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A STUDY OF THE EFFECTS OF INDIVIDUALIZING THE
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DISSERTATION

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

By

Patrick McCoy Ewing, B.A., Ed.M.

* * * * *

The Ohio State University
1973

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CHAPTER I

INTRODUCTION

Most mathematics departments in institutions of higher education are confronted with the problem of serving masses of beginning students with diverse backgrounds, abilities, attitudes and future needs in mathematics. This problem is magnified by the open access policy of various state supported institutions. The Ohio State University Department of Mathematics confronts this problem. The Department has adjusted its program and instructional methodology in terms of this diversity for some of its freshman level courses. However, for the large number of students needing the basic algebra course prerequisite to most other mathematics courses, the adjustment has not been made. The traditional, inflexible paced approach to this essentially high school algebra course has resulted in high attrition and inefficient progress by students pursuing the mathematics required for their majors.

This study examines the feasibility and pay-offs associated with using an instructional method which allows the student some control over the pacing of his learning in
the basic algebra course.

Enrollment in the basic algebra course is determined by placement procedures applied to all freshman students at The Ohio State University. The mathematics department has developed the placement procedures to cope with the problem of differences in backgrounds and abilities of students. Placement levels are determined by use of examinations designed by the department, standardized examinations (ACT), and high school records. A detailed description of the placement procedure is provided in Appendix A.

The problem of different needs has been dealt with at The Ohio State University by offering four basic sequences of mathematics courses at the freshmen level. Three of these are service sequences: one for elementary education majors, one for the liberal arts students, and one for students pursuing either business, social or biological sciences. The two latter sequences include some rudiments of calculus. The fourth sequence is the calculus sequence for the mathematics and physical science majors. For a more detailed description of these sequences and their prerequisites see Appendix B.

The first course in each of the sequences has a prerequisite knowledge of basic high school algebra indicated by the placement procedure or completion of a basic algebra course known as Mathematics 101. The focus of this study was the method of teaching this course.
The title for Mathematics 101 as found in The Ohio State University Bulletin is "Basic Mathematics". A more descriptive title would be "Basic Algebra". The course is an outgrowth of a non-credit remedial algebra course that was given in the 1950s and early 1960s at The Ohio State University. The course, as it has been taught recently includes the following topics: Sets, Properties of Numbers, Functions, Graphing, Linear and Quadratic Equations, Systems of Equations, Operations on Polynomials, Factoring Polynomials, Rational Expressions and Exponential Functions.

Ideally, all students entering college would have three or more years of high school mathematics from which they would retain sufficient knowledge of basic algebra to place at least in the beginning course of the sequence they desired. If this were the case, there would be no need for Mathematics 101. However, at the Mansfield Campus of The Ohio State University, 75 percent of the beginning students in the Autumn quarter of 1972, were below the level required for the calculus sequence or the sequence for business and biological science students. For the other two sequences, the elementary education and liberal arts sequences, 49 percent of the students were below the level required. On the main campus in Columbus, 62 percent of the beginning students Autumn quarter, 1972, were in the former category and 39 percent were in the latter. Furthermore, as Table 1 in Appendix A shows, these percentages
have been increasing in recent years. Correspondingly, Mathematics 101 is assuming greater significance in the mathematics offerings of The Ohio State University especially at the regional campuses.

The use of the mathematics placement level procedure as outlined in Appendix A provides for homogeneity of students taking Mathematics 101 with respect to a few specific attributes. These students would have either a level 3 or 4 placement. However, this homogeneity is in terms of mathematics achievement. The group ranges from students with no high school mathematics other than general mathematics to students with four years of high school mathematics (two years of algebra, a year of geometry and a year of senior mathematics). There is also a great range in age, motivation and interest. This diversity in age, motivation and interest is even more pronounced at the regional campuses than at the main campus of The Ohio State University.

The course has been a challenge for most students regardless of their backgrounds. The review nature of the course provided a rational for condensing two years of high school algebra into one short ten-week quarter. For many of the students the rapid, inflexible pace was devastating. The remedial character of the course contributed to its having low priority in the past in the departmental planning -- large sections of 30 to 45 students were scheduled.
The combination of these factors resulted in a rather large number of unsuccessful students. For example, at the Mansfield Campus of The Ohio State University, 42 percent of those enrolled in the course Autumn quarter, 1971, either dropped the course or received a failing grade. The corresponding figures for Autumn, 1970, were 29 percent and for Autumn, 1969, 31 percent.

The heterogeneity of the students, the rapid pace of the course, the large sections and low priority with the resulting high attrition rate demonstrated the need for a critical examination of the course, Mathematics 101, and a study of possible changes in its presentation.

Statement of Problem

The purpose of this study was to develop and explore the feasibility of an individualized pacing method of teaching basic algebra at the college level. In particular, did this individualized pacing method of teaching reduce the attrition rate in the Mathematics 101 course at the Mansfield Campus of The Ohio State University?

This study of individualizing Mathematics 101 was an extension of a program instigated several years ago on the main campus of The Ohio State University. A group of concerned mathematicians headed by Robert C. Fisher and John W.
Riner (13) conceived the idea of individualizing the beginning courses in both the calculus sequence and the sequence for business and biological science students. The result of this idea has been the development of the CRIMEL (Curriculum Revision and Instruction in Mathematics at the Elementary Level) program. This program is comprised of three principle facets: a flexible pacing system, a multimedia instructional approach, and a flexible retesting program. The individual student in CRIMEL has the opportunity to learn the mathematics he needs at a pace compatible with his ability and interests using the instructional resources most effective for him. The purpose of the author's project was to study the feasibility of an extension of CRIMEL to Mathematics 101. Although the program proposed was not identical to CRIMEL, it had the same objectives and the approach to the problem of individualization was similar.

Background and Relevant Research

The problems associated with remedial mathematics courses are not unique to The Ohio State University. Most public supported colleges and universities have open admission policies. Too often this open door to higher
education has been a revolving door for students. Many students with deficiencies in mathematics and other areas were admitted but no means were available for correcting these deficiencies. The result was frustration and high attrition.

The revolving door was unnoticed in the 1960s because of mushrooming enrollments. However, in the 1970s enrollments have leveled off and the time for accountability is at hand. The welcome result is that more emphasis is being placed on the improvement of the educational process in higher education.

In this section a survey of some of the efforts to improve the teaching of college mathematics is reported. Particular attention is given to those efforts to individualize basic algebra.

Most of the pioneering in the individualization of the educational process has been at the elementary and secondary school levels. Such innovations as the Nuffield project in England, the Individually Prescribed Instructional system (IPI) of the Learning Research Center at the University of Pittsburgh and more recently the Individualized Mathematics System (IMS) based on behavioral objectives of the Center for Individualized Instructional Systems of Durham, North Carolina, are a few of the many exciting reforms in progress at these levels.

Most innovation and experimentation in colleges and
universities has been done with courses at higher levels than remedial algebra. Individualization using CAI (computer assisted instruction) has been used on many campuses in teaching calculus and non-calculus courses. A discussion of two programs, one at Massachusetts Institute of Technology and the other at the University of Michigan, are included by ways of examples of innovative projects at levels other than remedial algebra.

Mattuck (9) reports of an exam-tutorial program that is being used at Massachusetts Institute of Technology for teaching calculus. Some individualized pacing is achieved by a testing program in which students may take an examination at any time. A student must repeat a parallel form of the examination until he performs satisfactorily (75 percent to 80 percent). The student also has three class options: one covers the complete course in 12 weeks, one starts with the second of six units and is paced so as to complete the course in nine to ten weeks, and the third option begins with the third unit and is paced to finish the course in six weeks.

Another intriguing example is the experimental programs reported by Kochen and Dreyfuss of the Mental Health Research Institute at the University of Michigan. A special experimental mathematics 'course' was designed to modify and shape attitudes. The objectives of the course were to help students (not necessarily mathematics or
science students) to approach all their studies more analytically, to acquaint them with "basic concepts and methods covering sets, algebra, logic, computers, analysis, probability, mathematics-statistics and topology in an over-all map of how they logically fit together and how they relate to problems of modern life", and "Read, with appreciation, mathematical literature previously incomprehensible to them." (7, 315) The writers claim these objectives were met. The course is built around a 'Growing Encyclopedia System' (GES) which is a constantly growing and changing programmed directory. Additional resources available to the students were a corps of tutors and a practicum-laboratory. By utilizing these three resources the student progressed through the 'course'.

Research more directly related to the individualization of the basic algebra course has been conducted primarily at the two-year college level. Stein (16) in addressing a meeting of the Mathematical Association of America told of various problems confronted by the "captured student" and some of the ways two-year colleges are attacking these problems.

Perry (12) reports on research he conducted at Lee College, a community junior college at Baytown, Texas. Some individualizing of pacing was obtained by using a programmed text. The three regular class sessions were restructured so that one was used for supplementing and
explaining material in the text. Another session was devoted to individual discussion between the instructor and the student. Perry found that students at this level did not take advantage of these sessions. The third session each week was used for giving and grading unit tests. Attendance was optional in that students took a test only when he felt prepared for it. Another facet of the study was the contracting for grades by the students. Pre and post attitude and achievement tests were given. The control group was taught by another instructor using the traditional lecture-discussion method. No significant difference was found in achievement. However, there was a significant difference in attitude with the experimental group showing the more positive attitude.

Williams (21) reports of the use of a mathematics laboratory at Pasadena City College in California. One use of the laboratory was in connection with an individually paced elementary algebra course. Students proceeded through the unit course at their own pace. However, they were required to complete the course in one semester but a provision was made that if they withdrew they could re-enter the following semester beginning were they left-off. Results showed that the use of the mathematics laboratory did not improve retention among the younger more immature students.

Ablon (1) at Staten Island Community College and
Gavurin (5) of Brooklyn College both of the City University of New York, in separate articles report of the problems in remedial mathematics as a result of the open door policy enacted in 1970 by CUNY. Ablon reports on the use of the individualized modular approach to preparatory mathematics and its apparently successful implementation.

Bloomberg (4) reports on the Basic Mathematics Review (BMR) program at Essex Community College. BMR was a remedial non-credit course taught on an individualized basis. Following diagnostic testing and placement, instruction utilized programmed materials, tutors and self-tests. Comparisons with the traditional remedial course showed 1) students who completed BMR achieved significantly higher in credit mathematics courses. 2) a smaller percent of the students passed the BMR course that passed the traditional remedial course.

Research was conducted at the University of Pittsburgh by Abplanalp (2) comparing achievement and attitudes of pre-calculus students using individualized instruction versus students using traditional methods. Individualization was achieved by each student taking a diagnostic examination before each unit which indicated areas of strengths and weaknesses. These results were used to help the instructor and student in planning the students' course of study for the unit. Results indicated that students in the experimental approach had a more favorable attitude
towards mathematics and higher achievement than those students taught by the traditional method.

A study comparing retention, achievement and success in college algebra using three different methods of instruction was conducted by Beck (3) at Auburn University. The three methods of instruction were traditional lecture-discussion, multi-method and programmed instruction. No significant difference was found in retention or success as a result of the different methods. The mean achievement of the multi-method and lecture-discussion groups were significantly higher than the programmed instruction group. There was no significant difference in achievement between the multi-method group and the lecture-discussion group.

In a study at the University of Pittsburgh, Urban (18) found that individualized instruction employing team teaching was a worthy alternative to conventional mathematics teaching methods. His experimental model incorporated team teaching, individualized instruction, and team supervision. The use of learning packets and student determined behavioral objectives along with a variety of available learning activities including lectures, small-group meetings, individual tutoring and independent study were the means of individualization. Results showed that the experimental group had higher achievement and more favorable attitudes towards mathematics than the control groups. Two control models were used -- one was large lecture, the other
coventional lecture-discussion.

This survey reveals some common features and findings in the studies on individualizing the learning process. A feature common to most of the studies was the use of a flexible testing program to individualize the pace of a course. Other common features are the use of tutors and learning resource centers. The flexible testing and tutor service are features of the individualized pacing method reported in this study.

Results common to the studies were that individualization produced: 1) more positive attitudes towards mathematics, 2) higher achievement in most cases and 3) lower attrition rates in most cases.

To conclude this section, a discussion of recent studies that have been conducted at The Ohio State University concerning various methods of teaching pre-calculus mathematics is given.

Waits (20) compared three large group instructional techniques. The three techniques used were the live, large lecture-recitation (LLL-R) method, the daily closed circuit television lecture-daily recitation (DTV-R) method, and the televised large lecture-recitation (TVLL-R) method. He found no significant difference in achievement between the two television methods. However, the large lecture-recitation method had significantly higher achievement.
Moore (10) compared the large televised lecture-recitation method with an individualized method using a commercial programmed text. The course used in the study was basic algebra. He found that the televised lecture-recitation method produced higher achievement.

A comparison of main campus versus branch campus students with regards to achievement in a pre-calculus course was conducted by Partner (10). The results indicated lower achievement for the branch campus students.

Shatkin (14) studied mathematics attitudes of prospective elementary teachers. He developed the instrument employed in this study to measure attitude change.

As mentioned in the proceeding section, the Mathematics Department of The Ohio State University has been developing an individualized approach to the teaching of freshmen mathematics called CRIMEL (13) (19). A study of the strategies for selection of students for the individually paced sections of the CRIMEL program was conducted by Mader (8). He found that the best results were obtained by using a multiple stage selection strategy which included in-course as well as pre-course measures. Evaluation of achievement data revealed that there were no significant difference in achievement between subsets of students at different pacing levels. That is, the student who took the reduced pace achieved as well but he required more time.
Overview of Instructional Procedures

The method used in this study for individualizing the pace to some degree the instruction of basic algebra (Mathematics 101) is described briefly below. This method was used Autumn quarter, 1972, at the Mansfield Campus of The Ohio State University.

The course was divided into seven units as outlined in Appendix C. For approximately the first two weeks of the quarter, lectures covering the first unit were given to large groups of students with small group recitation sections. The teaching schedule for this unit is given in Appendix G. The first examination over this material was administered to the students on Friday at the end of the second full week of classes.

There were no large lectures after the first examination. Instead, the teaching staff (three members at each of the hours, 9:00 and 12:00) conducted teaching groups, each instructor teaching a different topic at any one point of time. The student would check the master scheduling board to determine which section he wanted to attend. Throughout the quarter a given topic was taught by more than one instructor and on different days. Hence, a student who desired to see various approaches to topics which were troublesome for him could do so. For those topics which
he could understand by using the text and reference materials, he need not attend class. The text (6) is somewhat restricted in its development of various topics. Therefore, supplementary texts were put on closed reserve in the library (see Appendix E).

Another aspect of the program was the availability of individual assistance by the staff. There was a tutorial schedule (see Appendix F) which made available an instructor every hour from 8:00 to 3:00 daily except Friday afternoons.

The flexible testing permitted the student to be examined on a given unit three times. Each Friday was test day. If a student was not satisfied with his test score on a given unit he could take a parallel form of the test on the same unit the following Friday. After the third test he was required to progress to the next unit. As a result of the recommendation in the study by Moore (10), each student was required to take an examination every week. Thus a student could spend from one to three weeks on a given unit. The individualized pacing is achieved by means of this flexible testing procedure.

The course was divided into two modules for credit purposes. The student had to complete the first four units in order to receive three hours of credit for the first module called Mathematics 101.01. Upon completion of the last three units, he received two hours of credit for the second module called Mathematics 101.02. Mathematics 101.01
plus Mathematics 101.02 is equivalent in credit and content to Mathematics 101 (see Appendix C). A student could obtain five hours of credit in one quarter by completing all seven units. If he only completed the first four units, he received three hours of credit and would receive the remaining two hours of credit upon completing the last three units in a subsequent quarter. By taking the latter route the student distributes the normal quarter's work over two quarters.

With this flexible testing program and teaching schedule the capable, industrious student was able to complete the course of seven units in eight weeks. Likewise, the program enabled the student who lacked background, ability, and/or motivation to spend additional time on units that gave him difficulty and accelerate on units that he mastered more readily. In addition, the student who desired to improve his standing on a unit examination regardless of his original score could do so. Thus the student who was concerned with his grade point average had the option of retaking a parallel form of the examination in order to maintain a certain grade level.

A more complete description of the individualized pacing method of teaching is given in Chapter II.
Definition of Terms

The following definitions will be used throughout this study.

1. The **IP method** (individualized pacing method) is defined as the teaching method where students have the opportunity to proceed through the basic algebra course at their own pace as described in the proceeding section. This method was used on the Mansfield Campus of The Ohio State University, Autumn Quarter, 1972, in teaching Mathematics 101.

2. The **TVL-R method** (television lecture-recitation method) is defined as the teaching method where large groups of students (200-500) attend televised lectures three days a week and have small group (25-30) recitation sessions two days a week. This method was used in teaching Mathematics 101 on the main campus of The Ohio State University, Autumn Quarter, 1972.

3. The **DL-D method** (daily lecture-discussion method) is defined as the teaching method where students are in classes of 30 to 45 students meeting daily with the same instructor for lecture and discussion. This method was employed on the Lima Campus of The Ohio State University, Autumn Quarter, 1972, and on the Mansfield Campus prior to Autumn, 1972.

4. **Mathematics achievement** is defined to be content achievement in Mathematics 101 as measured by the raw score on the final examination.

5. **Attitude change** towards mathematics is defined to be the difference in the pre and post attitude score obtained on the mathematics opinionnaire.

6. **Students who complete the course** is defined to be those students who receive a grade of A through E for the course.
Successful students is defined to be those students who receive a grade of A through D for the course or the first module.

Attrition rate is defined to be the percent of students enrolled at the end of the second week of the quarter who do not receive a passing grade (A, B, C, or D) for the course or the first module.

Drop-out rate is defined to be the percent of students enrolled at the end of the second week of the quarter who do not complete the course or the first module.

Statement of Hypotheses

The primary purpose of this study was to determine if the IP method of teaching basic algebra (Mathematics 101) is feasible on the Mansfield Campus of The Ohio State University. That is, do the students achieve as well? Are their attitudes towards mathematics better? And, are more students retained by allowing them to work at their own pace? To explore the answers to these questions, the following hypotheses were considered:

1. There is no significant difference in the attrition rate between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method;
   c) the groups of Mansfield campus students taught by the DL-D method in quarters prior to Autumn, 1972.
2. There is no significant difference in the drop-out rate between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method;
   c) the groups of Mansfield campus students taught by the DL-D method in quarters prior to Autumn, 1972.

3. There is no significant difference in the mathematics achievement as measured by the final examination between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method.

4. There is no significant difference in attitude change towards mathematics between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method.

Limitations

In this feasibility study certain niceties of experimental design were sacrificed to permit the assessment on an on-going teaching program. For example, there was no opportunity to select random samples from a single population. In spite of this, useful comparisons were made between various methods of teaching basic algebra using similar but possibly different populations.
The absence of random samples from the same population was a result of constraints imposed by staffing and the availability of students. The study was conducted on the Mansfield Campus of The Ohio State University with a mathematics staff of five persons. Implementation of the IP method of teaching Mathematics 101 along with the other course responsibilities overloaded the staff. Thus, there was not staff to handle control groups on the Mansfield campuses. In addition, the number of students enrolled in the course did not justify the additional staff that would have been necessary to conduct both the experimental and control groups.

In order to have some means of comparison groups of students from the Columbus campus and the Lima campuses were used as controls. These students were taught the same course using the same text with the same prerequisites but employing different instructional procedures. Although the prerequisites and placement procedures were the same on all campuses, the fact that the groups were in different locations must be considered.

Partner (11), in his study of regional campus students versus main campus students, discovered that even though the students had the same mathematics background as indicated by the mathematics placement levels and received similar treatment, there were differences in achievement. He suggested the reasons for the differences in achieve-
ment are that a different type of student attends regional campuses and that the academic environment of the regional campus differs from the main campus. The comparison among the groups used in this study must be considered in light of these differences.

Design and Analysis of the Study

Since the purpose of this study was to determine the feasibility of using the IP method, comparisons were made with other methods of teaching. Five groups of students were considered in order to make these comparisons. They are:

Group A - 124 students enrolled in Mathematics 101, Autumn Quarter, 1972, at the Mansfield Campus. These students received the IP method of teaching.

Group B - 2103 students enrolled in Mathematics 101, Autumn Quarter, 1972, at the Columbus Campus. These students received the TVL-R method of teaching.

Group C - 153 students enrolled in Mathematics 101, Autumn Quarter, 1972, at the Lima Campus. These students received the DL-D method of teaching.

Group D - 181 students enrolled in Mathematics 101, Autumn Quarter, 1971, at the Mansfield Campus. These students received the DL-D method of teaching.

Group E - 62 students enrolled in Mathematics 101, Spring Quarter, 1972, at the
Mansfield Campus. These students received the DL-D method of teaching.

Groups A, B, C, and E were taught using the same text and syllabus: Group D was taught the same material using a different text (15).

The major part of this study is concerned with groups A, B, and C. The students in these three groups were given a common first midterm the second week of the quarter and a common final examination. The students were also given a mathematics opinionnaire during the first week and again the last week of the quarter. Pre and posttreatment data on the following items were studied for groups A, B, and C.

**Pretreatment**

1. Number of students enrolled
2. ACT mathematics scores
3. ACT composite scores
4. Mathematics placement levels
5. First midterm raw score
6. Mathematics opinionnaire scores

**Posttreatment**

1. Final examination raw scores
2. Number of students who completed the course
3. Number of students who were successful
4. Attrition rate
5. Drop-out rate
6. Mathematics opinionnaire scores

Groups D and E were included in the study in order to compare attrition and drop-out rates of these groups with the corresponding data for group A. Groups A, D, and E were all Mansfield campus students.
Organization of the Study

This study is organized in the following manner. Chapter II deals with methods and procedures employed in the study. This includes detailed descriptions of the IP method of teaching basic algebra at the Mansfield Campus of The Ohio State University, Autumn Quarter, 1972. Also included is a description of the TVL-R method used at the Columbus campus, the DL-D method used at the Lima Campus, and the manner in which these three methods were compared.

Chapter III deals with statistical aspects of the study. In this chapter the data is presented and analyzed. The summary and conclusion along with some related observations and recommendations by the author are presented in Chapter IV.
CHAPTER II

METHODS AND PROCEDURES

The Course

The concern of this study was the instructional procedures used in presenting the basic algebra course, Mathematics 101, at the Mansfield Campus of The Ohio State University. This course, or evidence of a basic knowledge and ability in the use of elementary algebra by the placement procedure, is a prerequisite for the beginning course in each of the freshman mathematics sequences. The purpose of Mathematics 101 is to review high school algebra. The topics normally covered are: Sets, Properties of Numbers, Graphing, Linear Equations and Inequalities, Linear Systems, Functions, Operations on Polynomials, Factoring of Polynomials, Rational Expressions, Quadratic Equations and Inequalities, Polynomial Equations and Exponential Functions.

This material has been taught in one ten-week quarter; of course, "being taught" doesn't guarantee being learned. If it were strictly a review with all students having two years of high school algebra, the course as it has been presented might be appropriate. However, many of the
students have had only one year of high school algebra, and this from three to thirty years prior to their enrolling in Mathematics 101. A few students have had no high school algebra -- only general mathematics, whereas others have had four years of high school mathematics.

In the past, the method of teaching at both the Mansfield and Lima campuses of The Ohio State University consisted of the traditional lecture-discussion approach. Sections ranged in size from 30 to 45 students with the instructors having one or two sections along with other course responsibilities. Although instructors attempted as best they could to meet the individual needs of the students, there was nothing in the structure of the course for doing so. Students either achieved a passing average on the two or three midterms and final or repeated the course.

The pace of the course with its inflexible structure and students with diverse backgrounds, motivations and abilities resulted in high attrition rates and disgruntled students. It was the intent of this study to determine the feasibility of using a new method of teaching this course, Mathematics 101, in hopes of alleviating some of these problems.
The Teaching Method

The teaching method under consideration was an attempt to individualize the pace and to some extent the instruction for the basic algebra course, Mathematics 101. This method of teaching will be referred to as the IP (individualized pacing) method. The method was employed on the Mansfield Campus of The Ohio State University, Autumn Quarter, 1972. There were 124 students enrolled in the course.

To implement the IP method, the contents of Mathematics 101 was divided into seven units as given in Appendix C. The first four units constituted the first module of the course, known as Mathematics 101.01. The first unit dealt with sets; properties of the natural numbers, integers, rationals, reals, and complex numbers; and the cartesian coordinate system. The second unit covered equations and inequalities involving one variable. Absolute value was also considered in this unit. The third unit considered several methods for solving systems of linear equations and inequalities. The concept of function was included in unit three. Addition, subtraction, multiplication and factoring of polynomials made up unit four. By completing these four units satisfactorily a student received three hours of credit.
The last three units composed the second module of the course labeled Mathematics 101.02. Unit five dealt with division of polynomials and manipulation of rational expressions. Quadratic equations and inequalities along with fractional equations and inequalities composed unit six. The last unit considered methods of solving polynomial equations. In addition the properties of rational exponents and the exponential function were included. For this module a student received two hours of credit.

Through the IP approach a student could do both modules in one quarter, thus receiving five hours of credit, or he could spend two quarters doing one module each quarter. He would thus receive three hours of credit the first quarter and two hours the second.

The course was taught by a staff of four instructors who worked as a team; teaching, tutoring and advising the students. Classes were held at 9:00 and noon daily. Two of the instructors taught both hours so there were three instructors for each class hour.

The first two and a half weeks of the quarter (the quarter started on a Wednesday) the students attended large lectures (one at 9:00 and one at 12:00) and small recitation groups, as illustrated by the schedule on page 96 of Appendix G. During this period the material in unit one was presented. On Friday at the end of the second full
week of class all students were given a common examination over unit one. Examinations were given every Friday thereafter. All examinations used for the course employed the multiple choice format. Copies of an examination for each unit and the final examination are given in Appendix K.

The examinations were graded on Friday afternoons, enabling the students to obtain the results on Monday morning. Each of the students was assigned to one of the four instructors for record-keeping and advising. Every Monday morning before class the students would check with their advisors concerning the test results. If a student was satisfied with his score he would proceed to the next unit. If not, he would repeat the unit and take another examination over the unit the following Friday.

A student was permitted to take a test on a given unit three times at most and he was required to take a test each Friday. Hence, he could spend from one to three weeks on a given unit. This enabled him to accelerate on units that he mastered easily and to take more time with those with which he had difficulty.

There were no more large lectures after the first examination. Instead, each student attended a small teaching section of his choice. Each Monday a teaching schedule was posted for the upcoming week. After receiving his examination score the student in consultation with an
instructor would determine whether to repeat the unit or go to the next unit. Upon making the decision he would check the teaching schedule for the week to determine which classes to attend. To illustrate, the teaching schedule for the week after the first test is given in Table 1 below. The teaching schedules for each week are given in Appendix G.

TABLE 1
TEACHING SCHEDULE WEEK OF OCTOBER 16 - 20

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Instructor</th>
<th>9:00 Sections in Text</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>10-16</td>
<td>A</td>
<td>4.1, 4.2</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>1.1, 1.2, 1.3</td>
<td>468</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>2.1, 2.2, 2.3</td>
<td>143</td>
</tr>
<tr>
<td>T</td>
<td>10-17</td>
<td>A</td>
<td>4.2, 4.3</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>1.4, 1.5</td>
<td>468</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>2.4, 2.5, 2.6</td>
<td>143</td>
</tr>
<tr>
<td>W</td>
<td>10-18</td>
<td>A</td>
<td>4.3, 4.4</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>2.1, 2.2, 2.3, 2.4</td>
<td>468</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>2.7, 2.8</td>
<td>143</td>
</tr>
<tr>
<td>R</td>
<td>10-19</td>
<td>A</td>
<td>Review Chapter 4</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>2.5, 2.6, 2.7, 2.8</td>
<td>468</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>Chapter 3</td>
<td>143</td>
</tr>
<tr>
<td>F</td>
<td>10-20</td>
<td>TEST Units 1 &amp; 2</td>
<td>Aud. 12:00</td>
<td></td>
</tr>
</tbody>
</table>

It should be noted that unit one consisted of chapters one through three and unit two consisted of chapter four. If a student decided to proceed to unit two he would attend instructor A's classes. If a student
repeated unit one he would determine which sections were troublesome and attend the corresponding classes.

Throughout the quarter a given topic was taught by more than one instructor and on different days. Hence, a student who desired to see various approaches to difficult topics could do so. For those topics which he could understand by using the text and reference materials, he need not attend class.

Another aspect to the IP program was the availability of individual assistance by the staff. There was a tutorial schedule (see Appendix F) assigning an instructor for tutoring every hour from 8:00 a.m. to 3:00 p.m. daily except Friday afternoon. However, the use of this service was rather disappointing.

To supplement the text, reference materials were put on closed reserve in the library. Each student was provided with an outline of the course giving the page numbers in the reference works that corresponded to the given topics in the text (see Appendix E). As with the tutoring most students didn't take advantage of this resource.

By considering the testing schedule illustrated in Table 2 one can get an idea of how a student could proceed at his own pace through the course.
TABLE 2

IP TESTING SCHEDULE AUTUMN, 1972

<table>
<thead>
<tr>
<th></th>
<th>Friday</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10-13</td>
<td>Test on Unit I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10-20</td>
<td>Tests on Units I &amp; II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10-27</td>
<td>Tests on Units I, II &amp; III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>11-3</td>
<td>Tests on Units II, III &amp; IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>11-10</td>
<td>Tests on Units II, III, IV &amp; V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>11-17</td>
<td>Tests on Units II, III, IV, V &amp; VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>11-22</td>
<td>Tests on any Unit I through VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>12-1</td>
<td>Tests on Units III, IV, VI &amp; VII</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>12-8</td>
<td>Tests on Units IV &amp; VII</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It should be kept in mind that a student could take a test over a given unit at most three times and that he must complete the first four units to get the three hours of credit for Mathematics 101.01. If he completed all seven units he received five hours of credit.

Consider the student who decided to spread the course work over two quarters. Since there were eight regular test days the student could take two tests on each of the four units in Mathematics 101.01. Or he could spend one
week on one unit and three weeks on another (recall that the tests were given at one week intervals). The test given the Wednesday before Thanksgiving was a free-for-all test. That is, a student could take the test on any unit he desired. He was not restricted to the unit he was working on at that time.

The capable, industrious student who progressed to a new unit each week could complete the course the week after Thanksgiving. If he found it necessary, he could repeat two units and still complete all seven units in one quarter.

To summarize, the IP method allowed the student to spend one or two quarters to complete Mathematics 101. He could accelerate when feasible and take more time when necessary. The student also had some choice in the type of instruction he received. He could choose among various instructors or he could work on his own. Tutorial staff was available at all times.

The approach described above has several shortcomings, some of which are easily resolved. The major one was using the Friday class period for tests each week with the result that the students received only four hours of instruction per week instead of five. The limited use of the reference materials and tutorial service constitutes an area of concern.
Another concern, particularly for administrators, is the personnel required to staff the course. In the past, using the traditional lecture discussion approach, four sections and thus four staff members at one-third load would have been required. Using the IP method the equivalent of six staff members at one-third load was required. However, there are some compensating factors and ways of making the staffing needs more equitable financially. The ramification and recommendations concerning these and other problem areas will be discussed more completely in Chapter IV.

The Experimental Methods and Procedures

This study was conducted in the Autumn Quarter, 1972, on the Mansfield Campus of The Ohio State University with a follow-up in the Winter Quarter, 1973. The study was concerned with the feasibility of using the IP method of teaching basic algebra. To give some indication as to the effectiveness of the IP method, data on students who were taught the same course using different methods were obtained.

As mentioned in Chapter I five groups of students were considered. They were as follows:

Group A - 124 students enrolled in Mathematics
Group B - 2103 students enrolled in Mathematics 101, Autumn Quarter, 1972, at the Columbus Campus. These students were taught by the TVL-R method.

Group C - 153 students enrolled in Mathematics 101, Autumn Quarter, 1972, at the Lima Campus. These students were taught by the DL-D method.

Group D - 181 students enrolled in Mathematics 101, Autumn Quarter, 1971, at the Mansfield Campus. These students were taught by the DL-D method.

Group E - 62 students enrolled in Mathematics 101, Spring Quarter, 1972, at the Mansfield Campus. These students were taught by the DL-D method.

The IP method of teaching has been described in detail earlier in this chapter.

The Columbus campus students, group B, were all taught by the TVL-R method. This meant television lectures every Monday, Wednesday, and Friday. The lecture was repeated at each of the following times: 8:00, 9:30, 11:00, 2:30 and 4:00. On Tuesdays and Thursdays the students met in recitation sections. There were sixty-eight recitation sections ranging in size from 18 to 38 students. The television lectures were given by William Klinger, the author of the textbook used for the course. The recitation sections were conducted by graduate assistants under the supervision of Mr. Klinger. This method of teaching, as mentioned in Chapter I, was studied in depth by Waits (20)
at The Ohio State University.

The Lima campus students, group C, comprised five sections of Mathematics 101, ranging in size from 20 to 40 students. Each section met daily with a regular faculty member using the traditional lecture-discussion method.

Groups D and E were Mansfield campus students who were taught by the traditional lecture-recitation method. However, group E students were taught using the same material as group A but without the opportunity for pacing. That is, the course was divided into seven units with a test on each unit.

Groups A, B and C used a common syllabus, a common text and were given common first and final examinations. These groups were also given a mathematics opinionnaire, a copy of which is in Appendix I. This instrument was administered during the first and the last weeks of the quarter. Additional data collected on all five groups were:

1. Number of students enrolled as indicated by the registrar's report taken the 14th day of the quarter.
2. ACT Mathematics raw score.
3. ACT Composite raw score.
5. The percent of each group that were successful.
6. The percent of each group that completed the course or the first module.
7. The attrition rate for each group.
8. The drop-out rate for each group.

The common first examination along with the data concerning ACT scores and placement levels were used to
determine whether the groups had similar initial mathematics achievement. Since the IP method did not come into play with group A until after the first examination, it was assumed that the first examination would be an indication of the pretreatment differences of the groups. However, as will be discussed in Chapter III, this assumption may not be valid.

As mentioned earlier, the first examination and the final examination were composed of multiple choice questions. Instructors from the participating campuses were asked to submit items for both the first examination and final examination. The examinations were compiled jointly by the author and Mr. Klinger. Questions were selected from the submitted items, from the composers' repertoires and from NLSMA Z-Population Test Batteries (22). Permission to include the NLSMA test items were granted by the SMSG director, E. B. Begle (for permission letter see Appendix J).

There were 30 items on the first examination. Using a population of 2478 students from the four regional campuses of The Ohio State University (Lima, Mansfield, Marion and Newark) and the main campus this test had a Kuder-Richardson - 20 reliability index of 0.772 and a Kuder-Richardson - 21 reliability index of 0.738. The mean item difficulty was .294 and the mean item discrimination
was .374.

The final examination had 36 multiple choice items. The evaluation of this examination using 1217 students (it was administered to only half of the Columbus campus students), yielded a Kuder-Richardson - 20 reliability index of 0.834 and a Kuder-Richardson - 21 reliability index of 0.802. The mean item difficulty was .287 with a mean item discrimination of .388. The test analysis was provided by Mr. Deem and Mr. Cassaudra of the Office of Evaluation of The Ohio State University.

The final examination was the posttreatment instrument used to measure achievement. This common examination was given on the same day at all three campuses. It was also given to group D Spring Quarter, 1971, at Mansfield. An analysis of covariance using the raw scores on the first examination as a covariate was used in analysing the data.

The data on attrition and drop-out rates was used to indicate the effectiveness of the IP method on retention of students in comparison with the teaching methods used with other groups. Of particular interest was the comparison with previous groups of students at Mansfield.

The attitude of students in previous classes of Mathematics 101 toward mathematics has been rather poor. A mathematics opinionnaire was employed in this study to determine whether any of these groups exhibit significant
attitude changes toward mathematics.

Tables of data and the analysis thereof can be found in Chapter III.
CHAPTER III

ANALYSIS OF DATA

Analysis of Pretreatment Data

The purpose of analysing the pretreatment data was to determine the extent of the similarity of the various groups involved in the study. Recall that the groups A, B, and C represent students from different campuses: Mansfield, Columbus, and Lima respectfully. Partner (11) found differences in performance between regional and main campus students. He speculated that these differences were due to several factors such as the regional campus having the commuter campus environment, students with full time jobs, a higher percentage of married and older students, and students with different motivations for attending college. These non-achievement differences were impossible to control and difficult to analyse. However, the purpose of this section is to determine if there were basic differences among the groups with respect to pretreatment mathematics achievement. It will be shown that even though the groups represented different campuses their initial achievement in mathematics was very much the same.
The first set of data considered was the standardized examination (ACT) scores and the mathematics placement levels. The results are tabulated in Table 3.

TABLE 3
ACT SCORES AND MATHEMATICS PLACEMENT LEVELS

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean ACT Mathematics Score</th>
<th>Mean ACT Composite Score</th>
<th>Mean Placement Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=Mansfield Aut.'72</td>
<td>19.52 (N=110^a)</td>
<td>20.69 (N=110)</td>
<td>3.45 (N=119)</td>
</tr>
<tr>
<td>B=Columbus Aut.'72</td>
<td>19.98 (N=51)</td>
<td>20.67 (N=51)</td>
<td>3.54 (N=57^b)</td>
</tr>
<tr>
<td>C=Lima Aut.'72</td>
<td>19.99 (N=132)</td>
<td>20.38 (N=132)</td>
<td>3.45 (N=146)</td>
</tr>
<tr>
<td>D=Mansfield Aut.'71</td>
<td>18.82 (N=141)</td>
<td>20.48 (N=141)</td>
<td>3.65 (N=152)</td>
</tr>
<tr>
<td>E=Mansfield Spring '72</td>
<td>19.11 (N=47)</td>
<td>19.26 (N=47)</td>
<td>3.48 (N=56)</td>
</tr>
</tbody>
</table>

^aACT test results and placement levels are not available on all students.
^bBy random selection, 68 subjects were chosen from the Columbus campus group. Data was not available on 11 of them.

The data in Table 3 reveal very little difference among the groups A, B, and C with respect to any of the three categories: Mean ACT Mathematics Scores, Mean ACT Composite Scores, or Mean Placement Levels. Group D had
a somewhat lower mean mathematics score on the ACT test and a lower mean placement level (the higher the value, the lower the placement; 5 being the lowest possible level and 1 the highest). But the mean composite score for group D was similar to that for groups A, B, and C. The mean placement level for group E was in accord with those in groups A, B, and C but group E's mean mathematics and composite ACT scores were slightly lower than those of the other groups.

Since the data for the Columbus campus resulted from a random sample of group B, a .95 confidence interval for the mean in each of the three categories was computed. The upper and lower limits of the confidence interval were computed using the following formulas:

\[ UL_{.95} = \bar{X} + 1.96 \frac{s}{\sqrt{N}}, \quad LL_{.95} = \bar{X} - 1.96 \frac{s}{\sqrt{N}}, \quad \frac{s}{\sqrt{N}} \]

where \( \bar{X} \) is the mean for the sample, \( s \) is the standard deviation and \( N \) is the number of students in the sample.

The .95 confidence interval for the mean ACT mathematics score was from 18.73 to 21.23 for the sample selected from group B. Though the other groups were not samples of the same population, all the mean ACT mathematics scores were within this interval.

The .95 confidence interval for the mean ACT composite score for group B was from 19.77 to 21.57. The mean scores for all the groups except E were in this interval. The .95 confidence interval for the mean placement level of group B was from 3.36 to 3.63. The means for all groups except D
were in this interval.

In comparing group A with previous classes at Mansfield (groups D and E) one might expect group A to perform at a slightly higher level, since both the mean ACT mathematics and the mean ACT composite scores were higher in group A than the respective scores for group D and E. Likewise, the mean placement level for group A was considerably higher than that for group D. However, there was little difference in mean placement levels between groups A and E.

To summarize, analysis of pretreatment data on standardized examinations and placement levels using confidence intervals indicated very little difference among groups A, B, and C. The data suggest that group A was slightly above groups D and E.

The other pretreatment data considered were the scores obtained on the first examination, given at the end of the second week of the quarter. This examination consisted of 30 multiple choice items. The same examination was given to groups A, B, and C. The data is presented in Table 4.
TABLE 4

RESULTS OF FIRST EXAMINATION

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Score</th>
<th>Standard Deviation</th>
<th>Median Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&lt;sub&gt;2&lt;/sub&gt; Mansfield</td>
<td>124</td>
<td>22.56</td>
<td>4.68</td>
<td>23</td>
</tr>
<tr>
<td>B&lt;sub&gt;2&lt;/sub&gt; Columbus</td>
<td>1963</td>
<td>21.36</td>
<td>4.56</td>
<td>22</td>
</tr>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt; Lima</td>
<td>149</td>
<td>21.09</td>
<td>4.54</td>
<td>22</td>
</tr>
</tbody>
</table>

The groups listed in Table 4 as A<sub>2</sub>, B<sub>2</sub>, and C<sub>2</sub> represent all students from the various campuses who took the first examination. The data reveal that there was very little difference between groups B<sub>2</sub> and C<sub>2</sub>, the mean scores being 21.36 and 21.09 respectively. This was as expected considering the ACT score and placement levels. However, the higher mean score by group A<sub>2</sub> was unexpected. The mean score for this group was 22.56, substantially higher than the mean scores for groups B<sub>2</sub> and C<sub>2</sub>.

To determine if the differences in the mean scores were significant, a z-test was used. The z value is given by the ratio of the difference of the means over the standard error: 

\[ z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}} \]

For reference, see Ullman (17).

The z-ratio computed for the difference between the
means for group A and B was 2.77. Therefore, the hypothesis that there was no difference in the mean scores was rejected using a probability level of .05 (z-value at .05 is 1.96). The z-ratio for groups A and C was 2.26, indicating that the hypothesis that there was no difference in mean scores for groups A and C must be rejected also. However, the z-ratio for groups B and C was only 0.70 indicating that the hypothesis that there is no difference in the mean scores for groups B and C need not be rejected.

Since there were only slight differences between the groups' ACT scores and placement levels, the higher mean score for group A on the first examination seemed out of line. There were several factors that might account for these differences. One factor to be considered was the effect of treatment during the first two and a half weeks of the quarter. The assumption that the effect of the treatment received during this period was negligible might be false. As mentioned in chapter II, the Mansfield group was taught by the author in large lecture three days a week with small recitation sections the other two days. The author was the principal writer of the first examination. He might have unconsciously stressed the same concepts and topics on the examination that were stressed in the lectures.

In order to determine if this was the cause of the high scores by group A an item analysis of the examination
was performed. If group A scored considerably higher than groups B and C on any particular question this might indicate that the concept examined by the question was stressed in the teaching of group A.

Appendix L contains the item analysis summary for both the first examination and the final examination. A comparison between the percent of students that correctly answer the items shows that group A did considerably better on items 10, 11 and 26 as shown in table 5 below.

**TABLE 5**

Percent of Correct Responses on Items Concerning Properties of Numbers on First Examination

<table>
<thead>
<tr>
<th>Item</th>
<th>Group A % Correct</th>
<th>Group B % Correct</th>
<th>Group C % Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>73.3</td>
<td>48.1</td>
<td>42.9</td>
</tr>
<tr>
<td>#11</td>
<td>90.0</td>
<td>70.3</td>
<td>66.7</td>
</tr>
<tr>
<td>#26</td>
<td>87.8</td>
<td>66.6</td>
<td>61.9</td>
</tr>
<tr>
<td>#12</td>
<td>78.9</td>
<td>36.7</td>
<td>81.7</td>
</tr>
</tbody>
</table>

The four items referred to in the table were all concerned with the properties of numbers. In addition, these were the only item on the examination concerning the
properties of numbers. This data indicates that perhaps more emphasis was placed on these concepts in the teaching of group A than the other two groups. This might account for the higher mean score on the examination for group A.

A second possible factor was the maturity of the students: 36 percent of the students in group A were not first quarter freshmen; only 18 percent and 20 percent of the students in groups B and C respectively were not first quarter freshmen. Those students who had experience in college courses might perform better on the first examination in a course than the first quarter freshmen. The fact that group A had a higher percentage of these experienced students, might account for this higher mean score.

In summary, the data on the first examination indicates that there was little difference between groups B and C. Group A had a higher mean score than the other two groups. However, the higher mean score by group A might be a result of uncontrolled variables during the first two weeks of the course.

Returning to the question raised at the beginning of the section concerning the extent of similarity of the groups, the data revealed that the groups were quite similar with respect to pretreatment achievement. The only exception was that group A had a higher achievement on the first examination. However, as discussed earlier, there were
factors contributing to this exception. The author concluded, then, that for the purpose of this study there were no significant differences among the groups A, B, and C with regard to pretreatment algebraic achievement. Groups D and E were perhaps slightly lower in pretreatment algebraic achievement.

Analysis of Posttreatment Achievement Data

Achievement was measured by means of the final examination. Recall that the examination consisted of 36 multiple choice items with a Kuder-Richardson-20 reliability index of .834.

This examination was given the same day at the Mansfield, Columbus, and Lima campuses (groups A, B, and C), Autumn quarter, 1972. This examination was also given to the Mansfield campus students and the Columbus campus students, Spring quarter, 1972. The latter group was not part of the study in that pretreatment data was not available, but is mentioned here for comparison purposes.

This group of Columbus campus students (henceforth referred to as group F) consisted of 47 sections of about 30 to 35 students each. These were taught by individual instructors (graduate assistants) using the traditional daily lecture-discussion method. One half of the group
took a different form of the same examination. Only data on those who took the same form was considered.

The data on achievement by these various groups presented in Table 6.

### TABLE 6

**RESULTS OF THE FINAL EXAMINATION**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Score</th>
<th>Standard Deviation</th>
<th>Median Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Mansfield</td>
<td>90</td>
<td>27.21</td>
<td>4.32</td>
<td>27</td>
</tr>
<tr>
<td>A11 Mansfield</td>
<td>70</td>
<td>27.71</td>
<td>4.11</td>
<td>28</td>
</tr>
<tr>
<td>A12 Mansfield</td>
<td>20</td>
<td>25.00</td>
<td>4.28</td>
<td>25</td>
</tr>
<tr>
<td>B1 Columbus</td>
<td>780</td>
<td>26.04</td>
<td>5.82</td>
<td>26</td>
</tr>
<tr>
<td>C1 Lima</td>
<td>126</td>
<td>25.61</td>
<td>5.18</td>
<td>26</td>
</tr>
<tr>
<td>E1 Mansfield Spring'72</td>
<td>44</td>
<td>24.25</td>
<td>5.16</td>
<td>24</td>
</tr>
<tr>
<td>F Columbus Spring'72</td>
<td>697</td>
<td>22.74</td>
<td>6.02</td>
<td>23</td>
</tr>
</tbody>
</table>

*AI denotes those students completing the course in one quarter. A12 Denotes those taking two quarters.

In comparing the data in Table 6, one notices a considerable difference between the Mansfield group (A1) taught by the IP method and the Mansfield group (E1) of the previous Spring quarter taught by the traditional DL-D method. Their respective mean scores were 27.21 and 24.25. The pretreatment data (see Table 3) indicate a slight dif-
ference in standardized scores with little or no difference in mean placement levels (3.45 versus 3.48). It appears that the IP method produced better achievement for the group A than the DL-D method did for the group E. However, approximately the same difference exists between groups B₁ and F (the Columbus Autumn and Spring quarter groups), thus indicating the difference may not be due to treatment but due to the time of the year offered.

The data on groups A₁₁ and A₁₂ was included to show the difference in achievement between those students taught by the IP method who completed the course in one quarter versus the students who took two quarters to complete the course. The A₁₁ group had a mean score of 27.71 whereas the A₁₂ group had a considerably lower mean score of 25.00. However, the score of the A₁₂ group was not as low as might be expected since a large number of these students would not have completed the course if they had not had the opportunity for individualized pacing. On the other hand, a high score might be expected due to the opportunity of students to take twice as long to cover the course. Note also that the mean score for group A₁₂ is higher than that for group B₁ and considerably higher than that of group F (Columbus campus students, Spring quarter, 1972). The ramifications of this are discussed further in the next section and in Chapter IV.
The table shows that mean scores for the groups A₁, B₁, and C₁ were 27.21, 26.04, and 25.61 respectively. There was little difference between group B₁ and C₁. Recall that the pretreatment data showed these two groups were very similar with respect to algebraic achievement. Thus, the pre and posttreatment data indicate little difference in achievement in the Columbus campus group taught by the TVL-R (TV Lecture-Recitation) method versus the Lima campus group taught by the traditional DL-D (Daily Lecture-Discussion) method.

When group A₁ was compared to B₁ and C₁, there was an apparent difference in the mean scores. Group A₁, which was taught by the IP (Individualized Pacing) method had a higher mean score. However, before concluding that the IP method had a positive effect on achievement the pretreatment data must be considered. Recall that group A₁ was similar to B₁ and C₁ with respect to standardized ACT scores and placement levels but showed a slightly higher achievement level as indicated by the scores on the first examination. The mean scores on that examination as given in Table 4 for groups A, B, and C were 22.56, 21.36, and 21.00 respectively. Therefore, before interpreting the achievement data as indicating better achievement produced by the IP method, a more critical analysis of the data was necessary. As mentioned earlier, since the sample groups
were not random samples from the same parent population
certain statistical assumptions were violated in analysing
the data. However, some insight regarding the difference
in mean scores on the final examination was obtained by
means of an analysis of covariance using the first examin-
ation scores as a covariate.

The computer program used for the analysis of
covariance was a version of the BMD04V Analysis of Covari-
ance with Multiple Covariates designed by the Health
Science Computer Facility at the University of California
at Los Angeles. The program was designed to compute
analysis of covariance information for one analysis-of-
variance variable with multiple covariates and unequal
treatment group sizes. However, there was only one
covariate considered.

The statistical model is

\[ \gamma_{ij} = \mu + \alpha_i + \beta(x_{ij} - \bar{x}_i) + \epsilon_{ij} \]

Where \( \gamma_{ij} \) is the final examination score for the \( j^{th} \)
student in the \( i^{th} \) group. \((i=1,2,3)\) and where:

- \( \mu \) is an overall mean
- \( \alpha_i \) is the effect for the \( i^{th} \) method
- \( \beta \) is the regression coefficient of the covariate.
- \( x_{ij} \) is the first examination score for the \( j^{th} \)
  student in the \( i^{th} \) group
- \( \bar{x}_i \) is the covariate mean for the \( i^{th} \) group
- \( \epsilon_{ij} \) is the error adjustment for the \( j^{th} \) student
  in the \( i^{th} \) group
The t-test data for the regression coefficient is reported in Table 7. The t-value was computed by dividing the regression coefficient $\beta$ by the standard error.

**TABLE 7**

<table>
<thead>
<tr>
<th>Regression Coefficient</th>
<th>Standard Error</th>
<th>t-value</th>
<th>df</th>
<th>t .01 df= $\infty$</th>
<th>t .05 df= $\infty$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8106</td>
<td>0.0370</td>
<td>21.8947</td>
<td>992</td>
<td>2.57</td>
<td>1.96</td>
</tr>
</tbody>
</table>

The data show that the hypothesis that $\beta = 0$ must be rejected. Hence, the student's score on the first examination is a valid covariate.

The hypothesis that there was no significant difference among groups after adjusting with the covariate was tested by using the analysis of covariance referred to above. (The analysis of covariance table is given in Appendix K). The resulting F statistic was .118 with df=(2, 991). The critical F values with (2, $\infty$) degrees of freedom at the .05 level is 3.00 and at the .01 level is 4.61. Hence, the analysis indicates that the hypothesis that there is no significant difference in the achievement
of the groups as measured by the final examination cannot be rejected.

Table 8 gives the unadjusted and adjusted final examination mean scores for the three treatment groups.

**TABLE 8**

**FINAL EXAMINATION ADJUSTED MEAN SCORES**

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Mean</th>
<th>Adjusted Mean</th>
<th>SE Adjusted Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&lt;sub&gt;1&lt;/sub&gt; Mansfield</td>
<td>27.2111</td>
<td>25.9141</td>
<td>0.4889</td>
</tr>
<tr>
<td>B&lt;sub&gt;1&lt;/sub&gt; Columbus</td>
<td>26.0449</td>
<td>26.0964</td>
<td>0.1650</td>
</tr>
<tr>
<td>C&lt;sub&gt;1&lt;/sub&gt; Lima</td>
<td>25.6111</td>
<td>26.2189</td>
<td>0.4111</td>
</tr>
</tbody>
</table>

The data show a sizable downward adjustment in the Mansfield (IP) group's mean score. This was a result of a relatively high mean score by this group on the first examination. As was mentioned in the previous section this high mean score on the first examination might have been caused by the instruction the first two weeks of the quarter.

For further study of the results of the final examination, the distribution of scores according to the grade cut-offs was considered. These cut-offs were mutually
determined by David T. Hayes, the mathematics coordinator at Lima, William Klinger, the course coordinator at Columbus and the author. Actual grades assigned for the course made use of this as only one of several variables considered. Comparison of course grades was not considered appropriate due to different grading practices at the various campuses.

Table 9 illustrates the final examination cut-off ranges and the percent of students from the various groups in each range.

**Table 9**

**FINAL EXAMINATION GRADE DISTRIBUTIONS**

<table>
<thead>
<tr>
<th>Cut-Off Ranges</th>
<th>Group A Mansfield N=90</th>
<th>Group B Columbus N=780</th>
<th>Group C Lima N=126</th>
<th>Group A**-** Mansfield N=70</th>
<th>Group A**-** Mansfield N=20</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=32-36</td>
<td>18.9%</td>
<td>7.5%</td>
<td>11.9%</td>
<td>22.9%</td>
<td>5.0%</td>
</tr>
<tr>
<td>B=28-31</td>
<td>32.2</td>
<td>28.2</td>
<td>28.6</td>
<td>32.9</td>
<td>25.0</td>
</tr>
<tr>
<td>C=24-27</td>
<td>32.2</td>
<td>25.4</td>
<td>25.4</td>
<td>32.9</td>
<td>35.0</td>
</tr>
<tr>
<td>D=20-23</td>
<td>10.0</td>
<td>15.4</td>
<td>22.2</td>
<td>8.6</td>
<td>15.0</td>
</tr>
<tr>
<td>E=0-19</td>
<td>6.7</td>
<td>13.5</td>
<td>11.9</td>
<td>2.9</td>
<td>20.0</td>
</tr>
</tbody>
</table>

It should be noted that a larger percent of the Mansfield group than either of the other two groups was
in the A and B ranges (51 percent versus 46 percent and 40 percent). Likewise, the Mansfield group had a much lower percent in the D and E ranges (17 percent versus 29 percent and 34 percent).

That data for the Mansfield sub groups A₁₁ and A₁₂ reveal that those who completed the course in one quarter scored much higher than those who took two quarters to complete the course. Approximately 56 percent of the students in group A₁₁ were in the A or B ranges with only about 11 percent of them in the D and E ranges. Whereas, only 30 percent of the students in group A₁₂ in the upper ranges with 35 percent of this group in the D and E ranges.

To summarize, the achievement data indicate that the IP method of teaching basic algebra to Mansfield students was as effective with respect to achievement as was the TVL-R method and the DL-D method used on the Columbus campus and the Lima campus respectively.

Analysis of Data on the Percentage of Students Completing the Course and Successful Students

Students who completed the course were defined to be those students who received a grade of A through E. Successful students were defined to be those students who
received a grade of A through D.

The data that were considered are given in Table 10.

### TABLE 10

**ENROLLMENT, COMPLETION AND SUCCESS DATA**

<table>
<thead>
<tr>
<th>Group</th>
<th>Number Enrolled</th>
<th>Completed Course with A through E</th>
<th>Successful students with A through D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Mansfield Autumn 1972</td>
<td>124 1st qt. 5 hrs</td>
<td>75 60.5</td>
<td>69 55.6</td>
</tr>
<tr>
<td></td>
<td>1st qt. 3 hrs</td>
<td>38 30.7</td>
<td>33 26.6</td>
</tr>
<tr>
<td></td>
<td>1st qt. total</td>
<td>113 91.2</td>
<td>102 82.2</td>
</tr>
<tr>
<td></td>
<td>(26) 2nd qt. 2 hrs</td>
<td>21 16.9</td>
<td>20 16.1</td>
</tr>
<tr>
<td></td>
<td>total 5 hrs.</td>
<td>96 77.4</td>
<td>89 71.7</td>
</tr>
<tr>
<td>B-Columbus</td>
<td>2103</td>
<td>1652 78.6</td>
<td>1412 67.1</td>
</tr>
<tr>
<td>C-Lima</td>
<td>153</td>
<td>127 83.0</td>
<td>121 79.1</td>
</tr>
<tr>
<td>D-Mansfield Autumn 1971</td>
<td>181</td>
<td>131 72.3</td>
<td>105 58.0</td>
</tr>
<tr>
<td>E-Mansfield Spring 1972</td>
<td>62</td>
<td>48 77.4</td>
<td>42 67.7</td>
</tr>
</tbody>
</table>

To explain the data on group A, recall that the students in this group had the option of taking one or two quarters to complete the Mathematics 101 course. Approximately 60 percent of the students completed the course in
one quarter. An additional 31 percent of the students completed the three credit hour module. Thus a total of 91 percent of the students enrolled completed at least one module of the course.

In considering the number of successful students the data indicated 82 percent of the students completed at least one module with a grade of D or better. Of the 33 students who were successful on the first module, 26 enrolled for the second module with 21 students completing it. Thus, 77 percent of the original enrollment completed the five hour course, 72 percent completing it successfully.

To compare the percent of successful students in group A with similar data for the other campuses and previous classes at Mansfield, consider the following:

1) 82 percent of group A were successful with either five or three hours of credit at the end of the first quarter.

2) 61 percent of the Columbus campus students were successful.

3) 79 percent of the Lima campus students were successful.

4) 58 percent of the Autumn quarter, 1971, Mansfield campus students were successful.

5) 68 percent of the Spring quarter, 1972, Mansfield campus students were successful.

Some caution must be used in taking these figures on successful students at face value. To do so one assumes that the grading standards are the same for all campuses
and all instructors. Although the mathematics coordinator for regional campuses continually emphasizes the importance of uniform grading standards, no formal procedure other than the final examination cut-offs, was employed in this study to insure such uniformity. In fact, as illustrated in Table 9 and mentioned in the previous section both groups B and C had lower scores on the final examination than group A, yet the mean grade point averages for both of these groups were higher than for group A. (Group A = 1.992 Group B = 2.068 Group C = 2.162) Thus, the author suggests that a better indication of success is given by the data in Table 9 where uniform final examination cut-offs were used.

It should be noted that seven of the 33 students who received three hours credit chose not to continue the course even though they were eligible to do so. If these students were limited to a choice between completing the course or receiving no credit whatsoever, one would assume that some might have failed or dropped the course but some would have successfully completed the course. This would have increased the percent of successful students.

Even without the above consideration the 72 percent of group A that were successful compares very well with the 61 percent for group C, 58 percent for group D and 68 percent for group D. It is less than the 79 percent for group B.
Analysis of Data Concerning Drop-out and Attrition Rates

Attrition rate was defined to be the percent of students enrolled at the end of the second week of the quarter who did not receive a passing grade in the course or the first module. Drop-out rate was defined to be the percent of students enrolled at the end of the second week of the quarter who did not complete the course or the first module. Table 11 gives data on drop-out and attrition rates for the groups at the various campuses.

TABLE 11

MANSFIELD, COLUMBUS, AND LIMA

DROP-OUT AND ATTRITION RATES

<table>
<thead>
<tr>
<th>Group</th>
<th>Enrollment</th>
<th>Drop-out %</th>
<th>Failure %</th>
<th>Attrition %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A=Mansfield</td>
<td>124</td>
<td>8.8</td>
<td>8.8\textsuperscript{a}</td>
<td>17.7</td>
</tr>
<tr>
<td>B=Columbus</td>
<td>2103</td>
<td>21.4</td>
<td>11.5</td>
<td>32.9</td>
</tr>
<tr>
<td>C=Lima</td>
<td>153</td>
<td>17.0</td>
<td>3.9</td>
<td>20.9</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Percent of students failing either the five or three hour module of the course.

The table shows that in group A only 8.8 percent of
the students dropped out the first quarter. This compares to 21.4 percent of group B and 17.0 percent of group C.

The author believes the extremely low drop-out rate represents the strongest evidence in support of the IP method of teaching basic algebra.

Since the purpose of the study was to determine the feasibility of using the IP method of teaching basic algebra at the Mansfield Campus of The Ohio State University, the drop-out and attrition data for the Mathematics 101 students at Mansfield for previous quarters is presented in Table 12.

### TABLE 12

MANSFIELD CAMPUS DROP-OUT AND ATTRITION RATES

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Enrollment</th>
<th>Drop-Out %</th>
<th>Failure %</th>
<th>Attrition %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn 72 (IP)</td>
<td>124</td>
<td>8.8</td>
<td>8.8(^a)</td>
<td>17.7</td>
</tr>
<tr>
<td>Spring 72</td>
<td>62</td>
<td>22.6</td>
<td>9.7</td>
<td>32.3</td>
</tr>
<tr>
<td>Autumn 72</td>
<td>181</td>
<td>17.7</td>
<td>14.2</td>
<td>42.0</td>
</tr>
<tr>
<td>Spring 71</td>
<td>61</td>
<td>39.3</td>
<td>18.0</td>
<td>57.3</td>
</tr>
</tbody>
</table>

\(^a\)Percent of students failing either the five or three hour module of the course.
The data reveal that the drop-out rate was from about three to four times as great in previous quarters. Likewise, the attrition rate was from two to three times as great.

The low drop-out rate has implications with regard to achievement of the group using the IP method. By retaining from 15 to 20 percent of the students enrolled in the course who would normally drop the course, the achievement distribution is shifted to the left. In other words, the students who are salvaged using the IP method, as indicated by the data on group \( A_{12} \) in Table 9, fall in the lower end of the achievement range. This has the effect then, of lowering the mean achievement scores. The implication is that if these students had not been included in group \( A_1 \) the data in the previous section on analysis of achievement might have been different. That is, the mean score on the final examination for the group \( A_1 \) would probably have been higher. The comparison among groups might have been more appropriate since none of the groups would have included these normal drop-outs. As a result group \( A_1 \) taught by the IP method, would have higher achievement scores than the other groups.

The data in this and the preceding section are dependent. To summarize both the following points are presented:

1. The percent of students in group A
who received either three or five hours of credit in one quarter was higher than any other group.

2. The percent of students in group A who received the full five hours of credit in one or two quarters was higher than all other groups except group C.

3. The percent of students in group A who dropped the course was markedly lower than any other group.

Analysis of Data Concerning Attitude Change

For the final section of this chapter, the author considered the attitudes of the students in the various groups toward mathematics. The purpose was to determine whether the IP method of teaching had any effect on attitude.

The instrument used to evaluate attitude was a mathematics opinionnaire given in Appendix I. This instrument consisted of twenty-two questions on attitude towards mathematics. The responses employed the use of the Likert scale. Half of the items were stated positively the other half negatively. In scoring the instrument a scale of one to five was used on the negative questions and a scale of five to one on the positive. Hence, the highest possible score was 110 and higher scores indicated
a positive attitude towards mathematics. The lowest possible score was 22 indicating a completely negative attitude towards mathematics. A middle score of 66 would indicate neither a strong positive nor a negative feeling towards mathematics.

The instrument was given to the students in groups A, B, and C the first and again the last week of the quarter. The data given in Table 13 for groups A\textsubscript{3} and C\textsubscript{3} represent all students in groups A and C who completed the opinionnaire both times it was given. Group B\textsubscript{3} was a random sample of those students in group B who completed the opinionnaire both times.

**TABLE 13**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pre-treatment Mean</th>
<th>Post-treatment Mean</th>
<th>Difference</th>
<th>t-test</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>A\textsubscript{3} Mansfield</td>
<td>88</td>
<td>66.48</td>
<td>65.40</td>
<td>-1.08</td>
<td>.428</td>
<td>174</td>
</tr>
<tr>
<td>B\textsubscript{3} Columbus</td>
<td>157</td>
<td>64.81</td>
<td>60.06</td>
<td>-4.75</td>
<td>2.108</td>
<td>312</td>
</tr>
<tr>
<td>C\textsubscript{3} Lima</td>
<td>109</td>
<td>69.05</td>
<td>69.87</td>
<td>+.82</td>
<td>-.721</td>
<td>216</td>
</tr>
</tbody>
</table>

The hypothesis that there was no significant differ-
ence in the pre and posttreatment mean scores at the .05 level of significance cannot be rejected for groups A3 and C3. However, this hypothesis must be rejected for group B3 at the .05 significance level. That is, there was no significant change in attitude towards mathematics by the students at Mansfield and Lima, while on the Columbus campus there was a significant negative attitude change.

The foregoing analysis implies that neither the IP method or the DL-D method of teaching basic algebra had any significant effect on the students attitude towards mathematics. However, those students who were taught by the TVL-R method had a negative attitude change towards mathematics. It is noted that the Columbus campus students had a negative attitude at the beginning of the course and this attitude was even more negative at the end of the course.

The author believes that attitude change occurs more as a result of the effect of the instructor than as a result of the type of instruction. As mentioned earlier, the majority of the recitation instructors on the Columbus campus were graduate assistants and many of these were of foreign origin. This often results in a communication problem as well as an identification problem for the students. On the other hand, the students on the regional campuses were taught by regular faculty members.
For this reason, perhaps there should have been a positive attitude change on regional campuses. However, previous studies on attitude change at The Ohio State University by Moore (10) and by Shatkin (14) have shown that in general there is a negative attitude change towards mathematics in lower division courses. The exception is the elementary education sequence where one of the major objectives of the course is to bring about a positive attitude change.

The author concludes that although the IP method of teaching basic algebra had no apparent effect on the students attitude towards mathematics, this method did not "turn off" the student with regards to mathematics.

The conclusions that can be drawn from the analysis of data that were presented in this chapter, along with the author's reflections on the IP method, are given in the next chapter.
CHAPTER IV

SUMMARY, CONCLUSIONS, REFLECTIONS
AND RECOMMENDATIONS

Summary and Conclusions

This study was concerned with the feasibility of teaching basic algebra by using an individualized pacing approach. This method gave the student the opportunity to complete the five credit basic algebra course in either one of two quarters. This individualized pacing (IP) method of teaching was used with 124 students on the Mansfield Campus of The Ohio State University, Autumn Quarter, 1972. The attrition rate and achievement of these Mansfield students was compared with the attrition rate and achievement of:

1) 2103 students on the Columbus campus taught by the TV lecture with small group recitation sections (TVL-R),

2) 153 students on the Lima campus taught by the traditional daily lecture-discussion method (DL-D),

3) students on the Mansfield campus taught by the traditional daily lecture-discussion method (DL-D) in previous quarters.

Although the students were from different campuses,
analysis of the pretreatment data indicated they were similar with respect to prior achievement in mathematics.

The primary concern in determining the feasibility of the IP method of instruction was the effect the method had on attrition rates. Recall that attrition rate was defined to be the percent of students who did not receive credit for the course or the first module. The attrition rate for the group using the IP method was much lower than any other group. Of particular importance was the comparison of the rate for the IP group with the rate for previous groups of students at the Mansfield campus. For the Autumn quarter, 1972, 18 percent of the students taught by the IP method at the Mansfield campus either dropped or did not receive credit for the course or the first module, whereas, 42 percent of the students taught by the traditional lecture-discussion method the previous Autumn quarter at Mansfield dropped or failed the course (see Table 12). In addition, this 18 percent attrition rate compares favorably with the 33 percent rate for the Columbus campus group using the TVL-R method and the 21 percent rate for the Lima campus group using the DL-D method (see Table 11).

Thus, the results, based strictly on attrition rates, indicate the use of the IP method of teaching basic algebra at the Mansfield campus is feasible. However,
before making a definite conclusion other criteria such as achievement, drop-out rate, and student attitudes must be considered.

A posttreatment comparison of achievement on the final examination was made by an analysis of covariance using the raw scores of the first examination as a covariate. The analysis showed no significant difference in adjusted mean scores of the final examination. However, the high scores on the first examination for the IP group might have been due to factors other than high level students. The author was the principal writer of the first examination and also the lecturer for the IP group the first two weeks of the quarter. The same ideas stressed in class might have been stressed on the examination. The item analysis of the first examination reported in Chapter III supports this conjecture. This effect was not present on the final examination. In addition, the pretreatment standardized test scores and placement levels showed no significant difference in the groups.

The author contends then, that the unadjusted mean scores might be better measures of the achievement. These unadjusted mean scores indicated that the achievement was higher for the IP group than any other group. This higher level of achievement was also reflected by a larger percent of the IP group with scores in the A and B ranges of
the final examination. Likewise, the percent of the IP group in the D and E ranges was less than any other group (see Table 9).

Another indication of the feasibility of using the IP method of teaching was the effect the method had on the "drop-out" rate. The data revealed that two to three times the number of students dropped out of the course at Lima and Columbus as compared to the group at Mansfield. In considering previous classes at Mansfield the percents were three to four times as great as the 9 percent of the students who dropped the course when taught by the IP method. In other words, as a result of using this method of teaching about 20 percent of the students enrolled in the course who normally would drop the course received either three or five hours of credit. The author believes the most significant revelation of this study is the low attrition and drop-out rates encountered when using the IP method. This along with slight gains in achievement is strong evidence in support of the use of the IP method of teaching basic algebra.

Another factor considered for purposes of comparison was the attitude of the students towards mathematics. A mathematics opinionnaire was used to measure attitude change. The results showed no change in attitude towards mathematics for either the group using the IP method or
the group using the DL-D method. The group that was taught by the TVL-R method had a small but significant negative attitude change. The author concludes, that, although the IP method doesn't produce the desired positive attitude change, it does as well as the traditional method and better than the TVL-R method.

These conclusions are summarized by considering the four hypotheses that were proposed in Chapter I. They were as follows:

1. There is no significant difference in the attrition rate between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method;
   c) the groups of Mansfield campus students taught by the DL-D method in quarters prior to Autumn, 1972.

2. There is no significant difference in the drop-out rate between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method;
   c) the groups of Mansfield campus students taught by the DL-D method in quarters prior to Autumn, 1972

3. There is no significant difference in the mathematics achievement as measured by the final examination between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method;
4. There is no significant difference in attitude change towards mathematics between the group of Mansfield campus students taught by the IP method and:
   a) the group of Columbus campus students taught by the TVL-R method;
   b) the group of Lima campus students taught by the DL-D method.

The first hypothesis concerning attrition rate must be rejected for all three cases. The group of Mansfield students taught by the IP method had an attrition rate much lower than the Columbus campus group and previous groups at Mansfield. The IP group's attrition rate was slightly lower than the Lima campus group. The opportunity for individualized pacing resulted in a reduced attrition rate.

The second hypothesis concerning drop-out rates must also be rejected. The drop-out rate for the IP group was from about one half to one third as great as the rates for the other groups. Again, by allowing students to work at their own pace they did not feel pressured into dropping the course.

The adjusted mean scores on the final examination support the third hypothesis. However, interpretation based upon these adjusted mean scores are subject to question.

The last hypothesis as stated must be rejected also. The groups of students taught by the IP method and the DL-D method showed no change in attitude towards math-
ematics, whereas the group taught by the TVL-R method shows a negative change in attitude toward mathematics.

The author concludes that the use of the IP method to teach basic algebra is feasible. Some limitations of the method and recommendations for improvement will be discussed in the next section.

Reflections and Recommendations

In the previous section conclusions were given based on the measurable aspects of this study. There are several non-measurable aspects of the IP method of teaching basic algebra that should also be considered in drawing conclusions about its feasibility. The purpose of this section is to examine some of these and make recommendations concerning them.

The author intended that an integral part of the IP method was the use of tutors. A faculty tutor was available from 8:00 to 3:00 daily except Friday afternoons. This tutor system was included in the IP method to enable students to obtain individualized assistance. It was anticipated that some students would progress through the course using only the text, the reference materials, and the tutors. The other anticipated use of tutors was for
students who attended class but were having difficulty with certain concepts. To the disappointment of the author and staff, no student worked on his own using the tutors. There were very few students that even attempted to do isolated sections on their own.

The main use of the tutors were by some of the students that were having difficulty with various concepts. However, there were many students who did not achieve well who should have been seeing the tutors. In fact 71 of the 124 students in the course never visited a tutor. Only 8 students visited a tutor more than five times.

A possible reason for the lack of utilization of the tutorial program was that the students were inhibited by the tutors. Since all of the tutors were faculty members, perhaps the students did not want to display their lack of understanding to these instructors. The author suggests that to avoid this "hang-up", non-faculty personnel be used instead. A person who would not be a regular faculty member could be employed for this purpose as is being done at the Mansfield campus for 1973 - 1974. An alternative solution would be to use student tutors. However, this latter solution presents a problem for small two year campuses due to the shortage of qualified students.

Another aspect of the IP method was the use of supplementary instructional materials. For this study
these materials were limited to reference books placed on closed reserve in the library. As in the case of the tutors, the students made only limited use of this resource. This lack of initiative on the part of the students was apparent in Moore's study on use of programmed instruction for the same course on the main campus in Columbus. He suggests and the author concurs, that "it was perhaps too ambitious to expect students in remedial mathematics to assume this responsibility." (10,47)

The author recommends that in addition to reference texts, supplementary material such as audio-video cassettes be employed. Both lecture and problem solving tapes are being used successfully in connection with the CRIMEL program on the Columbus campus. (19)

A third aspect of the IP method was the flexible testing program. Students were permitted to take two retests on each unit. This approach worked well the first part of the quarter. However, after several weeks some students were simply taking the first two tests without preparation. Thus, they relied on the third test to salvage the unit. In effect, they would coast for two weeks and cram the third. For weak students this was a disaster.

Another drawback of the testing program was the use of Friday's class time for testing. This allowed only four days of class between tests, which was inadequate for many
students. In designing the IP method the author assumed the students would do more work on their own and the class time would not be so crucial. This was an erroneous assumption. Achievement of the IP group might have been higher if the students had five days of instruction per week instead of four.

The author recommends that the testing program be redesigned to permit students only one retest. It is also recommended that instead of testing weekly at an assigned hour each student be permitted to take a test on a given unit whenever he feels he is prepared to do so. The test would be administered by the non-faculty tutor and graded in the presence of the student upon completion. This would accomplish two goals: (1) the student would gain immediate feedback and (2) the student would be working with the tutor on an individual basis.

The use of a non-faculty personnel for testing and tutoring raises the question of the staffing requirements of the IP method. As mentioned in Chapter II, six faculty members at one third load were required to implement the IP method at the Mansfield campus. Under the traditional method only four faculty at one third load was required. However, by using non-faculty personnel for testing and tutoring, the number of regular faculty needed can be reduced. The cost of the program would thus be approximate-
ly the same as the traditional program. The bonus comes by means of the reduced attrition rates. The faculty required to handle the large number of students that would normally repeat the course at a latter date can be used to handle the two hour module in the following quarter. There is the possibility that even less staff will be necessary to implement the program in the long run.

The last but certainly not the least important aspect to be considered in this section, is the reaction of the students to the IP method of teaching. Many students said they were grateful for the opportunity to proceed at their own pace. Most students appreciated not only the opportunity to be retested on any given unit but the availability for additional instruction on those units that they needed to repeat. A few students felt somewhat insecure by not having the same instructor throughout the quarter. Some students complained that different instructors presented the same material in different ways. The author feels that this is one of the advantages of this method. That is, students that do not comprehend an idea presented in one way might gain comprehension by a different presentation.

The academic advisors reported the students' reactions to the course as taught by the IP method were more positive than the student reactions were previous quarters when the course was taught by traditional methods.
In light of both the results of the measurable and non-measurable aspects of this study the author contends that the individualized pacing method of teaching basic algebra is both feasible and desirable. The author recommends that the method with the modifications suggested in this section be used at the Mansfield campus and other regional campuses of The Ohio State University. It is also recommended that the IP method with appropriate adjustment to accommodate the large enrollments be used on the main campus in Columbus. That is, the author believes that the extension of the CRIMEL program to include Mathematics 101 using a variation of the IP method is feasible.

Recommendations for Further Study

There are several aspects of this method of teaching basic algebra that warrant further study.

The final examination that was used in this study contained several items that were used in a national study of mathematics achievement (NLSMA) (22). A comparison of the students in various groups of the present study with high school students throughout the country would be enlightening.

The author recommends that a duplication of this
study of the IP method incorporating the modifications suggested in the previous section be conducted. Also recommended is an investigation of the effect of the inclusion of level five placement student on the achievement and the attrition rates in the course for the various methods of teaching that were used in the present study.

By means of continual innovation, modification and investigation of teaching methods the author hopes to contribute to a meaningful learning experience for students of mathematics.
APPENDIX A

Mathematics Placement Procedure
MATHMATICS PLACEMENT

Revised Autumn Quarter 1971

<table>
<thead>
<tr>
<th>Level</th>
<th>ACT Score Conditions</th>
<th>OSU Math Placement Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>D ≥ 13 and Mult* ≥ 57</td>
<td>impossible</td>
</tr>
<tr>
<td>II</td>
<td>5 ≤ D ≤ 12 or D ≥ 13 and composite ≤ 56</td>
<td>30 or higher on B test</td>
</tr>
<tr>
<td>III</td>
<td>D ≤ 4</td>
<td>19 ≤ B ≤ 29</td>
</tr>
<tr>
<td>IV</td>
<td>impossible</td>
<td>16 ≤ B ≤ 18 or 0 ≤ B ≤ 15 and ACT Composite Standard Score ≥ 20</td>
</tr>
<tr>
<td>V</td>
<td>impossible</td>
<td>B ≤ 15 and ACT Composite Standard Score ≤ 19</td>
</tr>
</tbody>
</table>

Mult = 2 X D score + H.S. Qual Pts.

H.S. Qual Pts. = \#(4 pts. semester A, 3 pts. semester B, etc.)
PERCENT

PLACEMENT LEVEL.

MATHEMATICS

Autumn Quarter\textsuperscript{a}

<table>
<thead>
<tr>
<th>Level</th>
<th>1966 (R\textsuperscript{b})</th>
<th>1967 (R\textsuperscript{b})</th>
<th>1968 (R\textsuperscript{b})</th>
<th>1969 (R\textsuperscript{b})</th>
<th>1970 (R\textsuperscript{b})</th>
<th>1971 (R\textsuperscript{b})</th>
<th>1972 (R\textsuperscript{b})</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>11 (3)</td>
<td>9 (4)</td>
<td>8 (3)</td>
<td>8 (4)</td>
<td>9 (4)</td>
<td>9\textsuperscript{dc} (3)</td>
<td>7 (3)</td>
</tr>
<tr>
<td>II</td>
<td>36 (22)</td>
<td>35 (24)</td>
<td>34 (26)</td>
<td>38 (27)</td>
<td>41 (30)</td>
<td>37 (30)</td>
<td>31\textsuperscript{d} (25)</td>
</tr>
<tr>
<td>III</td>
<td>25 (23)</td>
<td>24 (25)</td>
<td>23 (23)</td>
<td>21 (20)</td>
<td>16 (19)</td>
<td>19 (20)</td>
<td>23 (25)</td>
</tr>
<tr>
<td>IV</td>
<td>15 (23)</td>
<td>16 (20)</td>
<td>17 (19)</td>
<td>16 (22)</td>
<td>17 (21)</td>
<td>16 (20)</td>
<td>16 (20)</td>
</tr>
<tr>
<td>V</td>
<td>13 (29)</td>
<td>16 (27)</td>
<td>18 (29)</td>
<td>17 (27)</td>
<td>17 (26)</td>
<td>21 (21)</td>
<td>23 (27)</td>
</tr>
</tbody>
</table>

N 6222 1751 7133 1715 7689 1625 8370 1748 7848 1677 6946 1560 6710 1471

\textsuperscript{a} - Compiled by the office of Testing and Evaluation

\textsuperscript{b} - Represents the Regional Campuses

\textsuperscript{c} - Change in Level I: New - D\textsubscript{13} and Comp\textsubscript{57}
Old - D\textsubscript{12} and Comp\textsubscript{55}

\textsuperscript{d} - Change in Level III: Old - Level II Lowest level if ACT Math\textsubscript{25}
New - Level III if ACT Math\textsubscript{25} and D\textsubscript{4}. 
APPENDIX B

Freshman Mathematics Offerings
Student entering Ohio State (without transfer credit for math courses) take an Ohio State University Mathematics Placement Examination given by the University Testing Office. On this basis they are assigned a Math Placement Level of I, II, III, IV, or V. This determines the point at which they enter their mathematics program at Ohio State.

To determine which math courses a beginning student should take it is first necessary to know both the math courses he needs for his chosen field of study (this is determined by the requirements of his college and major department) and his placement level as determined by the examination mentioned above.

Once the mathematical needs and the placement level of the student are known, the following chart indicates the course in which he should enroll to begin to satisfy those needs.

SPECIAL COURSES

180 - This is a Liberal Arts course (insights into mathematics) intended to involve students with mathematics. Mathematics 180 will not change the student's mathematics level. Mathematics 180 will not serve as a prerequisite to any other mathematics course. Permission of the Department is needed to schedule the course.

194 - Under the special topic Number Mathematics 194, a special course designed for level 5 students has been created. Mathematics 194 will not consist of "remedial mathematics". Rather, the course will reflect the spirit of the freshman foundation mathematics course given by Dr. Arnold Ross on the Columbus Campus. Permission of the Department is needed by the student before scheduling this course.
<table>
<thead>
<tr>
<th>Level</th>
<th>Math 105</th>
<th>Math 116</th>
<th>Sciences</th>
<th>Engineering</th>
<th>Math 180</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>105</td>
<td>117(^h)</td>
<td>120.02(^h)</td>
<td>151(^h)</td>
<td>180(^3)</td>
</tr>
<tr>
<td></td>
<td>See Comment.</td>
<td>See Comment.</td>
<td>See Comment.</td>
<td>See Comment.</td>
<td>See Comment.</td>
</tr>
<tr>
<td>II</td>
<td>105</td>
<td>116</td>
<td>120.01 and 120.02</td>
<td>159.01 and 159.02</td>
<td>180(^3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>105</td>
<td>116</td>
<td>101</td>
<td>101</td>
<td>180(^3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>101</td>
<td>101</td>
<td>101</td>
<td>101</td>
<td>180(^3)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>See 5 below</td>
<td>See 5 below</td>
<td>See 5 below</td>
<td>See 5 below</td>
<td>180(^3)</td>
</tr>
</tbody>
</table>

1. Math 105, 106, 107 is open only to students majoring in elementary education.
2. By departmental invitation only. Interested students should contact a math counselor. (Available on Columbus Campus only.)
3. Credit for Math 180 does not change a student's placement level or serve as a prerequisite for any other math course.
4. Students placing in Level I, who have reservations about scheduling Math 117, 120.02, or 151 should see a math counselor (room 150 Math Building).
5. Students who place Level V must be reclassified into one of the Levels I - IV before they are eligible to take any of the math courses offered by the University, with the exception of Math 194 or Math 180.
APPENDIX C

Individualized Pacing Units
# INDIVIDUAL PACING PROJECT

## I.P.P.

Mathematics 101.01 and 101.02

<table>
<thead>
<tr>
<th>Units</th>
<th>Chapters in Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Sets and Cartesian Coordinates</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>II. Open Sentences in One Variable</td>
<td>4</td>
</tr>
<tr>
<td>III. Linear Systems and Functions</td>
<td>5, 6</td>
</tr>
<tr>
<td>IV. Polynomials</td>
<td>7, 8</td>
</tr>
<tr>
<td>V. Division of Polynomials and Rational Expressions</td>
<td>9, 10</td>
</tr>
<tr>
<td>VI. Quadratic and Fractional Open Sentences and Functions</td>
<td>11, 12</td>
</tr>
<tr>
<td>VII. Polynomial Equations and Exponential Functions</td>
<td>13, 15</td>
</tr>
</tbody>
</table>

Mathematics 101.01 consists of Units I through IV

Mathematics 101.02 consists of Units V through VII

*Basic Algebra* by William Klinger and Robert Wright
APPENDIX D

Testing and Lecture Schedule for
Autumn and Winter Quarters
<table>
<thead>
<tr>
<th>Week</th>
<th>Days</th>
<th>Schedule Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
<td>WRF</td>
<td>Large lectures (9:00 &amp; 12:00 Ewing)</td>
</tr>
</tbody>
</table>
| 2nd week   | TR, WNF | Large lectures  
               | Recitation groups                                                              |
| 3rd week   | T, WR  | Large lectures  
<pre><code>           | Recitation groups                                                              |
</code></pre>
<p>| 4th week   | MTWR  | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Test 1                                                                 |
| 5th week   | TWR   | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Tests 1, 2                                                            |
| 6th week   | MTWR  | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Tests 2, 3                                                            |
| 7th week   | MTWR  | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Tests 2, 3, 5                                                        |
| 8th week   | MTWR  | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Tests 2, 3, 4, 5                                                     |
| 9th week   | MT    | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Wednesday Unit Tests 3, 4, 5, 6                                                   |
| 10th week  | MTWR  | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Tests 3, 4, 6, 7                                                     |
| 11th week  | MTWR  | 3 Teaching groups at 9:00 and 12:00                                             |
|            |       | Friday Unit Tests 4, 7                                                           |</p>
<table>
<thead>
<tr>
<th>Math 101.02</th>
<th>SCHEDULING</th>
<th>WINTER 1973</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
<td>W</td>
<td>Large lecture</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>3 Teaching groups</td>
</tr>
<tr>
<td>2nd week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>3rd week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>4th week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>5th week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>6th week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>7th week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>8th week</td>
<td>TWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>9th week</td>
<td>MTWR</td>
<td>Teaching groups</td>
</tr>
<tr>
<td>10th week</td>
<td>M</td>
<td>Large lecture</td>
</tr>
<tr>
<td></td>
<td>TWRF</td>
<td>Teaching groups (Final Review)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Friday Unit Test 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Friday Unit Tests 5,6</td>
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<tr>
<td></td>
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<td>Friday Unit Tests 5,6, 7</td>
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<td>Friday Unit Tests 6,7</td>
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<td></td>
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<td>Friday Unit Tests 6,7</td>
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<tr>
<td></td>
<td></td>
<td>Friday Unit Test 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Friday Unit Test 7</td>
</tr>
</tbody>
</table>
APPENDIX E

Supplementary Reference Material
## MATHEMATICS 101
### SUPPLEMENTARY REFERENCE MATERIAL

**Text** - *Basic Algebra* by Klinger & Wright  
**Reference texts on closed reserve in Library**  
1. *Intermediate Algebra* by Mumen and Tschirhart  
2. *Pre-Calculus Mathematics - Algebra* by Howes

<table>
<thead>
<tr>
<th>Chapters in Text</th>
<th>Reference in Mumen</th>
<th>Reference in Howes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sets</td>
<td>pp 3-13</td>
<td>pp 27-34</td>
</tr>
<tr>
<td>2. Some Special Sets</td>
<td>pp 13-28</td>
<td>pp 38-78; pp 99-142</td>
</tr>
<tr>
<td>3. Graphing</td>
<td>pp 221-236</td>
<td>pp 78-95</td>
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APPENDIX F

Tutor Schedule
# Faculty Tutorial Hours

## Autumn Quarter, 1972

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APPENDIX G

Weekly Teaching Schedules
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97
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APPENDIX H

Examinations
Math 101  MIDTERM I  FORM A

Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question number. There are 30 questions.

In questions 1-3 let \( A = \{1,2,3,\ldots,10\}, B = \{2,4,6,8,10\}, C = \{1,3,5,6\}, D = \{2,3,6\}, \) and \( E = \{3,5\} \).

1. \( B \cup C = \) (a) \( \{6\} \) (b) \( \{1,2,3,4,5,6,8,10\} \) (c) \( A \) (d) \( \emptyset \) (e) none of these

2. \( D \cap C = \) (a) \( \{3,6\} \) (b) \( \{1,2,3,5,6\} \) (c) \( A \) (d) \( \emptyset \) (e) none of these

3. \( D \times E = \) (a) \( \{2,3,5,6\} \) (b) \( \{(2,3),(2,5),(3,3),(3,5),(6,3),(6,5)\} \) (c) \( \{6,10,9,15,18,30\} \) (d) \( \{(3,2),(5,2),(3,3),(5,3),(3,6)\} \) (e) none of these

For question 4.

4. The numbered regions which compose \( (A \cap C) \cup B \) are:
   (a) \( 4,5,6 \) (b) \( 5 \) (c) \( 2,4,5 \) (d) \( 2,3,4,5,6 \) (e) none of these

5. Which of the given sets are equal to the set \( \{1,3,5\} \)?
   \( A = \{3,1,5\}, B = \{1,3,5,3\}, C = \{x \mid x \in \mathbb{N}^* \text{ and } x \leq 5\}, \)
   \( D = \{y \mid y \in \mathbb{N}, y \text{ is odd, and } y < 6\} \)
   (a) \( A \) only (b) \( A \) and \( D \) (c) \( A, B, C, \) and \( D \) (d) \( A, B, D \) (e) none of these

6. Let \( A = \{1,3,5\} \). The set \( A \) has how many subsets?
   (a) 3 (b) 6 (c) 7 (d) 8 (e) 9
7. If \( A \) is a subset of \( B \), then which of the following are true?
1. \( A \subseteq B \)  
2. \( A \cap B = A \)  
3. \( A \cup B = A \)

(a) 1, 3  
(b) 1, 2  
(c) 2, 3  
(d) 1, 2, 3  
(e) none of these

8. Which of the following best relates \( \emptyset \) and \( \{0\} \)?
(a) \( \emptyset \) is a subset of \( \{0\} \)  
(b) \( \{0\} \) is a subset of \( \emptyset \)  
(c) \( \{0\} = \emptyset \)  
(d) they are third cousins  
(e) none of these

9. \( A \cup (B \cap C) = (A \cup B) \cap (A \cup C) \) illustrates
(a) closure  
(b) associative law  
(c) commutative law  
(d) distributive law  
(e) none of these

10. Which of the following properties distinguish the set of rationals from the set of integers?
(a) multiplicative inverse  
(b) additive inverse  
(c) multiplicative identity  
(d) additive identity  
(e) none of these

11. \( 3a(b + c) = (b + c)3a \) is valid because of what property?
(a) associative law for addition  
(b) associative law for multiplication  
(c) commutative law for addition  
(d) commutative law for multiplication  
(e) distributive law

12. Which of the following is not closed under addition?
(a) \( \{1, 2, 3, \ldots\} \)  
(b) \( \{2, 4, 6, \ldots\} \)  
(c) \( \{1, 3, 5, \ldots\} \)  
(d) \( I \)  
(e) none of these

In questions 13 - 22 simplify:

13. \( 5 - (3 - 4) + 2(1 - 7) = \) (a) -6  
(b) -7  
(c) -8  
(d) -9  
(e) none of these

14. \( \frac{3}{4} + \frac{4}{5} - \frac{5}{6} = \) (a) \( \frac{87}{120} \)  
(b) \( \frac{2}{5} \)  
(c) \( \frac{17}{24} \)  
(d) \( \frac{43}{60} \)  
(e) none of these
15. \[ |(2 - 5) + (3 - 1)| - |-4| = \] (a) 1 (b) -3 (c) 9 (d) 15 (e) none of these

16. \( \sqrt{45} = \) (a) \(9\sqrt{5}\) (b) \(3\sqrt{15}\) (c) \(5\sqrt{9}\) (d) \(15\sqrt{3}\) (e) none of these

17. \((3 - \sqrt{2})(4 + 2\sqrt{2}) = \) (a) \(12 - 2\sqrt{2}\) (b) 8 (c) \(8 - 2\sqrt{2}\) (d) \(8 + 2\sqrt{2}\) (e) none of these

18. \(\frac{\sqrt{2} - 2}{\sqrt{2} - 4} = \) (a) \(\frac{3 + \sqrt{2}}{7}\) (b) \(\frac{10 - 2\sqrt{2}}{14}\) (c) \(\frac{3 - \sqrt{2}}{7}\) (d) \(\frac{-2\sqrt{2} - 6}{18}\) (e) none of these

19. \(2 - \sqrt{-9} = \) (a) 5 (b) -1 (c) \(2 - 9i\) (d) \(2 + 3i\) (e) none of these

20. \((3 + 2i) - (6 - 5i) = \) (a) \(-3 - 3i\) (b) \(-3 + 3i\) (c) \(-3 - 7i\) (d) \(-3 + 7i\) (e) none of these

21. \(i^{43} = \) (a) 1 (b) 1 (c) -1 (d) -1 (e) none of these

22. \(\frac{2 - \frac{4i}{3} + i}{4} = \) (a) \(\frac{5 - 7i}{4}\) (b) \(\frac{1 - 7i}{5}\) (c) \(\frac{5 - 7i}{5}\) (d) \(\frac{6 - 5i}{10}\) (e) none of these

23. The point \((-2,3)\) lies in the (a) first quadrant (b) second quadrant (c) third quadrant (d) fourth quadrant (e) fifth quadrant
True or False:

24. Division is a commutative operation on the set \( \mathbb{R}^* \).

25. \( \mathbb{N} \subset \mathbb{N}^* \)

26. The set \( \mathbb{N} \) has an additive identity.

27. If \( x = -3 \) then \( |-x| = x \).

28. \( \sqrt{-2} \cdot \sqrt{-8} = 4 \)

29. For all real numbers \( a \) and \( b \), \( \sqrt{a + b} = \sqrt{a} + \sqrt{b} \).

30. \( \frac{2}{\sqrt{2}} < \sqrt{2} \).
Math 101

UNIT II

Form C

Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question's number.

1. The solution set for \(-8x + 7 = -3\) is:
   a) \(\left\{-\frac{1}{2}\right\}\)  b) \(\left\{\frac{1}{2}\right\}\)  c) \(\left\{\frac{5}{4}\right\}\)  d) \(\left\{-\frac{5}{4}\right\}\)  e) none of these

2. Which of the following statements is not always true.
   a) if \(a \leq b\), then \(a - b \leq 0\)  b) if \(a \geq b\), then \(a + c \geq b + c\)
   c) if \(a > b\), then \(ac > bc\)  d) if \(a = b\), then \(ac = bc\)
   e) all of the above are true.

3. The solution set for \(6 + x = 4x + 3\) is:
   a) \(\left\{-\frac{21}{15}\right\}\)  b) \(\left\{-\frac{5}{7}\right\}\)  c) \(\left\{\frac{7}{5}\right\}\)  d) \(\left\{\frac{27}{17}\right\}\)  e) none of these.

4. The solution set for \(5x + 3 < 9 - x\) is:
   a) \(\left\{x \mid x < 3\right\}\)  b) \(\left\{x \mid x < 2\right\}\)  c) \(\left\{x \mid 0 < x < 1\right\}\)  d) \(\left\{x \mid x < 1\right\}\)  e) none of these.

5. The solution set for \(|x| - 2 = 7\) is:
   a) \(\left\{9\right\}\)  b) \(\left\{-9\right\}\)  c) \(\left\{-5, 5\right\}\)  d) \(\mathbb{R}\)  e) none of these.

6. \(\frac{1}{2} - \frac{3}{4} + \frac{1}{3} - \frac{1}{2} =\)
   a) \(\frac{1}{3}\)  b) \(-\frac{1}{4}\)  c) \(-\frac{1}{12}\)  d) \(\frac{1}{4}\)  e) none of these

7. The solution set for \(|x-6| < 2\) is:
   a) \(\left\{x \mid x < 8\right\}\)  b) \(\left\{x \mid x > 8 \text{ or } x < 4\right\}\)  c) \(\emptyset\)  d) \(\left\{x \mid 4 < x < 8\right\}\)
   e) none of these

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8. The solution set for $|4-3x|>5$ is:
   a) $\left\{ x\mid x>\frac{1}{3} \text{ or } x<3 \right\}$
   b) $\left\{ x\mid x<-\frac{1}{3} \text{ or } x>3 \right\}$
   c) $\left\{ x\mid -\frac{1}{3}<x<3 \right\}$
   d) $\mathbb{R}$
   e) none of these

9. The solution set for $|2-3x|<5$ is:
   a) $\emptyset$
   b) $\mathbb{R}$
   c) $\left\{ x\mid -1<x<\frac{7}{3} \right\}$
   d) $\left\{ x\mid x>\frac{7}{3} \right\}$
   e) none of these

10. The solution set for $|4-2x|\geq 0$ is:
    a) $\emptyset$
    b) $\mathbb{R}$
    c) $\left\{ 2 \right\}$
    d) $\left\{ x\mid x\leq 2 \right\}$
    e) none of these

11. The solution set for $2x-3=2(x-\frac{3}{2})$ is:
    a) $\emptyset$
    b) $\mathbb{R}$
    c) $\left\{ 2 \right\}$
    d) $\left\{ x\mid x\geq 0 \right\}$
    e) none of these

12. The solution set for $|2x-3|=x-3$ is:
    a) $\emptyset$
    b) $\mathbb{R}$
    c) $\left\{ 0 \right\}$
    d) $\left\{ 2 \right\}$
    e) none of these

13. The solution set for $|3-x|<2x+5$ is:
    a) $\emptyset$
    b) $\mathbb{R}$
    c) $x\mid x>-\frac{2}{3}$
    d) $\left\{ x\mid -\frac{2}{3}<x\leq 3 \right\}$
    e) none of these

14. The solution set for $|2-3x|=6$ is:
    a) $\left\{ -\frac{8}{3}, \frac{8}{3} \right\}$
    b) $\left\{ -\frac{4}{3}, \frac{8}{3} \right\}$
    c) $\left\{ -\frac{4}{3}, -\frac{8}{3} \right\}$
    d) $\left\{ \frac{4}{3}, -\frac{8}{3} \right\}$
    e) none of these

15. If $|x|<2$, then:
    a) the distance between $x$ and 2 is zero units.
    b) the distance between $x$ and the origin is 2 units.
    c) the distance between $x$ and the origin is greater than 2 units.
    d) the distance between $x$ and the origin is less than 2 units.
    e) none of these.
True or False

16. $x=5$ is a member of the solution set for $3x-|-5| \leq 10$.

17. $|x| + 2 = |x + 2|$ for all real numbers $x$.

18. $a < b$ means $a$ lies to the left of $b$ on the number line.

19. $3 - (4 - 8) + |-7| = 0$

20. If $|x| > 2$ then either $x > 2$ or $x < -2$. 
Math 101 Unit III Test A

Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question's number.

1. The number of elements in the solution set for the system of equations
   \[
   \begin{align*}
   3x+10 &= 5y, \\
   6x-10y &= -20
   \end{align*}
   \]
   is:
   a) none  
   b) one  
   c) two  
   d) more than two  
   e) none of these.

2. The sum of the coordinates for the solution to the system of equations
   \[
   \begin{align*}
   2x-3y &= 4, \\
   6y-x &= 4
   \end{align*}
   \]
   is:
   a) 8  
   b) 16  
   c) -11  
   d) \frac{1}{2}  
   e) none of these.

3. The $z$-coordinate for the solution to the system
   \[
   \begin{align*}
   x+y-2z &= -3, \\
   2x+4y+6z &= -8, \\
   3x-9y-2z &= 3
   \end{align*}
   \]
   is:
   a) -3  
   b) 0  
   c) -45  
   d) \frac{1}{16}  
   e) none of these.

4. The solution to the system
   \[
   \begin{align*}
   x+2y &= 3, \\
   2x+4y &= 5
   \end{align*}
   \]
   is:
   a) (-5,-1)  
   b) (1,1)  
   c)  \emptyset  
   d) \{x|x+2y=3\}  
   e) None of these.

5. The graph of \( \{(x,y) \mid x > 0 \text{ and } y > 0\} \) is the set of points
   a) on the x-axis and y-axis  
   b) in the first quadrant  
   c) in the first or third quadrants  
   d) in the third quadrant  
   e) none of these.
6. Which of the following graphs best describes the solution set for:

\[
\begin{align*}
2y + 3x &\leq 6 \\
x - y &< 4
\end{align*}
\]

a) \[ \text{a) none of these} \]

7. Which of the following graphs represent functions?

A) \[ \text{A and D} \]

B) \[ \text{B and C} \]

c) B  d) B and C

e) none of these
8. Which of the following sets are functions:
A. \{ (2,6), (3,6), (4,7) \}
B. \{ (2,4), (2,5), (3,6) \}
C. \{ (2,4) \}
D. \{ (1,7), (2,7), (3,7) \}
a) Only A and D  b) Only A, C, and D  c) Only B  d) Only B and C 
  e) none of these

9. If \( f(x) = \sqrt{x-2} \), then \( f(6) = \)
a) 2  b) -2  c) 3  d) 6\sqrt{x-2}  e) none of these

10. If \( f(x) = 3x+2 \), then a solution is:
a) (1,5)  b) (5,1)  c) (1,2)  d) (2,3)  e) none of these.

11. The domain of \( h(t) = \sqrt{t-1} \) is:
a) \( t > 1 \)  b) \( t < 1 \)  c) \( t \geq 1 \)  d) \( t \leq 1 \)  e) none of these

12. If the slope of a line is negative, the line:
a) is horizontal  b) falls from left to right  c) rises from left to right  
d) is vertical  e) none of these

13. If \( f(x) \) is a linear function and \( (2,3) \in f \), then which of the following statements is false.
   a) \( f(2) = 3 \)  b) \( f(x) = mx+b \)  c) \( 3 = 2m+b \)  d) \( f(3) = 2 \).
e) all of the statements are true.

14. The line \( 3x-2y=5 \) has slope
   a) 3  b) -2  c) -5  d) \( \frac{-2}{3} \)  e) \( \frac{3}{2} \)

15. The equation of a line through \( (0,4) \) parallel to \( 2x-y = 8 \) has:
   a) y-intercept equal to -8  
b) slope of \( \frac{-1}{2} \)  
c) x-intercept equal to 2  
d) all of the above  
e) none of the above
16. The equation of a line having an x-intercept of 2 and a y-intercept of 3 is:
   a) \( \frac{x}{2} + \frac{y}{3} = 1 \)  
   b) \( y = x + 3 \)  
   c) \( y = \frac{3x}{1} - 3 \)  
   d) \( 3x + 2y = 1 \)  
   e) none of these

17. If \( f(x) = 3x - 5 \) and \( g(x) = \sqrt{x} \), then:
   a) 0 is not in the domain of \( f(g(x)) \)
   b) 0 is not in the domain of \( g(f(x)) \)
   c) \( g(f(0)) = \sqrt{5} \)
   d) \( f(g(0)) = \sqrt{5} \)
   e) none of these

18. The graph of \( 2x - 4y + 12 = 0 \) is best represented by:

   a)  
   b)  
   c)  
   d)  
   e) none of these
19. The graph of $y = |x-1| + 1$ is best represented by:

(a) ![Graph A]

(b) ![Graph B]

(c) ![Graph C]

(d) ![Graph D]

(e) none of these

20. The graph of $y = |\lfloor x \rfloor|$ is best represented by:

(a) ![Graph A]

(b) ![Graph B]

(c) ![Graph C]

(d) ![Graph D]

(e) none of these
Math 101

UNIT IV

Form D.

Direction: On the answer sheet provided choose one best response to each of the following questions by marking with pencil in the appropriate space after the question's number.

1. \[ \left( \frac{1}{3} x^3 + x^2 - 1 \right) - \left( \frac{2}{3} x^3 - x + 5 \right) = \]
   a. \[ -\frac{1}{3} x^3 + x^2 + x - 6 \]
   b. \[ -\frac{1}{3} x^3 + x^2 + x + 4 \]
   c. \[ -\frac{1}{3} x^3 + x^2 - x - 6 \]
   d. \[ -\frac{1}{3} x^3 + x^2 - x + 4 \]
   e. none of these

2. \[ \frac{4x^3 - 5}{y^2 z} \]
   a. \[ 45 x^{-3} y^3 z^2 \]
   b. \[ 4^3 x^{-3} y^3 z^18 \]
   c. \[ 4^3 x^{-3} y^3 z^{-2} \]
   d. \[ 4x^{-3} y^{-3} z^{18} \]
   e. none of these

3. \[ (2x-3)^2 = \]
   a. \[ 4x^2 - 9 \]
   b. \[ 4x^2 + 9 \]
   c. \[ 4x^2 - 6x + 9 \]
   d. \[ 4x^2 - 12x + 9 \]
   e. none of these

4. \[ (3x-5y+4) (2x-5) = \]
   a. \[ 6x^2 - 10xy - 15x - 20 \]
   b. \[ 5x - 5y - 1 \]
   c. \[ 6x^2 - 10xy - 7x - 20 \]
   d. \[ 5x^2 - 5y - 1 \]
   e. none of these

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5. \((2a + 3b)^3 = \)
   a. \(2a^3 + 3b^3\)
   b. \(8a^3 + 12ab + 27b^3\)
   c. \(8a^3 + 36a^2b + 36ab^2 + 27b^3\)
   d. \(8a^3 + 27b^3\)
   e. none of these

6. \(x^2 - y^2 = \)
   a. \((x-y)^2\)
   b. \((x+y)^2\)
   c. \((x+y)(x-y)\)
   d. \((y-x)(y+x)\)
   e. none of these

7. One factor of \(8x^3 - 1\) is:
   a. \(2x + 1\)
   b. \(4x^2 - 2x + 1\)
   c. \(4x^2 + 2x + 1\)
   d. \(4x^2 + 4x + 1\)
   e. none of these

8. Which one of the following is not a factor of \(-3x^3 + 2x^2 - 12x - 8\) is:
   a. \(x-2\)
   b. \(x+2\)
   c. \(x^2 - 4\)
   d. \(3x+2\)
   e. all of the above are factors.

9. One factor of \(x^2 + 4\) is:
   a. \(x+2\)
   b. \(x-2\)
   c. \(x + 2i\)
   d. \(2i\)
   e. none of these
10. The prime factorization of $4x^4 - 11x^3 + 6x^2$ is:
   a. $x^2 (4x^2 - 11x + 6)$
   b. $x^2 (4x - 6)(x - 1)$
   c. $(4x^2 - 3x)(x^2 - 2x)$
   d. $x^2(x - 2)(4x - 3)$
   e. none of these

11. The prime factorization of $4x^2 + 8x - 8$ over $C$ is:
   a. $4(x^2 + 2x - 2)$
   b. $4(x - 2)(x + 1)$
   c. $4(x + 1 - \sqrt{3}) (x + 1 + \sqrt{3})$
   d. $(x + 1 + \sqrt{3}) (x + 1 - \sqrt{3})$
   e. none of these

12. Which of the following is a trinomial square?
   a. $x^2 - 2x - 1$
   b. $\frac{1}{4} x^2 + \frac{1}{3} x + \frac{1}{9}$
   c. $x^2 + 2x - 1$
   d. $\frac{1}{4} x^2 + \frac{1}{3} x - \frac{1}{9}$
   e. none of these

13. One factor of $(2a - b)^2 + 10(2a - b) + 9$ is:
   a. $2a - b + 1$
   b. $2a - b$
   c. $2a^2 + 9ab + 1$
   d. $2a - b - 9$
   e. none of these

14. One factor of $\frac{1}{2} x^2 - 6x + 18$ over $C$ is:
   a. $x^2 - 3x + 9$
   b. $x + 6$
   c. $2x - 3 - 3 \sqrt{3} i$
   d. $(x-6)^2$
   e. none of these
15. \(9-x^2\) is:
   a. \((3-x)^2\)
   b. \((9-x)(1-x)\)
   c. \((x+3)(x-3)\)
   d. \((3-x)(x+3)\)
   e. none of these

True or False:
16. \(3x^2-4\) is factorable over \(\mathbb{I}\).
17. The prime factorization of \(y^4-25\) over \(\mathbb{C}\) is: \((y^2+5)(y-\sqrt{5})\)
18. \(3x^2+2x-5\) is a polynomial over \(\mathbb{C}\). \((y+\sqrt{5})\)
19. \((x+y)^3 = x^3 + 3xy^2 + 3x^2y + y^3\)
20. \((x^3 - y^3)(x^3 + y^3) = x^6 - y^6\)
Math 101

UNIT V

Form A

Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question's number.

1. \((x^2 + 4x - 5) \div (x - 1) = \)
   a. \(x + 3 - \frac{8}{x-1}\)
   b. \(x + 3 - \frac{2}{x-1}\)
   c. \(x + 5\)
   d. \(x - 5\)
   e. none of these.

2. \((x^4 - 3x^3y + 2xy^3 - y^4) \div (x + y)\) yields a remainder of:
   a. 0
   b. \(y^4\)
   c. \(-3y^4\)
   d. \(-y^4\)
   e. none of these.

3. \((x^5 + y^5) \div (x + y) = \)
   a. \(x^4 + y^4\)
   b. \(x^4 - y^4\)
   c. \(x^4 + x^3y + x^2y^2 + xy^3 + y^4\)
   d. \(x^4 - x^3y + x^2y^2 - xy^3 + y^4\)
   e. none of these.

4. The second term of quotient of \((x^3 - 3x - 4) \div (3x - 1)\) is:
   a. \(\frac{1}{3}x\)
   b. \(-\frac{1}{3}x\)
   c. \(\frac{1}{9}x\)
   d. \(-\frac{1}{9}x\)
   e. none of these.

5. If \(\frac{4x + 4}{xy + y}\) is reduced to its lowest terms, the sum of the numerator and denominator is:
   a. \(8 + 2y\)
   b. \(4 + y\)
   c. \(4y\)
   d. \(x + y\)
   e. none of these.

6. \(\frac{15xyz}{16a^2} \div \frac{10y^3}{9x^2a} \div \frac{12xa^2}{25y^2z} = \)
   a. \(\frac{1}{3} - \frac{xy^2}{a}\)
   b. \(\frac{y^2}{6}\)
   c. \(\frac{5}{9}x\)
   d. \(\frac{y}{6a}\)
   e. none of these.

7. \(\frac{x^2 - 4}{x^2 - 4x + 3} \div \frac{3x + 6}{x^2 - 9} = \)
   a. \(\frac{3(x+2)^2(x-2)}{(x-3)^2(x+3)(x-1)}\)
   b. \(\frac{x^2 + x - 6}{3x - 3}\)
   c. \(\frac{x^2 + x - 2}{x-1}\)
   d. \(\frac{(x+3)(x-2)(x+2)}{(x-1)(3x + 6)}\)
   e. none of these.
8. \( \left( \frac{x^2 - x}{y^2 - y} \right) \cdot \frac{y^2 x - xy}{x - 1} \cdot \frac{x^2}{x - 1} = a. \frac{x + 1}{x - 1} \quad b. \frac{1}{x - 1} \\
\quad c. x - 1 \quad d. \frac{(x^2 - x) y}{(x - 1) (y^2 - y)} \quad e. \text{none of these} \\
9. \text{The L.C.M. of } x^2 + 4x + 3 \text{ and } x^2 + 6x + 9 \text{ is:} \quad a. (x^2 + 4x + 3) (x^2 + 6x + 9) \quad b. (x + 1) (x + 3) \\
\quad c. (x + 1) (x^2 + 6x + 9) \quad d. x + 3 \quad e. \text{none of these} \\
10. \frac{5}{xy} - \frac{6}{yz} + \frac{7}{xz} = a. \frac{6}{xyz} \quad b. 6 \quad c. 5z - 6x + 7y \\
\quad d. \frac{5z - 6x + 7y}{xyz} \quad e. \text{none of these} \\
11. \frac{x + 1}{x - 1} - \frac{x - 1}{x + 1} = a. 0 \quad b. 1 \quad c. \frac{4x}{x^2 - 1} \\
\quad d. \frac{2x^2 + 2}{x^2 - 1} \quad e. \text{none of these} \\
12. \frac{1}{x - y} - \frac{xy + 2y^2}{x^3 - y^3} = a. \frac{x + y}{x^2 + xy + y^2} \quad b. \frac{x + y}{x^2 - xy + y^2} \\
\quad c. \frac{x^2 + 3y^2}{(x - y) (x^2 + xy + y^2)} \quad d. \frac{1}{x - y} \quad e. \text{none of these} \\
13. \left(2 + \frac{1}{x}\right) \left(2 - \frac{1}{x}\right) = a. 3 \quad b. 4 - \frac{1}{x^2} \quad c. \frac{-3}{x^2} \quad d. \frac{3}{x} \\
\quad e. \text{none of these} \\
14. \frac{x - 1/y}{1 - x/y} = a. \frac{1}{y} \quad b. -\frac{1}{x} \quad c. \frac{x}{y} \quad d. -\frac{1}{y} \quad e. \text{none of these}
15. \[
1 - \frac{2}{3 - \frac{4}{5-y}} = \begin{cases} 
\frac{13}{5-y} & a. \\
\frac{-3 - 2y}{7} & b. \\
\frac{1-5y}{11-3y} & c. \\
\frac{1-y}{11-3y} & d. \\
\text{none of these} & e. 
\end{cases}
\]

16 - 20 True or False

16. If the deg \((A(X)) \geq \deg (B(X))\) and \(B(X) \neq 0\) then \(A(X) = B(X) \cdot Q(X) + R(X)\) where \(0 \leq \deg R(X) < \deg Q(x)\).

17. \[
1 + \frac{1}{x + \frac{1}{x}} = \frac{x^2 + x + 1}{x^2 + 1}
\]

18. \[
\frac{x}{x-y} = -\frac{1}{y}
\]

19. \[
\frac{\frac{2}{3} - \frac{1}{5}}{\frac{4}{3} - \frac{2}{5}} = \frac{13}{14}
\]

20. \[
\frac{1}{x} + \frac{1}{y} = \frac{1}{x + y}
\]
Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question's number.

1. Which of the following is not a quadratic equation?
   (a) $3x^2 - 4x = 8$       (b) $3x^2 = 5$       (c) $3x^2 - 6x^{-1} = 0$
   (d) $3x^2 = 0$       (e) none of these

2. The sum of the solutions to $x^2 - x = 42$ is:
   (a) -1       (b) 1       (c) 85       (d) 83
   (e) none of these

3. The solution set of $x^2 + 4x = 1$ is:
   (a) $\left\{2 - \sqrt{5}, -2 + \sqrt{5}\right\}$,       (b) $\left\{-2 - \sqrt{5}, 2 + \sqrt{5}\right\}$
   (c) $\left\{2 \pm \sqrt{5}\right\}$       (d) $\left\{-2 \pm \sqrt{5}\right\}$
   (e) none of these

4. The solution set of $2x^2 - 3x + 5 = 0$ is: (a) $\left\{3 \pm \sqrt{31} i\right\}$
   (b) $\left\{3 + \sqrt{31} i\right\}$       (c) $\left\{3 + \sqrt{31} 2 \right\}$
   (d) $\left\{3 + \sqrt{31} \right\}$
   (e) none of these.

5. If the discriminant is negative then the solution set has:
   (a) one real solution       (b) two real solutions
   (c) two complex solutions       (d) one real, one complex solution
   (e) none of these

6. The sum of the solution to $\sqrt{10x - 1} + x = 4$ is:
   (a) -18       (b) 18       (c) 1       (d) 17       (e) none of these.
7. The solution set to \( \sqrt{3x - 4} - 2 = -3 \) is:
   (a) \( \mathbb{R} \)  (b) \( \emptyset \)  (c) \( \left\{ \frac{5}{3} \right\} \)  (d) \( \left\{ \frac{3}{5} \right\} \)  (e) none of these

8. The solution set for \((x^2 - 4) - (x-2)(x+3) = 0\) is:
   (a) \( \left\{ -3, -2, 2 \right\} \)  (b) \( \left\{ -3 \right\} \)  (c) \( \left\{ -2 \right\} \)  (d) \( \left\{ 2 \right\} \)  (e) none of these

9. The solution set for \((x-2)(3x+4) < x-2\) is:
   (a) \( \{ x < -1 \} \)  (b) \( \{ -1 < x < 2 \} \)  (c) \( \{ x < -1 \text{ or } x > 2 \} \)  (d) \( \{ x < -\frac{3}{4} \} \)  (e) none of these

10. The graph of which of the following equations is a parabola?
    (a) \( y = x^4 + x^2 + 1 \)  (b) \( y = x^3 + 1 \)  (c) \( y = x^2 + 2x + 1 \)
    (d) \( y = -x + 4 \)  (e) None of these

11. The solution set of \( \frac{x^2 - 16}{x + 4} = 6 \) is:
    (a) \( \{ -4, 10 \} \)  (b) \( \{ -4, 4 \} \)  (c) \( \{ -4 \} \)  (d) \( \{ 10 \} \)  (e) none of these

12. The solution set for \( \frac{3}{x - 2} = \frac{4}{x - 3} \) is:
    (a) \( \emptyset \)  (b) \( \mathbb{R} \)  (c) \( \{ -1 \} \)  (d) \( \{ 1 \} \)  (e) none of these

13. The solution set for \( \frac{x-1}{x+4} > 0 \) is:
    (a) \( \{ x > 1 \} \)  (b) \( \{ x < -4 \} \)  (c) \( \{ x < -4 \text{ or } x > 1 \} \)  (d) \( \mathbb{R} \)
    (e) none of these

14. The solution set for \( \frac{x^2 + 4}{4x} \leq 1 \) is:
    (a) \( \{ 2 \} \)  (b) \( \emptyset \)  (c) \( \{ x < 0 \text{ or } x = 2 \} \)  (d) \( \{ 0 < x \leq 2 \} \)
    (e) none of these
15. The domain of \( f(x) = \frac{x - 1}{\sqrt{x - 3}} \) is

(a) \( \mathbb{R}^* \)  
(b) \( \{1, 3\} \)  
(c) \( \{x \geq 3\} \)  
(d) \( \{1 < x < 3\} \)  
(e) none of these

True or False:

16. The solution set for \( x^2 + 2x - 1 \geq 0 \) is the set of all real numbers,

17. The point \((3, 18)\) belongs to the function \( f(x) = 2x^2 - x + 3 \).

18. The real number \( x = 3 \) is not in the domain of the function \( f(x) = \frac{1}{x^2 - 5x + 6} \).

19. The solution set for \( x^2 < 49 \) is \( \{x \mid x < 7\} \).

20. The domain of \( f(x) = \sqrt{x - 3} \) is \( \{x \mid x > 3\} \).
Math 101

UNIT VII

Form B

Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question's number.

1. X + 2 is a factor of which of the following.

   a. \( x^3 - 4x + 5 \)  
   b. \( x^8 + 2 \)  
   c. \( x^5 + 32 \)  
   d. \( x^5 - 32 \)  
   e. none of these

2. The set of possible rational solutions to the equation

   \[ 3x^4 + 2x^3 - 3x + 6 \]

   a. \( \{ \pm 1, \pm 1/3, \pm 2/3, \pm 2, \pm 3, \pm 6 \} \)  
   b. \( \{ \pm 1, \pm 1/3, \pm 3/2, \pm 1/2, \pm 1/6, \pm 6 \} \)  
   c. \( \{ \pm 3, \pm 6 \} \)  
   d. \( \{ \pm 1, \pm 2, \pm 3, \pm 6 \} \)  
   e. none of these.

3. The sum of the solutions to \( x^3 - 8x^2 + 17x - 10 = 0 \) is:

   a. 8  
   b. -8  
   c. 6  
   d. -6  
   e. none of these.

4. The sum of the solutions to \( x^4 + 2x^3 - x^2 - 2x = 0 \) is:

   a. 2  
   b. -2  
   c. 0  
   d. -4  
   e. none of these.

5. \(-a^{5/2} =\)

   a. \(-\sqrt[5]{a^2}\)  
   b. \(-\sqrt[5]{a^5}\)  
   c. \(\sqrt[5]{a^2}\)  
   d. \(\sqrt[5]{-a^5}\)  
   e. none of these

6. \((8)^{-5/3} =\)

   a. \(-\frac{1}{32}\)  
   b. -32  
   c. 32  
   d. \(\frac{1}{32}\)  
   e. none of these

7. If \( x = 5/2 \) is a solution to \( P(x) = 0 \), then which of the following is a factor of \( P(x) \)?

   a. \( 2x - 5 \)  
   b. \( 2x + 5 \)  
   c. \( x + 5/2 \)  
   d. \( 5x - 2 \)  
   e. none of these

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8. \( \frac{x^{2/3}\sqrt{x^3}}{x^{-1/3}} = \) a. \( x^{4/3} \) b. \( x^{11/6} \) c. \( \sqrt{x^5} \) d. \( \frac{3\sqrt{x^2}}{x^3} \) e. none of these

9. \( \frac{x^{4/3}}{\sqrt[3]{x^{11}}} = \) a. \( \frac{3\sqrt{x^2}}{x^3} \) b. \( \frac{3\sqrt{x}}{x^7} \) c. \( \frac{x^{7/3}}{x} \) d. \( \frac{3\sqrt{x^2}}{x} \) e. none of these

10. \( 4\sqrt{x} \sqrt[3]{x} = \) a. \( x \) b. \( x^{16} \) c. \( 12\sqrt{x} \) d. \( x^{1/3} \) d. none of these

11. \( 3\sqrt{xy} \cdot \frac{4\sqrt{xy}}{\sqrt{xy}} = \) a. \( 12\sqrt[2]{x^2y^2} \) b. \( \sqrt[2]{x^2y^2} \) c. \( 12\sqrt{x^7y^7} \) d. \( 12\sqrt{x^4y^4} \) e. none of these

12. \( \left( \frac{x^{2/3} y^{1/3}}{x^{1/2} y^{-1/3}} \right)^{-9} = \) a. \( \frac{1}{x^9y} \) b. \( \frac{1}{x^2y^5} \) c. \( \frac{1}{x^8y^8} \) d. \( \frac{1}{y^{2\sqrt{x}}} \) e. none of these

13. If (-4, 81) is a point on the graph of an exponented function, then which of the following is the base of the exponential function?

a. 3 b. -3 d. 1/3 d. -1/3 e. none of these
14. Which of the following best represents the graph of $y = -5^x$

a. 

b. 

c. 

d. 

e. none of these

15. Which of the following represents the graph of $y = \left| \frac{1}{2} x \right|$ 

a. 

b. 

c. 

d. 

e. none of these
Math 101 Final Examination

Directions: On the answer sheet provided choose the one best response to each of the following questions by marking with pencil in the appropriate space after the question number.

In questions 1-3 let \( A = (-2,0,2), \, B = [0,1,2,3], \, C = \{1,3,5,7,\ldots\} \) and \( D = \{8,9\} \).

1. \( A \cap C = \) (a) \( \emptyset \) (b) 0 (c) \( \{3,5,7\} \), (d) \( \emptyset \) (e) none of these

2. \( (A \cup B) \cap C = \) (a) \( \{1,3\} \) (b) \( \{0,1,2,3,4,5,7,\ldots\} \) (c) \( \{3\} \) (d) \( \emptyset \) (e) none of these

3. \( A \times D = \) (a) \( \{(8,-2), (9,-2), (8,0), (9,0), (8,2), (9,2)\} \) (b) \( \{(-2,8), (-2,9), (0,8), (0,9), (2,8), (2,9)\} \) (c) \( \{-2,0,2,8,9\} \) (d) \( \{(-2,8), (0,9)\} \) (e) None of these

4. If \( A \subset B \) then (a) \( A \cap B = A \) (b) \( A \cap B = B \) (c) \( A \cap B = \emptyset \) (d) \( A \cap B = A \) (e) none of these

5. Which of the following illustrates a distributive principle?
   (a) \( 2+6 = 6+2 \) (b) \( (4+2) + 6 = 4 + (2+6) \) (c) \( 4 \cdot (2+6) = (4 \cdot 2) + (4 \cdot 6) \) (d) \( (4 \cdot 2) + 6 = (2 \cdot 4) + 6 \) (e) \( 4 \cdot (2 \cdot 6) = (4 \cdot 2) \cdot 6 \)
6. Which of the following sets is not closed under multiplication?
   (a) \([0,1]\)  (b) \([0]\)  (c) \([3,9,27,\ldots]\)  (d) \([1,2]\)
   (e) \([2,4,6,8,\ldots]\)

Perform the indicated operations and simplify:

7. \((\sqrt{2} + \sqrt{3})(\sqrt{2} - \sqrt{3}) = \)  
   (a) \(-21\)  (b) \(-3\)  (c) \(-\sqrt{3}\)  (d) \(3\)
   (e) \(7\)

8. \(\frac{3}{\sqrt{3}} = \)  
   (a) \(3\)  (b) \(-3\)  (c) \(\sqrt{3}\)  (d) \(-\sqrt{3}\)  (e) none of these

9. \(\sqrt{20} - \sqrt{18} + \sqrt{2} - \sqrt{5} = \)  
   (a) \(\sqrt{5} - 2\sqrt{2}\)  (b) \(\sqrt{5} + 2\sqrt{2}\)
   (c) \(\sqrt{5} - 4\sqrt{2}\)  (d) \(\sqrt{5} - 4\sqrt{2}\)  (e) none of these

10. \((2x+3y) - (3x-2y) = \)  
    (a) \(-x - 5y\)  (b) \(-x - y\)  (c) \(x - 5y\)
    (d) \(x - y\)  (e) none of these

11. \(2\sqrt{3} = \)  
    (a) \(2\sqrt{3}\)  (b) \(-2\sqrt{3}\)  (c) \(\sqrt{3}\)  (d) \(-\sqrt{3}\)
    (e) none of these

12. \((3 + 2i)(2 - 3i) = \)  
    (a) \(-12 + 5i\)  (b) \(-12 - 5i\)
    (c) \(12 + 5i\)  (d) \(12 - 5i\)  (e) none of these

13. \(\left(\frac{5x^2 - 1}{y}\right) = \)  
    (a) \(\frac{y}{25x^2}\)  (b) \(-\frac{5x^2}{y}\)
    (c) \(\frac{5}{x^2y}\)  (d) \(\frac{x^2y}{5}\)
    (e) none of these

14. \(3 - \frac{x - 3}{x^2 - 5x + 6} - \frac{x - 1}{x - 2} = \)  
    (a) \(\frac{2x - 6}{x - 2}\)  (b) \(\frac{2x + 6}{x - 2}\)
    (c) \(\frac{2x - 6}{x - 3}\)  (d) \(\frac{2x + 6}{x - 3}\)  (e) none of these

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15. \[ \frac{\frac{1}{x} + \frac{1}{y}}{\frac{1}{x} - \frac{1}{y}} = \] (a) \( \frac{1}{y-x} \) (b) \( \frac{1}{x-y} \) (c) \( x-y \) (d) \( y-x \) (e) none of these

16. \[ \frac{3x^2 - 8x + 1}{x^2 - 8x + 12} : \frac{6x^2 - 13x + 6}{4x^2 - 6x} = \] (a) \( \frac{2}{x-6} \) (b) \( \frac{2}{x-2} \) (c) \( \frac{2x}{x-6} \) (d) \( \frac{2x}{x-2} \) (e) none of these

In questions 17-25 find the solution set:

17. \( 10 - x = 8 - 3x \) (a) \(-3\) (b) \(-\frac{5}{2}\) (c) \(-1\) (d) \(0\) (e) \(1\)

18. \( |x - 2| = 4 \) (a) \(6\) (b) \(-6\) (c) \(\mathbb{R}-\text{(reals)}\) (d) \(\emptyset\) (e) none of these

19. \( 2x^2 - 2x + 2 = 0 \) (a) \(\left\{ \frac{-1 + \sqrt{3}}{2} \right\} \) (b) \(\left\{ \frac{-1 - \sqrt{3}}{2} \right\} \) (c) \(\left\{ \frac{-1 + \sqrt{3}}{2} \right\} \) (d) \(\left\{ \frac{-1 - \sqrt{3}}{2} \right\} \) (e) none of these

20. \( x^2 + x - 12 > 0 \) (a) \(\{ x \mid x < -4 \text{ or } x > 3 \}\) (b) \(\{ x \mid 12 < x < 12 \}\) (c) \(\{ x \mid x > 4 \text{ or } x < -3 \}\) (d) \(\{ x \mid x < -1 \text{ or } x > 3 \}\) (e) \(\{ x \mid x > 4 \text{ or } x < 3 \}\)

21. \(-5x + 3 < -3x + 5 \) (a) \(\{ x \mid x > -1 \}\) (b) \(\{ x \mid x < -1 \}\) (c) \(\{ x \mid x < 1 \}\) (d) \(\{ x \mid x > 1 \}\) (e) none of these

22. \(|x + 3| < -1 \) (a) \((-1\) (b) \(1\) (c) \(\mathbb{R}\) (d) \(\emptyset\) (e) none of these
23. \(|x - 7| < 6\) (a) \([-6 < x < 13]\) (b) \([-3 < x < 7]\) (c) \([-13 < x < 13]\) (d) \([-13 < x < -1]\)

24. \(x^3 - 5x^2 + 7x - 2 = 0\) (a) \((-2, \frac{3}{2}, \sqrt{5})\) (b) \((-2, -\frac{3}{2}, -\sqrt{5})\)
(c) \((2, \frac{3}{2}, \sqrt{5})\) (d) \((2, -\frac{3}{2}, -\sqrt{5})\) (e) none of these

25. \(\frac{x - 2}{x + 1} \leq 0\) (a) \([-1 < x \leq 2]\) (b) \([-2 \leq x \leq 1]\)
(c) \([x | x < -1 \text{ or } x > 2]\) (d) \([x | x \leq -2 \text{ or } x > 1]\)
(e) none of these

26. The sum of the elements in the solution set of \(\frac{1}{x-2} - \frac{2}{x+1} = \frac{1}{2}\) is (a) -4 (b) -1 (c) 1 (d) 3 (e) none of these

27. The solution set for the equation \(x + 5 = \sqrt{7 + x}\) has (a) no elements (b) exactly one element (c) exactly two elements (d) exactly three elements (e) more than three elements

Find the solution set of the following system:

28. \(x + 4y - z = 10\) (a) \([(2,2,0)]\) (b) \([(2,0,-8)]\)
\(2x - y + z = -4\) (c) \([(1,3,3)]\) (d) \([-(-1,3,1)]\)
\(4x - 3y + z = -12\) (e) none of these

29. Which of the following is an equation of the straight line through the points \((0, -2)\) and \((3, 4)\)?
(a) \(y = -2x + 2\) (b) \(y = \frac{1}{2}x - 2\) (c) \(y = \frac{2}{3}x - 2\)
(d) \(y = x - 2\) (e) \(y = 2x - 2\)
30. The slope of the line \( x + 2y = 3 \) is  
(a) -2  (b) 2  
(c) \( -\frac{1}{2} \)  (d) \( \frac{1}{2} \)  (e) none of these

31. The range of \( g(x) = |x - 2| \) is  
(a) \([y' y \geq 2]\)  (b) \([y' y > 2]\)  (c) \([y' y \geq 0]\)  (d) \(\mathbb{R}^+\)  
(e) none of these

32. The domain of \( h(x) = \frac{x}{x-2} \) is  
(a) \([x|x \geq 0]\)  (b) \([x|x \geq 2]\)  
(c) \([x|x > 2]\)  (d) \(\mathbb{R}^\times\)  (e) none of these

33. Factor \( x - xy + y^2 - y = (a) (y - 1)(x + y) \)  
(b) \((y + 1)(y - x)\)  (c) \((y - 1)(x - y)\)  
(d) \((1 - y)(x - y)\)  (e) none of these

34. Which one of the following is the graph of a function?

(a)  
(b)  
(c)  
(d)  
(e)
35. Which of the following could be the graph of \( y = (1/2)^x \)?

(a) \[ \text{Graph A} \]

(b) \[ \text{Graph B} \]

(c) \[ \text{Graph C} \]

(d) \[ \text{Graph D} \]

(e) none of these

36. \[ \left( \frac{\theta x^{1/2} y^{3/2}}{x^3} \right)^{2/3} = \]

(a) \[ \frac{4xy^3}{x^2} \]

(b) \[ \frac{16y}{x^{3/2} x^2} \]

(c) \[ \frac{2y}{x^{5/3}} \]

(d) \[ 4xy^{5/2} y \]

(e) none of these

37. You have now completed FORM A. Please fill in 37(A).
APPENDIX I

Mathematics Opinionnaire
MATHEMATICS OPINIONNAIRE

Directions: Each statement below expresses a feeling which a particular person has toward mathematics. You are asked to express the extent to which you personally agree or disagree with the opinion stated, on a 5-point scale: SA (Strongly Agree), A (Agree), U (Undecided), D (Disagree), and SD (Strongly Disagree). Fill in the circle with the feeling expressed.

SA A U D SD

1. I feel at ease at ease with mathematics. 0 0 0 0 0
2. When I hear the word mathematics, I have a distinct feeling of dislike. 0 0 0 0 0
3. I do not feel sure of myself in mathematics. 0 0 0 0 0
4. Mathematics is a subject I feel I can sink my teeth into. 0 0 0 0 0
5. Mathematics makes me feel uncomfortable, uneasy, irritable and impatient. 0 0 0 0 0
6. Mathematics is something which I enjoy doing a great deal. 0 0 0 0 0
7. Mathematics is fascinating and fun for me. 0 0 0 0 0
8. I enjoy the challenge of mathematics problems. 0 0 0 0 0
9. I feel under a great strain in a mathematics class. 0 0 0 0 0
10. I approach mathematics with a feeling of hesitation. 0 0 0 0 0
11. Mathematics is stimulating to me. 0 0 0 0 0
12. Mathematics is my most dreaded subject. 0 0 0 0 0
13. I have a definite favorable reaction to mathematics; it's enjoyable.  
14. Working with mathematics is fun.  
15. It scares me to have to take mathematics.  
16. At present, I would rate my general attitude toward mathematics as favorable.  
17. Mathematics is very interesting to me.  
18. When I approach my mathematics work, I experience a sense of fear of not being able to do it.  
19. I have a feeling of insecurity when attempting mathematics.  
20. Mathematics is a subject in school which I have liked and enjoyed studying.  
21. The feeling I have toward mathematics is a positive feeling.  
22. Mathematics makes me feel as though I'm lost in a jungle and can't find my way out.
APPENDIX J

NLSMA Permission Letter
June 25, 1973

Mr. Patrick M. Ewing  
Department of Mathematics Education  
The Ohio State University  
Columbus, Ohio  

Dear Mr. Ewing:

You are free to use NLSMA test items for the purposes stated in your letter of June 20, 1973.

Yours very truly,

E. G. Begle

EGB/db
APPENDIX K

Analysis of Covariance Table
### Analysis of Covariance Table

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Difference for testing adjusted treatment means ... 4.9805 2
APPENDIX L

Item Analysis of First Examination and Final Examination
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Mean difficulty = .191  .274  .270  

Mean discrimination index = .268  .316  .324
## Item Analysis Final Examination

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Mean difficulty = 

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Mean discrimination index = 

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BIBLIOGRAPHY


