strategy each student received was determined by the modulo four equivalent of the randomly assigned area number.

The level of achievement of each student in mathematics content was measured during the first class session by administering "A Test of Basic Mathematical Understandings" (TBMU) (Glennon, 1960). Students completed the CAI modules at their convenience during the sixth through tenth week of the quarter. Instructional modules could be completed on any computer terminal on campus. However, the criterion-referenced test for each module could only be completed on either of two Hazeltine 2000 terminals available to students. The Hazeltine 2000 terminals were used for the criterion-referenced testing to prevent students from acquiring printed copy of test items.

The level of achievement of each student was measured by administering the TBMU during the final examination period for the course. The level of
knowledge of teaching methods was based upon the raw score of each student on the final examination for the course developed by the instructor. Also, at the time of the final examination, each student was asked to complete an instrument to assess general attitude toward CAI.

Based upon data collected from previous Education 502 classes the average change from the first meeting of the class until the final examination period on the TBMU was established as six raw score points. The average change score serves as a basis for comparing the achievement of the students receiving the CAI approach with the achievement of students receiving only classroom instruction.

Instruments

Three instruments were utilized to collect data for this study. "A Basic Test of Mathematical Understanding" was developed by Glennon (1960) specifically for elementary education majors. The instrument has been used historically in Education 502 as a measure of knowledge of basic mathematics. A copy of the instrument is included in Appendix C.

The final examination for Education 502, Spring Quarter, 1974 was developed by the course instructor
to measure the content of the course. It is comprised of multiple choice items, completion items, short answer items, and an essay question. A copy of the final examination is included in Appendix C.

The attitude of students toward CAI was assessed utilizing an instrument to assess general attitude toward CAI developed by Carlton P. Robardey (1971) at the University of Michigan. The instrument consists of twenty statements concerning CAI. Students express agreement or disagreement with the statements on a five point Likert scale. A copy of the instrument is included in Appendix C.

Data Analysis

The design to test the effects of individualization and personalization in a CAI instruction module is depicted in Figure 4. The three null hypotheses tested were:

$H_1$: There is no significant difference in the level of achievement in mathematics content (posttest) and knowledge of teaching methods (final) between the two levels of personalization.

$H_2$: There is no significant difference in the level of achievement in mathematics
content (posttest) and knowledge of teaching methods (final) between the two levels of individualization.

$H_3$: There are no significant differences in the level of achievement in mathematics content (posttest) and knowledge of teaching methods (final) among the four combinations of personalization and individualization.

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th></th>
<th>P2</th>
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</thead>
<tbody>
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<td>01</td>
<td>02</td>
<td>01</td>
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<td></td>
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<tr>
<td></td>
<td>03</td>
<td>02</td>
<td>03</td>
</tr>
</tbody>
</table>

01 - Pretest raw score on "A Test of Basic Mathematical Understandings"

02 - Posttest raw score on "A Test of Basic Mathematical Understandings"

03 - Raw score on the final examination in Education 502

FIGURE 4

A Representation of the Design to Study the Effects of Individualization and Personalization
The three hypotheses were tested utilizing a multivariate analysis of covariance of the posttest score on the TBMU and the final examination score as dependent variables and the pretest on the TBMU as the covariate. The general model for the analysis of covariance was:

\[ Y_{ijk} = U + A_i + B_j + AB_{ij} + R_{xy} + E_{ijk} \]

\[ i = 1, 2 \]

\[ j = 1, 2 \]

\[ k = 1 \text{ to the number of subjects in the } i\text{th, } j\text{th cell of the design} \]

The components of the model were all one by two vectors with one element for each of the dependent variables. \( R_{xy} \) represents an estimate of each dependent variable based upon a linear relationship with the covariate. The errors, \( E_{ijk} \), were assumed to be distributed according to a bivariate normal distribution with an expected value of zero and variance \( \sigma^2 \). In addition, it was assumed that the correlation between errors of measurement for each dependent variable was zero. The data were analyzed utilizing the MANOVA (Clyde, 1969) computer program at the Instruction and Research Computer Center of the Ohio State University.
Bartlett's tests of the null hypotheses of homogeneity of variance of the pretest, posttest, and final examination scores in each cell of the design are summarized in Table 4. The null hypothesis of homogeneity of variance of the final examination was rejected (p < .01).

**TABLE 4**

Summary of Bartlett's Test of Homogeneity of Variance for Original and Transformed Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Chi-Square</th>
<th>df</th>
<th>P</th>
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<tbody>
<tr>
<td>Pretest raw scores</td>
<td>3.09</td>
<td>3</td>
<td>&lt; .50</td>
</tr>
<tr>
<td>Posttest raw scores</td>
<td>3.90</td>
<td>3</td>
<td>&lt; .30</td>
</tr>
<tr>
<td>Final raw scores</td>
<td>48.10</td>
<td>3</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Transformed Pretest</td>
<td>6.09</td>
<td>3</td>
<td>&lt; .20</td>
</tr>
<tr>
<td>Transformed Posttest</td>
<td>6.13</td>
<td>3</td>
<td>&lt; .20</td>
</tr>
<tr>
<td>Transformed Final</td>
<td>7.00</td>
<td>3</td>
<td>&lt; .10</td>
</tr>
</tbody>
</table>

Therefore, the pretest, posttest, and final examination scores were transformed by taking the square root of each score. Bartlett's test of homogeneity of variance was applied to the transformed scores. The null hypotheses of homogeneity of variance of the transformed scores could not be rejected. The tests are summarized in Table 4.
The results of the multivariate analysis of covariance of the transformed scores are summarized in Table 5. A test of equality of regression in all the cells in the design was completed as the first step of the analysis. The null hypotheses of equality of regression could not be rejected.

Hypotheses one and three cannot be rejected based on the analysis. However, the second hypothesis that there is no difference in the pretest and final between the two levels of individualization can be rejected \( p < .069 \). Based upon the univariate F tests for individualization, the difference between the two levels of individualization on the posttest was not significant \( p < .514 \). However, the difference between the two levels on the final examination was significant \( p < .079 \).

The mean transformed scores of the posttest and final examination adjusted for the transformed pretest for each cell and all marginals of the design are shown in Table 6. The adjusted mean transformed final score for students who received the second level of individualization was 8.23 compared to an adjusted mean of 7.82 for students who received the first level of individualization. The raw scores for the pretest, posttest, and final examination are summarized in Table 7.
### TABLE 5

Summary of a Multivariate Analysis of Variance of Covariate of Transformed Posttest and Final Scores with the Transformed Pretest As a Covariate

<table>
<thead>
<tr>
<th>Test</th>
<th>df</th>
<th>df</th>
<th>Hypotheses</th>
<th>Error</th>
<th>F#</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equality of Regression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.583</td>
<td>&lt; .742</td>
</tr>
<tr>
<td>Root 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.222</td>
<td>&lt; .802</td>
</tr>
<tr>
<td>Univariate F (Posttest)</td>
<td>3</td>
<td>30</td>
<td></td>
<td></td>
<td>.160</td>
<td>&lt; .922</td>
</tr>
<tr>
<td>Univariate F (Final)</td>
<td>3</td>
<td>30</td>
<td></td>
<td></td>
<td>.788</td>
<td>&lt; .510</td>
</tr>
<tr>
<td>Regression (Multivariate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.167</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Univariate F (Posttest)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>4.666</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Univariate F (Final)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>7.334</td>
<td>&lt; .011</td>
</tr>
<tr>
<td>I (Multivariate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.903</td>
<td>&lt; .069</td>
</tr>
<tr>
<td>Univariate F (Posttest)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>4.36</td>
<td>&lt; .014</td>
</tr>
<tr>
<td>Univariate F (Final)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>3.274</td>
<td>&lt; .079</td>
</tr>
<tr>
<td>P (Multivariate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.856</td>
<td>&lt; .434</td>
</tr>
<tr>
<td>Univariate F (Posttest)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>1.463</td>
<td>&lt; .235</td>
</tr>
<tr>
<td>Univariate F (Final)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>.003</td>
<td>&lt; .959</td>
</tr>
<tr>
<td>IP (Multivariate)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.074</td>
<td>&lt; .929</td>
</tr>
<tr>
<td>Univariate F (Posttest)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>.125</td>
<td>&lt; .726</td>
</tr>
<tr>
<td>Univariate F (Final)</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
<td>.001</td>
<td>&lt; .993</td>
</tr>
</tbody>
</table>

*The F test for multivariate hypotheses is based on Rao’s F approximation for Wilks’ lambda criterion.*
TABLE 6

Plot of Transformed Posttest and Transformed Final Adjusted for the Covariate of Transformed Pretest

Adjusted Cell Means

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Posttest TBMU (O₂)</th>
<th>Final (O₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1 P₁</td>
<td>7.71</td>
<td>7.82</td>
</tr>
<tr>
<td>I1 P₂</td>
<td>7.47</td>
<td>7.81</td>
</tr>
<tr>
<td>I2 P₁</td>
<td>7.56</td>
<td>8.22</td>
</tr>
<tr>
<td>I2 P₂</td>
<td>7.42</td>
<td>8.21</td>
</tr>
<tr>
<td>I1</td>
<td>7.60</td>
<td>7.82</td>
</tr>
<tr>
<td>I2</td>
<td>7.49</td>
<td>8.23</td>
</tr>
<tr>
<td>P₁</td>
<td>7.61</td>
<td>8.08</td>
</tr>
<tr>
<td>P₂</td>
<td>7.43</td>
<td>8.08</td>
</tr>
<tr>
<td>All</td>
<td>7.53</td>
<td>8.08</td>
</tr>
</tbody>
</table>

Transformed Posttest TBMU

Transformed Final
TABLE 7

Means, Standard Deviations, and Number of Observations for Cells and Marginals of the Design to Test Hypotheses One through Three for Pretest, Posttest, and Final Raw Scores

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Final Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1 P1 (N=7)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>51.3</td>
<td>(17.1)</td>
<td>57.3</td>
</tr>
<tr>
<td>I1 P2 (N=6)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45.3</td>
<td>(13.7)</td>
<td>48.2</td>
</tr>
<tr>
<td>I2 P1 (N=13)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>56.5</td>
<td>(11.0)</td>
<td>59.5</td>
</tr>
<tr>
<td>I1 P2 (N=12)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>59.3</td>
<td>(8.5)</td>
<td>59.9</td>
</tr>
<tr>
<td>I1 (N=13)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>48.5</td>
<td>(15.3)</td>
<td>53.1</td>
</tr>
<tr>
<td>I2 (N=25)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>57.9</td>
<td>(9.7)</td>
<td>59.7</td>
</tr>
<tr>
<td>P1 (N=20)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>54.7</td>
<td>(13.2)</td>
<td>58.7</td>
</tr>
<tr>
<td>P2 (N=18)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>54.7</td>
<td>(12.2)</td>
<td>56.0</td>
</tr>
<tr>
<td>All (N=38)</td>
<td>Mean</td>
<td>S.D.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>54.7</td>
<td>(12.6)</td>
<td>57.4</td>
</tr>
</tbody>
</table>

Reliability: \( KR_{21} = .90 \) \( KR_{21} = .91 \)
At the beginning of Spring Quarter 1974, fourteen (14) students were randomly assigned to each of the four treatment groups. However, data for students who did not complete the pretest, posttest, final examination, attitude scale, or all of the CAI modules were excluded from the analysis. The exclusion of these data reduced the number of students included in the analysis in both the II Pl and II P2 cells of the design. The pretest scores of students assigned to each cell of the design and of students who were included in the analysis are summarized in Table 8. The mean and standard deviations of pretest scores of all students assigned to a treatment group and of students included in the analysis were comparable for each cell.

The largest difference between the means of students who were pretested and students who were included in the analysis was 2.3 raw score points in the II Pl cell. A t test of the largest difference was not significant \( (p < .80) \). The hypothesis that the students who were included in the analysis has a pretest mean different than all of the students originally assigned to the II Pl cell cannot be rejected.

The univariate F ratios for the effect of personalization on the final examination and for the
TABLE 8

Means, Standard Deviations, and Sample Size for Pretest Scores of all Students Tested and of Students Included in the Analysis

### Analysis

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>51.3</td>
<td>45.3</td>
</tr>
<tr>
<td></td>
<td>(17.1)</td>
<td>(13.7)</td>
</tr>
<tr>
<td></td>
<td>N = 7</td>
<td>N = 6</td>
</tr>
<tr>
<td>I2</td>
<td>56.5</td>
<td>59.3</td>
</tr>
<tr>
<td></td>
<td>(11.0)</td>
<td>(8.5)</td>
</tr>
<tr>
<td></td>
<td>N = 13</td>
<td>N = 12</td>
</tr>
</tbody>
</table>

### Pretest

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>53.6</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td>(15.1)</td>
<td>(12.0)</td>
</tr>
<tr>
<td></td>
<td>N = 10</td>
<td>N = 10</td>
</tr>
<tr>
<td>I2</td>
<td>55.0</td>
<td>61.0</td>
</tr>
<tr>
<td></td>
<td>(10.8)</td>
<td>(6.8)</td>
</tr>
<tr>
<td></td>
<td>N = 13</td>
<td>N = 12</td>
</tr>
</tbody>
</table>
interaction between personalization and individualization on the final examination were both less than .10. The sum of squares for error was larger than the sum of square for the effect. That is, the experimental effect was negligible in comparison to sources of random error.

In summary, there was a significant difference between the two levels of individualization. The group of students, who following an incorrect response, received feedback that their response was incorrect, the correct response, and the reasons why it is correct scored higher on the final examination for the course than did students who received only feedback that their response was incorrect and the correct response.

The design to compare the level of achievement of students receiving the CAI approach with the scores of students receiving the traditional program is depicted in Figure 5. The null hypothesis tested was:

\[ H_4: \text{There is no significant difference in the level of achievement in mathematics between the students receiving the traditional program (} \mu_5 \text{) and students receiving the CAI approach (} \mu_4 \text{).} \]
<table>
<thead>
<tr>
<th>CAI Approach</th>
<th>04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Approach</td>
<td>05</td>
</tr>
</tbody>
</table>

- Change scores from pretest to posttest on "A Test of Basic Mathematical Understanding" raw score of students receiving the CAI Approach in Spring Quarter of 1974.

- Average change score from pretest to posttest on "A Test of Basic Mathematical Understanding" of students completing Education 502 prior to Spring Quarter 1974.

**FIGURE 5**

A representative of the Design to Compare the Scores of Students receiving the CAI Approach with the Scores of Students Receiving the Traditional Program
Based on an analysis of TBMU scores of students enrolled in Education 502 prior to Spring Quarter 1974, the average increase in raw score on the TBMU from the first week of the quarter until the scheduled final examination was six raw score points. The null hypothesis that the average change score on the TBMU of students participating in this study was six raw score points was tested by utilizing a t test. Based on the analysis summarized in Table 9, hypothesis four cannot be rejected (p<.05). The change scores ranged from -6 to 26 with an average increase of 2.7 raw score points.

In summary there was no significant difference between the level of achievement as measured by the TBMU of students receiving the traditional program and students receiving the CAI approach.

Secondary Analyses

In addition to the pretest TBMU, posttest TBMU, and final examination, data were collected on a number of other variables for each student. Table 10 includes the definition of the variables and the correlations among all of the variables.

Several points can be suggested from the data presented in Table 10. All of the correlations
TABLE 9
SUMMARY OF THE DATA UTILIZED TO TEST HYPOTHESIS FOUR

<table>
<thead>
<tr>
<th>CAI Approach</th>
<th>Post Test Mean</th>
<th>57.4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest Mean</td>
<td>54.7</td>
</tr>
<tr>
<td></td>
<td>Average Change Score</td>
<td>2.7</td>
</tr>
<tr>
<td>Traditional Approach</td>
<td>Average Change Score</td>
<td>6.0</td>
</tr>
<tr>
<td>t Test</td>
<td>t = - .5324</td>
<td></td>
</tr>
<tr>
<td></td>
<td>df = 37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p &lt; .80</td>
<td></td>
</tr>
</tbody>
</table>
between online time and measures of student achievement are negative indicating that students with lower levels of achievement required a longer time to complete the modules. The correlation between the essay portion of the final examination and the pretest, posttest, and objective portion of the final examination were all less than .10 suggesting that the essay was not assessing the same skills.

The attitude of students toward CAI was assessed during the scheduled final examination utilizing a test of general attitude toward CAI. The test consists of twenty statements concerning CAI. Students expressed agreement or disagreement with the statements on a five point Likert scale. Student responses to statements which expressed a negative attitude toward CAI were reflected before summing across all responses to obtain an overall score for attitude toward CAI. A reliability of .87 was estimated for the attitude survey using Cronbach's alpha.

Only one of the correlations between the attitude toward CAI and other variables shown in Table 10 was significant at the .05 level. The correlation between attitude towards CAI and online time of .28 indicates that students who spent the most time on CAI expressed a less favorable attitude toward CAI.
TABLE 10

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>1</td>
<td>---</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
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<td>3</td>
<td>.58</td>
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<td>4</td>
<td>.08</td>
<td>.05</td>
<td>.02</td>
<td>---</td>
<td>5</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>.48</td>
<td>.56</td>
<td>.75</td>
<td>.68</td>
<td>---</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>-.26</td>
<td>-.30</td>
<td>-.16</td>
<td>-.13</td>
<td>-.20</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>-.23</td>
<td>-.26</td>
<td>-.18</td>
<td>.07</td>
<td>-.08</td>
<td>.28</td>
<td>---</td>
</tr>
</tbody>
</table>

1. Pretest TBMU
2. Posttest TBMU
3. Objective portion of final examination
4. Essay portion of final examination
5. Total score on final examination
6. Time (minutes) to complete modules
7. Attitude toward CAI score
The correlations between the pretest TBMU, the posttest TBMU, the final examination and attitude toward CAI score were all negative. In general, students who scored higher on the achievement measure had more positive attitudes toward CAI.

An analysis of variance of the online time measured in minutes is summarized in Table 11. Neither of the main effects nor the interaction effect yielded a significant F ratio so the null hypothesis of equal means in all cells cannot be rejected. That is, none of the CAI feedback strategies employed in this study differed significantly in terms of student time to complete the modules.

The means and standard deviations of all the cells and marginals are presented in Table 12. The mean of the T2P2 cell was affected by one student who logged 486 minutes of online time.

Summary

A significant difference between the two levels of individualization was found (p < 0.069). The group of students, who following an incorrect response, received feedback that their response was incorrect, the correct response, and reasons why it is correct scored higher on the final examination for the course than did students who received only feedback that their response was incorrect and the correct response.
TABLE II

Analysis of Variance and Plot of Cell Means for Online Time

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>238.999</td>
<td>1</td>
<td>238.999</td>
<td>0.032</td>
<td>&lt;.859</td>
</tr>
<tr>
<td>P</td>
<td>12191.398</td>
<td>1</td>
<td>12191.398</td>
<td>1.626</td>
<td>&lt;.211</td>
</tr>
<tr>
<td>IP</td>
<td>8289.707</td>
<td>1</td>
<td>8289.707</td>
<td>1.106</td>
<td>&lt;.300</td>
</tr>
<tr>
<td>Error</td>
<td>254884.438</td>
<td>34</td>
<td>7496.598</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plot of Cell Means
TABLE 12
Mean and Standard Deviations of Student Online Time by Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>142.15</td>
<td>66.03</td>
</tr>
<tr>
<td>I2</td>
<td>147.44</td>
<td>96.40</td>
</tr>
<tr>
<td>P1</td>
<td>128.60</td>
<td>73.74</td>
</tr>
<tr>
<td>P2</td>
<td>164.56</td>
<td>97.03</td>
</tr>
<tr>
<td>I1P1</td>
<td>144.57</td>
<td>72.07</td>
</tr>
<tr>
<td>I1P2</td>
<td>130.33</td>
<td>64.91</td>
</tr>
<tr>
<td>I2P1</td>
<td>120.00</td>
<td>76.06</td>
</tr>
<tr>
<td>I2P2</td>
<td>177.17</td>
<td>110.06</td>
</tr>
<tr>
<td>All</td>
<td>147.63</td>
<td>86.31</td>
</tr>
</tbody>
</table>
Students who received the CAI approach to Education 502 gained an average of 2.7 points on the TEMU from pretest to posttest. Historically, students enrolled in the traditional approach to Education 502 have exhibited an average gain score of 6 points from pretest to posttest. The null hypothesis that the average gain scores of students receiving the CAI approach is the same as the average gain score of students receiving the traditional approach could not be rejected.

The average time required to complete the CAI modules was 147 minutes. Based on an analysis of variance the null hypothesis of equal online time for the four feedback treatments could not be rejected.

In general, students who scored higher on the achievement measures had more positive attitudes toward CAI. Students who spent the most time on CAI expressed a less favorable attitude toward CAI.

All of the correlations between the essay portion of the final examination and the other achievement measures employed were less than .10. The correlations among the other achievement measures ranged from .48 to .88. The essay question was apparently not measuring the same skills as the other achievement measures.
CHAPTER V
SUMMARY AND CONCLUSIONS

An instructional system including four CAI instructional modules was developed by the researcher. Each of the modules provided instruction on one of the four basic arithmetic operations with rational numbers to achieve specified behavioral objectives.

College students in an elementary education methods course in mathematics were randomly assigned to one of four treatment groups. Four treatment groups resulted from the crossing of two levels of each of two feedback variables called individualization and personalization.

Under the first level of individualization a student, following an incorrect response, received feedback that his response was incorrect and the correct response. The second level of individualization included all the feedback of the first level with the added feedback of why the correct answer is correct.

The two levels of personalization were merely the presence or absence of the name of the student in feedback.
All students were administered a pretest of "A Test of Basic Mathematical Understandings" (TBMU) before completing the CAI modules and were administered a posttest of the TBMU, a survey of attitudes toward CAI, and the final examination during the scheduled final examination.

A multivariate analysis of covariance was completed to test the null hypotheses of no differences between the levels of individualization and personalization on the posttest and final examination utilizing the pretest as a covariate. A significant difference (p < .069) was found between the two levels of individualization with students receiving the second level of the individualization scoring higher on the final examination in the course.

A t test was utilized to compare the change scores from pretest to posttest on the TBMU of students who participated in this study with the average change score of students who completed the course during prior quarters. The difference between mean change scores for the two groups was not significant (p < .80).

Conclusions

1. Feedback to an incorrect response that included information that the response
was incorrect, the correct response, and reasons why it is correct resulted in significantly greater achievement than did feedback that the response was incorrect and the correct response only.

2. None of the four feedback strategies employed in the study differed significantly in terms of online time required for students.

3. In general, students who required more time to complete the four CAI modules expressed a less favorable attitude toward CAI.

4. There were no significant correlations between the pretest, posttest, objective portion of the final, and essay portion of the final and attitude toward CAI.

5. The essay portion of the final examination for Education 502 in Spring Quarter 1974 did not correlate significantly with any other achievement measures utilized in the study. The correlations among pretest, posttest, final examination, and objective portion of the final were significant at the .01 level and ranged from .48 to .88.
Suggested Further Research

Other studies discussed in Chapter II have come to different conclusions regarding the effects of personalization as defined in this study. However, each study has dealt with samples from populations of students of different age levels and of different levels of knowledge of mathematics. It may be hypothesized that the effects of personalization may be related to the mathematics skill level of the students receiving instruction. The effects of personalization should be studied with students of different mathematical backgrounds to determine the effect of personalization as a function of knowledge of the subject matter.

The relationship between the age level of students and the effects of personalization should be studied. A CAI module incorporating a content unfamiliar to subjects of all age groups could be developed. For example, a module requiring students to make logical deductions from a set of stated axioms could be devised such that the likelihood of any students having had prior experience with content would be remote. The effect of personalization could then be studied across age levels of students.
Only two levels of the individualization variable were investigated in the current study. Several other strategies of individualization are employed frequently in CAI. Additional studies should be conducted incorporating as many feedback strategies as feasible for an instructional module. Specifically, the two levels of individualized feedback employed in this study should be compared with feedback to an incorrect response that provides the correct response and reasons why the student's response was incorrect. That is, combine the individualized feedback strategies employed in this study and the strategies employed by Schoen (1971) into one study.

In general, the individualization procedures built into current instructional programs operate on the basis of a very small amount of information about the student and for the most part are incapable of taking account of many student traits and transient psychological, sociological, situational, social, and attitudinal variables. These variables were randomly distributed across all four treatment groups in the current study and may be sources of alternative explanations for the findings. Further research on the effects of individualization should control for these variables through the use of appropriate design procedures.
The comparison between the traditional approach and the CAI approach made in this study should be replicated with students enrolled during the same quarter. Prior to the quarter in which the study was conducted, the Department of Early and Middle Childhood initiated a highly-selective screening process for students enrolled in their program. Hence, the students who participated in the CAI approach of this study had been through the more stringent selection process while the students in the traditional approach were not subject to the same screening process. The screening process is a possible explanation for the smaller gain scores on the TBMU of the CAI approach students compared to students in the traditional approach.

An alternative approach to study the effects of feedback in CAI could be based upon the work of Pambookian (1974). It may be hypothesized that feedback differentially affects students who score in the upper, middle, or lower third of a pretest over the material covered by CAI. If Pambookian's findings extend to CAI, students scoring in the middle third on the pretest should exhibit significant improvement in comparison to students scoring in the upper or lower third of the pretest. Pretest scores could be used
as an independent variable along with other feedback variables such as individualization and personalization.

CAI provides an opportunity to investigate the effects of an instructional strategy in a controlled environment. However, the generalization of the findings of CAI research to a classroom environment is questionable. The effects of the variables defined in this study could be investigated in a classroom setting. Instructors of sections of a course could incorporate feedback strategies similar to the individualization and personalization strategies of this study with students in their classes. Alternately, the feedback strategies could be incorporated into written responses to homework.
TOPICAL OUTLINE OF COURSE

I. Sets
   A. Relations on Sets
   B. Operations on Sets

II. Integers
   A. Cardinality of Sets
   B. Order Relations
   C. Operations
   D. Proper Subsets

III. Rationals
   A. Definition
   B. Operations
   C. Order Relations

IV. Numeration Systems
   A. Historical Examples
   B. The Arabic System
   C. Bases other than Ten

V. Sentences
   A. Open Sentences
      1. Involving equality
      2. Involving Inequality
   B. Replacement Sets
C. Solution Sets
   1. graphing solution sets
   2. algebraic methods

D. Utilization in Problem Solving

VI. Geometry

A. Definitions
   1. one-dimensional elements
   2. two-dimensional elements
   3. three-dimensional elements

B. Measurement
   1. linear
   2. areal
   3. volumetric

C. Estimation
   1. linear
   2. areal
   3. volumetric
APPENDIX B
BEHAVIORAL OBJECTIVES

1. Given a model representing a fraction the student will choose the model in fractional form.

2. Given an addition problem with two proper fractions the student will choose the model which represents the problem from among a set of alternative models.

3. Given a verbal statement describing a fraction addition problem, the student will choose the problem which the statement describes from among a set of problems.

4. Given an addition problem with two improper fractions the student will choose the model which represents the problem from among a set of alternative models.

5. Given a verbal statement describing an addition problem with two improper fractions, the student will choose the problem which the statement describes from among a set of problems.

6. Given a subtraction problem with two proper fractions the student will choose the model which represents the problem from among a set of alternative models.

7. Given a verbal statement describing a fraction subtraction problem, the student will choose the problem which the statement describes from among a set of problems.
8. Given a subtraction problem with two improper fractions the student will choose the model which represents the problem from among a set of alternative models.

9. Given a verbal statement describing a subtraction problem with two improper fractions the student will choose the problem which the statement described from among a set of problems.

10. Given a problem involving the multiplication of two fractions the student will choose a verbal statement which describes the problem from among a set of verbal statements.

11. Given a verbal statement describing a fraction multiplication problem, the student will choose the problem which the statement describes from among a set of problems.

12. Given a multiplication problem with two proper fractions the student will choose the model which represents the problem from among a set of alternative models.

13. Given a multiplication problem with two improper fractions the student will choose the model which represents the problem from among a set of alternative models.
14. Given a verbal statement describing a fraction division problem, the student will choose the problem which the statement describes from among a set of problems.

15. Given a problem involving the division of two fractions the student will choose a verbal statement which describes the problem from among a set of verbal statements.

16. Given a division problem with two proper fractions the student will choose the model which represents the problem from among a set of alternative models.

17. Given a division problem with two improper fractions the student will choose the model which represents the problem from among a set of alternative models.

18. Given a fraction which is not in lowest terms, the student will reduce it to lowest terms.

19. Given an improper fraction, the student will rewrite it as a mixed numeral or vice versa.

20. Given a problem involving addition of fractions with like denominators, the student will find the sum.

22. Given a subtraction problem of unlike fractions of less than one, the student will find the difference and express it in simplest terms.
23. Given a subtraction problem of mixed fractions with like denominators the student will find the difference.

24. Given a subtraction problem of unlike mixed fractions, the student will compute the difference and express it in simplest terms.

25. Given a problem involving the multiplication of two proper fractions, the student will find the product.

26. Given a problem involving the multiplication of mixed fractions, the student will find the product.

27. Given a problem involving the division of two proper fractions, the student will find the quotient.

28. Given a problem involving the division of mixed fractions, the student will find the quotient.

29. Given a pair of proper fractions the student will choose the smaller.
PLEASE NOTE:

Pages 89-105, "A test of Basic Mathematical Understanding", test author-Vincent J. Glennon, not photographed at request of author. Available for consultation at the library of Ohio State University.

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