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The Ohio State University, Ph.D., 1979

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AN EXPERIMENTAL STUDY TO DETERMINE THE EFFECTIVENESS OF
SKETCHING PRACTICE AS A PART OF AN AUDIO-VISUAL PRESENTATION
ON GRAPHICAL CALCULUS

DISSERTATION

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

By
Clair Roger Lemasters, B.S., M.A.

* * * * *

The Ohio State University
1979

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INTRODUCTION TO THE PROBLEM

Much literature has been devoted to the advancement of teaching methods during the past fifty years. During the decade beginning in 1960, programmed instruction stimulated much interest in further development of automated instructional technology. Earle (1964) has stated that "The research available generally concurs that there is definite need for more experimental research in all areas of instructional media" (p. 1).

Further, an observation which should inspire greater concentration on the developmental phase of experimental research efforts, Baker and Shutz (1972) envision that research emphasis should be placed on "how" utility rather than on "why" utility. They suggest that our obsession with "why" utility has been the general difficulty with educational research for the last fifty years. In addition to his own research in engineering graphics, Earle (1964) recommended that "further research should be performed to determine the suitability of programmed instruction in other areas of industrial arts and engineering" (p. 101).

Most proponents of programmed instruction, individualized instruction, and other forms of automated instructional technology would probably admit to a very personal concern regarding the efficient use of classroom time. Trends toward adding more subject matter to existing course content have further complicated the matter
of efficiently utilizing class time. Engineering graphics courses have not escaped this dilemma. Holland (1973) has noted that "while it was once limited to a course in drafting or mechanical drawing, engineering graphics now covers such topics as problem solving, the design process, graphical statics, graphical analysis and nomography" (p.1). Also, various treatises on graphical integration and differentiation, the focus of this experimental study, have been included in the latest edition of almost every engineering graphics textbook.

While numerous experimental research studies have been conducted in the field of engineering graphics, the majority of them deal with methods of instruction for presenting course content of a more traditional nature. Several of these studies have established significantly successful instructional techniques and presentation formats. Additional research needs to be conducted in order to study the effectiveness of these instructional techniques and formats (or combinations thereof) to further ascertain their success and effectiveness for presenting some of the new and aforementioned topics now being included in modern engineering graphics courses.

PROBLEM STATEMENT

The problem of this investigation was the lack of experimental evidence with regard to the relative effectiveness of two programmed audio-visual methods for presenting graphical differentiation and graphical integration subject matter to pre-engineering and engineering technology students in the Virginia Community College System.
combination of previously research tested and moderately successful (when presented independently) instructional development techniques were presumed to be useful in resolving the problem.

SIGNIFICANCE OF THE STUDY

The value of a number of previously researched instructional development techniques for presenting engineering graphics subject matter has been well documented. The significance of this study lies in combining a number of these techniques which have been presented independent of each other by earlier researchers. This study should be significant when its results are generalized as follows:

1. The study could provide evidence of a more effective method of initially presenting the math concepts of differentiation and integration.

2. The study may suggest additional application of the combined step method/slide-tape format in engineering graphics, descriptive geometry, mathematics, or other technical subject areas.

3. The study may reveal student attitudes in relation to an individualized and/or a self-instructional systems approach in the Virginia Community College System.

4. The study may contribute to the development and/or implementation of other types of individualization instructional materials at the participating community colleges.
5. The researcher will derive information that may lead to improved instructional materials design and application for other related units of instruction.

ASSUMPTIONS

1. Graphical differentiation and graphical integration are important and desirable subject matter content for modern engineering graphics courses.

2. With an increasing number of engineering technology students extending their education to the baccalaureate level, graphical integration and differentiation are important and desirable subject matter content for current engineering technology curriculums.

3. Learning is not a passive process, but comes only through active participation (Deterline, 1962).

4. More effective means of teaching students and utilizing class time are both feasible and desirable (Cozzens, 1965).

5. Slide-tape presentations are effective methods of presenting engineering graphics concepts (Holland, 1973).

6. Criterion tests and retention tests are valid means of measuring student achievement.

7. The students in each section could not be randomly selected; therefore, the conclusions should not be generalized.

8. Subjecting the researcher constructed slide-tape materials, response formats, criterion tests, and retention tests to both a
pilot study and the scrutiny of a jury-panel consisting of the cooperating instructors will provide sufficient feedback in order to validate and test the reliability of these materials.

SCOPE OF THE STUDY

The study was completed within the following limitations:

1. The content was limited to two units of instruction on the subjects of graphical integration and graphical differentiation.
2. The sample was drawn from a population of pre-engineering and engineering technology students enrolled in engineering graphics and drafting courses during the fall quarter, 1978, at participating community colleges within the Virginia Community College System.

HYPOTHESES

1. Research Hypothesis: The students who have been shown the slide-tape presentation, complete with the slide-quiz questions and the step method with color and with the sketch format will score higher on the criterion test than students who have seen the slide-tape presentations with slide-quiz questions and step method with color format—but without the sketch format.
Null Form: There is no significant difference in the initial achievement favoring the experimental group.

2. Research Hypothesis: The students who have been shown the slide-quiz questions and the step method with color and with the sketch format will score higher on the retention test than students who have seen the slide tape presentations with slide-quiz questions and the step method with color format— but without the sketch format.

Null Form: There is no significant difference in retention favoring the experimental group.

3. Research Hypothesis: The students will prefer the slide-tape presentations complete with the step method in color and sketch format over the slide-tape presentations with the step method in color— but without the sketch format.

Null Form: There is no significant difference in the students' preference favoring the experimental method of presentation.

4. Research Hypothesis: The cooperating instructors will prefer the slide-tape presentations complete with the step method in color and with the sketch format over the slide-tape presentations with the step method in color— but without the sketch format.

Null Form: There is no significant difference in the instructors' preference favoring the experimental method of presentation.

5. Research Hypothesis: The instructors will prefer slide presentations of graphical methods (such as the chordal method) complete with slide quiz questions, step method with color instruction sheets, criterion referenced review quizzes, and taped narrations
over the traditional lecture-chalkboard method of instruction as a means of initially introducing students to the concepts of differentiation and integration.

Null Form: There is no significant difference in the instructors' preference favoring the experimental method, as presented in this study, versus the traditional method of instruction when initially introducing students to the math concepts of differentiation and integration.

6. Research Hypothesis: Students with previous formal classroom experience with differentiation and integration will prefer to have first been shown the slide-tape presentations on graphical integration and differentiation prior to that classroom experience.

Null Form: There is no significant difference in the students' (with previous calculus experience) preference in favor of first receiving either the experimental method of instruction as compared to their initial math (calculus) class experience.

OBJECTIVES

The specific objectives of the proposed study were to determine:

1. The relative effectiveness, as measured by a criterion test, of: (a) an experimental slide-tape series, presented with the step method with color and response format, which included required sketch responses and quiz questions inserted at intervals throughout the presentations versus (b) a control slide-tape series presented by the step method with color format but omitting sketching practices.
2. The relative effectiveness, as measured by a retention test, of: (a) an experimental slide-tape series, presented with the step method with color and response format, which included required responses and quiz questions inserted at intervals throughout the presentations versus (b) a control slide-tape series presented by the step method with color format but omitting sketching practices.

3. Whether students prefer the slide-tape presentations as described above with slide-quiz questions and required sketch responses over the slide-tape presentations without the required sketch responses.

4. Whether the cooperating instructors will prefer the slide-tape presentations complete with the step method in color and with the sketch format over the slide-tape presentations with the step method in color—but without the sketch format.

5. Whether instructors prefer the experimental method as an instructional method by which to best initially present the math concepts of differentiation and integration over a traditional lecture-chalkboard method of instruction.

6. Whether students who have had previous classroom exposure to the concepts of differentiation and integration in mathematics courses would prefer to have first been shown the slide-tape presentations, complete with slide-quiz questions, step method in color instruction sheets, and criterion tests prior to that classroom experience.
DEFINITION OF TERMS

Slide-tape Presentation

This kind of presentation in this study included:

1. a sheet stating the learning objectives for the instructional content,
2. a series of 60 to 70 35mm slides,
3. a recorded narrative accompanying the slides,
4. a step method with color format instruction sheet (control) and/or a step method with color and response format instruction sheet (experimental),
5. a self-scoring response card answer sheet for slide quiz question responses, and
6. a criterion test at the conclusion of the slide presentation.

Step Method

According to Earle (1964), the step method illustrates the steps necessary in solving a problem by separating the basic processes involved. The problem is first presented with the requirements outlined. Each step is shown separately with a brief mention of theory directly under the illustration (p. 9).

Step Method with Color Format

This method is the same format as the step method with the only difference being that each succeeding step is in color in order to more clearly define it from the preceding illustration (Earle, 1964, p. 9).

Step Method with Color and Sketch Format

A researcher designed format which includes the same attributes as the step method with color but also provides a format for students
to practice (by sketch) the concepts explained in each progressive step presented in the slide sequence.

**Self-scoring Response Card**

A commercially available answer sheet (Van Valkenburgh, Nooger, and Neville, Inc.) which is designed to lead students to the correct answer, thereby providing a type of feedback reinforcement.

**Control Method**

Students are given an instructional sheet which utilizes the step method with color format. A slide-tape presentation is then presented which facilitates and further describes the concepts on that instruction sheet.

**Experimental Method**

Students are given a step method with color and sketch format. The same slide-tape presentation (utilized in control method) is presented except that brief time lapses are allowed at intervals in order to allow students to practice (by sketch) the concept presented in each step.

**Graphical Differentiation**

Consists of (Kepler, 1973) obtaining the slopes of various tangents along a given curve and plotting these slope values to establish a second curve. The second curve is said to be the derivative of the first curve (p. 220).

**Graphical Integration**

This is the process of determining (estimating) the area under a given curve. It is the reciprocal process of differentiation.
Criterion Test

A test which concludes a slide-tape presentation. It is a researcher designed test consisting of performance, completion, and objective types of questions and was used to measure a student's mastery of the learning objectives specified at the beginning of a slide-tape presentation.

Retention Test

This test is the same criterion test described above. It was administered a second time two weeks after the slide-tape presentation to measure student recall of the information in that presentation.

PROCEDURES OF THE STUDY

For this study, the two methods of instruction were: (1) experimental slide-tape sequence utilizing a step method with color and response format requiring students to respond intermittently by a brief sketch and/or a multiple choice quiz or true-false selection, (2) control slide-tape sequence utilizing a step method with color format including the required multiple choice or true-false selections but without the required sketch response.

The following procedures were utilized in this study:

1. The above performances were evaluated on the basis of researcher designed criterion tests.

2. Both the experimental method and control methods utilized the Van Valkenburgh et al. patented "Trainer-Tester" response card which provided for immediate feedback or reinforcement to the student's slide-quiz selection(s), thus leading him to the correct answer.
3. Each student in the study participated once as a member of an experimental group and once as member of a control group. All of the students were given the graphical integration learning package first. If a student was in the experimental treatment group while learning graphical integration, he was subsequently a member of the control group to study graphical differentiation.

4. The slide-tape material, experimental and control response formats, quiz items, criterion tests, and retention tests were all prepared by the researcher.

5. All of the instructional materials, criterion tests, and retention tests were subjected to both a pilot study conducted during the spring and summer quarters (1978) and a critique by a jury-panel comprised of the cooperating instructors and revised accordingly.

6. The study itself was conducted during the fall quarter, 1978, at the participating community colleges.

7. The Verbal Reasoning and Abstract Reasoning tests of the Differential Aptitude Test Battery were administered to the students two weeks after the experimental or control treatments.

8. Differential Aptitude Test scores were utilized as covariates with criterion test scores in the statistical treatment known as the analysis of covariance in order to ascertain the significance of the difference between treatments. According to Huck (1972),

In addition to its ability to control for initial differences between groups, the analysis of covariance increases the sensitivity of the analysis, thus making it more likely that significant differences will be "picked up" by the statistical test (p. 42).
9. Based on Gay's (1976) discussion of the Post-test Only Control Group design and how it can be used in educational research, this design was chosen for the study. Analysis of covariance helped to control for the inability to randomly select students. Random assignment of the treatments to the groups was utilized and the statistical results of the data were reported two ways with: (1) the classroom as the unit of analysis and (2) the individual as the unit of analysis. The results should be interpreted by the reader with due consideration to the qualities of each of the methods.

10. Additional data were gathered to ascertain student and faculty preferences regarding the control and experimental treatments. In fact, the experimental and control treatments in the second learning package, graphical differentiation, were administered solely for the purpose of ascertaining student preference of the treatments (i.e., if a student were in an experimental group while learning graphical integration, he was subsequently a member of the control group while studying graphical differentiation and vice versa). Therefore, the data collected from the graphical differentiation experimental and control treatments were not analyzed statistically for purposes of determining the quality of student performances— but only to ascertain student opinions and preferences. The rationale for this is that since the chordal method procedure utilized for graphical differentiation is basically the reverse of the chordal method procedure for graphical integration (which all students had been previously exposed to), a potential interaction effect existed
and would have confounded a serious statistical analysis of experi-
mental and/or control graphical differentiation data.

SUMMARY

A number of authors and proponents of graphical solutions to
math-related engineering problems contend that solving these problems
with graphical solutions can lead students to a better comprehension
of the concepts involved. This kind of a personal experience basically led the researcher to select graphical integration and differenti-
ation as the instructional subject matter for the experiment described
in this chapter.

The rationale for the instructional materials developed for this
study was based upon combining several features from research proven
instructional formats and methods. By combining these features and
including sketching practice as an added instructional strategy, an
attempt was made to design and subsequently test an improved
instructional system for drafting and engineering graphics courses.
Chapter 2

REVIEW OF LITERATURE

Holland (1973) commented on a related literature review in engineering graphics as follows: "Literature related to engineering graphics can generally be classified into one of two broad categories: (1) content or (2) method of instruction" (p. 15). The literature included in this review has been limited to the "methods of instruction;" and also, because the instructional materials developed for this study bear a compatible resemblance and are similar in rationale to some forms of programmed instruction, the researcher decided it was necessary to include in this review the origins and a brief history of programmed instructional materials. Therefore, the literature pertinent to this study is organized as follows in terms of (a) a brief history of automated or programmed instruction and (b) a chronological review of pertinent related research on various forms of instructional development utilized in college level engineering graphics or mechanical drafting courses.

LITERATURE ON AUTOMATED OR PROGRAMMED INSTRUCTION

"Programmed learning is a combination of the Socratic and Cartesian methods, in the sense that the material is taught by question and answer and is broken down into a series of small, logical sequences arranged in a hierarchical order" (Thomas, Davies, Openshan,
and Bird, 1963, p. 11). Regarding the origin of automated or programmed instructional development, Garner (1966) records that

The U.S. Patent Office granted a patent to H. Chard in 1809 for a device designed to teach reading. Halcyon Skinner developed and patented another device in 1866 to teach spelling. This, B. F. Skinner has called the first real teaching machine (p. 8).

The thoughts of Thorndike, who traditionally is attributed with a key role in the evolution of programmed instruction, are recorded by Thomas with additional comment regarding the contribution of Pressey from The Ohio State University.

Dr. Edward L. Thorndike, in his book Education, published in 1912, wrote: "If, by miracle of mechanical ingenuity, a book could be so arranged that only to him who has done what was directed on page one would page two become visible, and so on, much that now required personal instruction could be managed by print." Unfortunately, Dr. Thorndike's appeal went unheeded until, in the early nineteen twenties, Dr. Sidney L. Pressey, of The Ohio State University, designed a mechanical device for testing and scoring simple attainment tests (Thomas, et al., 1963, p. 12).

The Pressey Drum-Tutor, as the machine was known, has been described as follows:

The Pressey Drum Tutor was the first teaching machine designed to handle varied subject matter. It recorded correct and incorrect responses and compelled the respondent to discover the correct response to an item before a new one was presented. The device operated in this manner: the testee was offered an objective item with four possible responses. There were four keys on the machine similar to those found on a typewriter. To use the device, the student first read an item and then indicated a response by pressing a key. The machine recorded the response and if it were correct another item was presented. If an incorrect response was recorded, the testee was required to continue making responses until the correct response was found (Pressey, 1926, pp. 374-375).
The reinforcement/feedback concept innate to the Pressey Drum Tutor is fundamental to programmed instruction. Pressey reasoned that this type of reinforcement would aid in learning. To test this hypothesis, a punch-board was used in college classes of Russian vocabulary, English vocabulary, and psychology. The results indicated that immediate reinforcement was an aid to learning and retention.

At the conclusion of the experiment, Pressey (1950) said:

The investigation has shown that when the self-instruction tests were used systematically in college courses as an integral part of the teaching method, gains were substantial, and sufficiently generalized to improve understanding of a topic as a whole—even help on related topics (pp. 417-447).

Cozzens (1965) states that further analysis led to four other conclusions regarding the punchboard:

1. The punchboard is a simple way to facilitate learning by combining testing, scoring, and immediate feedback.

2. The punchboard is an effective means for transforming testing into a program of self-instruction.

3. The punchboard is one of a variety of means for transforming testing into a program of self-instruction.

4. The punchboard is one of a variety of means by which automatic scoring and self-instruction can be achieved (p. 20).

Popham and Baker (1970) explain that Pressey's initial hopes for a revolution in education did not begin to be realized for another quarter of a century.

In the late 1950's programmed instruction received its major impetus from the writing of B. F. Skinner, who argued that what had been learned in the animal laboratory
(operant conditioning) had considerable relevance for the classroom and that if we wished to design a systematic scheme for modifying human behavior we had to use reinforcement procedures such as those employed in his laboratory. He urged that the most efficient method for providing subtle reinforcement contingencies was through the use of teaching machines that presented carefully arranged or "programed" instructional materials. Because of Skinner's influence during those early days, the concept of programmed instruction came to include three significant characteristics:

1. Active response of the student to carefully sequenced instructional materials.

2. The provision of immediate knowledge of results, whereby the learner could judge whether his response was correct or incorrect.

3. Self-pacing, whereby the student was able to move at his own rate through the instructional program (pp. 111-112).

The early programmed texts, subscribing rather thoroughly to a Skinnerian concept of learning, tended to be based upon a linear conception of instruction. Holland (1973) summarizes programmed instruction as follows:

The Skinnerian theory of operant conditioning is a modernized version of the behavioristic and stimulus response theories of Watson and Thorndike . . . . Materials may be programmed using one of two acceptable formats—linear or branching. The format of linear program is designed so that every student proceeds through a uniform set of frames to complete the program. A branching program, on the other hand, requires the student to read the material and then make a response. If the response is correct, the student is directed to another page and a new unit of information; if incorrect, the student is given additional information to overcome the error (p. 16).

More recently, the literature suggests that behavioral or learning objectives have been written to accompany most currently available forms of programmed, automated, or audio-tutorial kinds of
instructional technology. Further, Alpren (1974) states that while the behavioral objectives movement had its origins in the work of Thorndike, the more recent antecedents are the work of Skinner, Tyler, and the editors of the Taxonomy of Educational Objectives. He further submits that

Skinner provided the theory and research that led to programmed instruction and a return to the ideas on efficiency training of the 1920's. Tyler gave credence and a rationale to the movement. The taxonomists provided the bibles that permitted Mayer, Popham, and others to promote the current movement (Alpren and Baron, 1974, p. 43).

Herrscher (1971) summarizes the background and characteristics typical of programmed instruction and reflects on its current attributes:

Harvard Professor B. F. Skinner pioneered the programmed instruction movement in the 1950's from which evolved the teaching principles which are characteristic of both programmed instructions and the broader individualized instruction approach . . . (which includes) . . . presenting subject matter in small steps, active student involvement, immediate confirmation of student progress, positive reinforcement, student self-pacing, and revision of instructional materials until the desired level of achievement is attained by the learners. The characteristics of this approach to instruction are portability, variety, and flexibility. A course composed of a series of self-instructional units is highly individualized, yet uniform instruction is provided for a large number of students on an individual basis (p. 10).

Herrscher further suggests that terms such as individualized instruction and/or Instructional Systems (Banathy, 1968) have most surely evolved from the earlier works of Pressey, Skinner, and others. A broad investigation of current literature reveals that Popham, Baker, Bloom, Mayer, Banathy, and others have influenced volumes of
literature from which one may obtain a widely diversified view of current theory and practice on instructional development. The ideas of a number of these authors are included in Chapter 3 as a basis for the rationale for the development of the instructional packages utilized in this experiment.

LITERATURE ON RELATED RESEARCH ON METHODS OF TEACHING ENGINEERING GRAPHICS

It was noted earlier (page 1) that a number of experimental research studies have been conducted in the field of engineering drawing instruction. Several of these have established significant data regarding instructional techniques, presentation formats, and student preference which merit additional investigation. The following is a chronologically-presented review of the more notable studies.

Hepler (1957) conducted a study to ascertain the relative effectiveness of teaching orthographic projection first, followed by pictorial presentation, as compared to teaching these concepts in the reverse order.

Six classes of engineering drawing at the University of Missouri were divided into two "equated" groups which were paired on the basis of Army General Classification Test Scores, subject matter pretest scores, and secondary school drafting experience. Groups were compared on information achievement, drawing skill, ability to visualize, speed, and attitude of student toward subject.

Findings indicate that teaching orthographic projection followed by pictorial representation is superior to or a more effective approach
in the development of informational achievement, drawing skill, and ability to visualize. There was no significant difference found between the two methods with respect to speed developed and/or attitudes of students toward the methods of instruction.

In 1962 Clayton W. Chance conducted a study at the University of Texas which was supported by the National Science Foundation. The purpose of Chance's research was to determine the relative effectiveness of presenting descriptive geometry problems by projecting colored transparencies onto a screen with an overhead projector as compared to the traditional lecture-chalkboard method of presentation. In the experimental group, each transparency illustrated a descriptive geometry problem by utilizing a different color in each sequential step toward the solution. Chance's sample consisted of a sample of 104 students which were randomly divided into two groups. In his conclusions, Chance (1960) reported that:

1. The lecture demonstration period was reduced by five minutes when transparencies were used allowing more time for supervised laboratory periods.

2. The classes receiving benefit of the transparencies earned an average of 83 on daily drawings compared to 81 for the classes seeing no transparencies.

3. More time was available for questions.

4. The faculty preferred teaching with the visual aids.

5. The final grades for the classes taught with transparencies averaged 79.3 while the average for the other group was 74.9 (pp. 3-40).

Chance (1962) further reported from his findings that:
Transparencies that are prepared previous to the lecture demonstration allow for two very important features to transpire. First, a much improved presentation in color over a blackboard-white chalk method will increase students' attentiveness many fold. Secondly, because students actually are not learning anything new while the instructor is drawing lines which form the end result, colored overlays indicate subsequent theoretical steps to a problem solution and saves much of the students' concentration time (pp. 10-16).

Earle (1964) reports having had personal correspondence with Chance; and his own subsequent research efforts suggest that Chance's experimentation with color on descriptive geometry visuals provided, in fact, the very focus of Earle's doctoral research (p. 16). Earle devised a format which he refers to as "the step method in color," which is basically a variation of programmed instruction. Earle conducted an experimental investigation in which he tested 474 engineering graphics students at Texas A & M University to determine the relative effectiveness of four instructional methods:

1. step method in color,
2. step method in black and white,
3. conventional textbook technique of presentation, and
4. the lecture method.

The hypotheses of Earle's study were that students would be able to solve descriptive geometry problems in less time:

1. when using a step method guide than when using a conventional textbook presentation,
2. when using the step method in color guide than when using the step method (black and white) guide, and
The cooperating teachers gave no instruction (except the lecture method), but merely handed out the tests and/or the appropriate presentation formats to be used in solving the problem. Earle reported that he analyzed the data by using the analysis of variance and Duncan's multiple range test in order to arrive at the following statistical conclusions:

1. The conventional method requires significantly greater comprehension time than the next best method, the step method. This statement can be made with 99 percent confidence based on the two thousand, eight hundred and forty-three experimental samples taken.

2. The step method in color was superior to the step method at the .05 level of confidence. This conclusion is based on the total analysis of the entire experiment and the opinions of the participating students.

3. The lecture method was considered to be of equal effectiveness as the step method, but of less value than the step method in color in decreasing time required to solve descriptive geometry problems.

4. The students preferred the step methods over the conventional method and the step method in color over both the step method and the lecture method. It was the consensus of student opinion that the step method, whether in black and white or in color, is a valid format for a descriptive geometry workbook to supplement a conventional textbook as a self-instructional aid (pp. 98-99).

Earle recommended that further research be conducted in order to:

(1) determine the suitability of programmed instruction in "other areas of industrial arts and engineering;"

(2) study the usefulness of color in textbook formats,
(3) determine if other formats for self-instruction can be developed,

(4) determine other subject areas that may be significantly improved when presented in two colors,

(5) measure the effectiveness of the step method in color when accompanied by a teacher presentation, and

(6) determine the contribution of step methods to comprehension and retention of descriptive geometry principles (pp. 101-102).

A principle of programmed instruction, that of immediate feedback or reinforcement, was not incorporated into Earle's study; however, he also recommended that additional research be conducted in engineering graphics on this aspect of programmed instruction.

Cozzens (1965) pursued Earle's recommendation to investigate the immediate feedback or reinforcement aspect of programmed instruction by developing and testing a series of self-instructional and self-scoring problem sheets for descriptive geometry. These instruments were unique in that they consisted of a problem to be solved, a sheet of carbon paper, and a completed answer sheet. These three were all sealed around the edges so that the solution was not revealed until a student had attempted the problem and subsequently tore the perforations from the edge. Cozzens states that the purpose of his research was to determine:

which technique (conventional or self-scoring) was more effective in presenting the material covered by six principles of descriptive geometry, student accuracy in reporting scores when using the self-scoring devices, and which technique could be scored by experienced graders in less time (p. 129).

Cozzens administered a pretest to approximately 360 students in order to determine the homogeneity of the sample sections.
Utilizing the analysis of variance, Cozzens concluded that these sample sections were in fact from the same population. After the instructor had presented a descriptive geometry principle in class, the self-scoring devices were utilized by members of the experimental group, to be completed as preparatory assignments for their next class. They were encouraged to complete the problem at home and then tear away the carboned answer beneath to analyze the correctness of their solution prior to their next class meeting. A scoring key on each sheet permitted members of the experimental group to evaluate their solutions. These sheets, along with the evaluations, were returned to the instructor at the next meeting and subsequently analyzed to determine student accuracy in self-evaluation.

The control group was taught the same principle, except that their work was completed in class with instructional assistance. Members of the control group were not given the option of scoring their own sheets.

A performance exam, which tested students on that particular descriptive geometry principle was given to both groups at the next class meeting. These scores were then analyzed to determine student performance.

Cozzens concluded that the self-scoring device had a beneficial effect on student performance in that the overall mean scores on the performance test averaged 86.56 percent for the experimental group compared to 81.58 percent for the control group. Regarding student preferences, Cozzens concluded that:
Only general statements may be made regarding student opinion of the two techniques. Generally, the students seemed to prefer working descriptive geometry problems using the self-scoring devices. Moreover, they stated a preference for the self-scoring devices when working all descriptive geometry problems (p. 132).

Wilkes (1966) conducted a study at the University of Missouri to determine the relative effectiveness of 35mm slides versus the traditional lecture-chalkboard method of presenting engineering graphics material. After administering the experimental and control treatments, data were gathered from the sample of 132 engineering students on an achievement test developed by Blum (1963), a two-hour performance test developed by Sanbacher (1961) and Remmer's Scale for Measuring Attitude toward Any School Subject.

These data were analyzed in regard to (1) student achievement, (2) quality of student work, and (3) student attitude toward the method of instruction. From this analysis Wilkes concluded that:

1. The teaching of engineering drawing using comprehensive film slides appears to be a more effective means of teaching than the conventional chalkboard approach in terms of instructional information.

2. The two approaches seem to be equally effective in terms of the quality of work completed by the students.

3. Students taught by the film-slide approach have a better attitude towards the course than those taught by the regular chalkboard approach (pp. 141-142).

Amthor (1967) analyzed data gathered from 113 students from Stout State University and Texas A & M University in order to determine the relative effectiveness of silent filmstrip, sound filmstrip, and the conventional lecture-demonstration methods of instruction in descriptive geometry.
Filmstrips, covering each of the six descriptive geometry principles as stated by Earle (1964), were designed by the researcher in order to maintain uniformity of grading; six performance tests were also designed and scored with a special grading key designed by the researcher.

Students were randomly assigned to one of three treatment groups according to levels of ability and were systematically rotated through each mode of presentation. The effectiveness of the methods was tested in an experimental design using three criteria: (1) performance test of initial learning, (2) retention, and (3) attitudes towards the course.

The findings of the study supported the following conclusions: (1) there were no significant differences among the three treatments as measured by initial learning, (2) there were no significant differences among ability levels and treatments as measured by initial learning, and (3) there were no differences in the achievement of students between the two participating institutions. While there were no differences among the treatments, students preferred the lecture-discussion method of instruction to the filmstrip presentations. (Joint Research Committee of the ACIATE, AIAA, and NAITTE, 1970)

Nystrom (1969) conducted an experimental study at Texas A & M University to determine the relative effectiveness of 16mm sound animated films to the conventional lecture-demonstration method of teaching selected units in engineering graphics. Four hundred beginning engineering students were randomly assigned by section to experimental and control groups. Holland (1973) has concisely summarized Nystrom's study as follows:

The effectiveness of the animated filmstrip method of presentation was evaluated using a pretest-posttest instrument consisting of multiple-choice and performance-type questions prepared by the researcher to compare student informational gain in both the experimental and control groups. In addition, a test of retention was
administered four weeks after each posttest to compare the experimental and control groups' ability to recall information presented by each of the two methods.

Nystrom concluded that (1) there was a significant difference favoring the experimental group in the amount of initial learning, and (2) there was a significant difference favoring the experimental group in the retention of subject matter. He also analyzed the results of an opinionnaire administered to both control groups at the end of the study, and concluded that the students preferred the conventional lecture-chalkboard over the animated 16mm film method of presentation (pp. 26-27).

Holland (1973) conducted a study to determine whether audiovisual presentations accompanied by intermittent multiple choice slide-quiz questions were of value in helping students understand specific engineering graphics concepts.

The problem was to evaluate the effectiveness of two methods of audio-visual instruction in an engineering graphics learning situation. The two methods of instruction were: (1) experimental tape-slide series complete with slide-quiz questions inserted at intervals throughout the presentations, and (2) control tape-slide series without slide-quiz questions. Information was also gathered to evaluate student preference regarding the two audio-visual methods (Holland, 1976, p. 27).

In an attempt to increase active student involvement and interest, the experimental treatment incorporated the use of a response card similar to that described earlier (page 16) by Pressey, which provided for immediate reinforcement on the slide-quiz questions.

This study was developed and tested on a total of 96 students at three different institutions: Texas A & M University, College Station, Texas; Thomas Nelson Community College, Hampton, Virginia; and San Jacinto College, Pasadena, Texas. Tape recorded narrations
accompanied each of the six slide presentations to control for any teacher effects, and researcher designed review quizzes were administered to both the experimental and control groups immediately following the treatment to measure initial achievement.

Each student participated three times as a member of both a control group and as a member of an experimental group, and retention tests were given to all students two weeks after the last slide presentation for each unit that was shown. In this experiment the researcher tested hypotheses pertinent to the following:

(1) student initial achievement,
(2) student retention,
(3) student preference of the methods, and
(4) faculty preference of the methods.

Holland reported in his findings that:

(1) There was a significant difference in initial achievement favoring the experimental group at the .01 level.

(2) There was no appreciable difference in experimental and control students' ability to recall the concepts after a two-week lapse.

(3) Student preference favored the experimental treatment.

(4) Cooperating faculty members favored the experimental method (pp. 109-110).

Horne (1977) at Virginia Polytechnic Institute and State University conducted a study, the purpose of which was to determine if students using an individualized instructional systems approach scored significantly higher on an achievement test in elementary drafting principles as compared to students taught by traditional
methods of instruction. This study included the use of a number of researcher constructed instructional materials covering three units of instruction including: (1) use of equipment and materials, (2) technical sketching, and (3) orthographic projection. Each researcher constructed module contained the following sections: introduction and rationale, learning systems sequence, specific performance objectives, supplemental learning materials, learning activities, pre-post evaluation, and instructional materials evaluation forms.

A total of 99 drafting students participated as subjects in this experiment at four community colleges within the Virginia Community College System. These included John Tyler Community College, Chester; Thomas Nelson Community College, Hampton; Central Virginia Community College, Lynchburg; and Piedmont Virginia Community College, Charlottesville.

In the abstract on his study Horne summarized his investigation as follows:

Students at each of the four community colleges were enrolled in two treatment groups: control (traditional method) and experimental (individualized method), and treatment method was randomly assigned. One instructor taught both treatment groups at each college. All students in the control and experimental groups were administered a teacher-made Drafting Achievement Pre-Test. The experimental treatment groups were then instructed, utilizing the individualized materials, while the control groups were taught by the traditional approach. Upon completion of the instruction, students in all groups were given the Drafting Achievement Post-Test. An Instructional Attitude Inventory was completed by students in each group in order to determine opinions toward the instructional treatments. Instructor opinions and recommendations were assessed by the structured interview technique. Educational ability of each student was measured by the SRA Short Test of Educational Ability.
Multifactorial analysis of covariance with Multiple Classification Analysis was employed to determine the effects of the independent variables (treatment, college, and ability level) on the dependent variables (achievement and attitude toward treatment). Scores on the Drafting Achievement Pre-Test and SRA Ability Test were used as covariates (pp. 139-140).

Horne reported the following results upon statistical analysis of the data:

1. There was a significant difference at the .05 level in mean Post-test scores as measured by the Drafting Achievement Test, between the control (traditional) and experimental (individualized) treatment groups, with the individualized groups scoring higher.

2. There was a significant difference in mean Post-test scores on the Drafting Achievement Test between urban and suburban-rural community colleges, when comparing treatment method. The suburban-rural schools scored lower than the urban community colleges.

3. There was no difference in student attitudes toward either treatment method (traditional or individualized) as measured by the Instructional Attitude Inventory.

4. Instructor opinions toward the individualized materials, determined by structured interviews, were found to be favorable. Valuable data concerning modification and revision of the experimental materials were also collected by this technique (pp. 83-89).

A major conclusion of Horne's study was that the instructional systems approach is superior to traditional methods in teaching technical drawing to community college students. Horne recommended that community college administrators provide the support and materials resources necessary to continue development and evaluation of various individualized materials by technical faculty.
SUMMARY

A good deal of the related research on automated instructional technology in engineering drawing education has taken the form of evaluational studies in which teaching by 35mm slides, overhead transparencies and/or various formats closely associated with programmed instruction have been compared to the "conventional" method. The review of the related research generally reveals that direct research applications in drafting and design programs at the community college or post-secondary level have been somewhat limited. Although none of the studies included in the review presented here were identical, several utilized similar instructional techniques, and most of the researchers recommended that the study be replicated with or without certain modifications to reaffirm their conclusions. Several of these studies have established notably significant instructional methods and/or presentation formats either in terms of superiority or student preference.

In summary, this researcher believes that authors Impellitteri and Pinch (1971) have captured the essence of the necessary and concerted research efforts which will be required (not only of engineering graphics and drafting educators and academicians) if the current state of the art in instructional development is to be significantly improved.

Programmatic research and development efforts are needed to improve the current status of individualized instruction in vocational and technical education. Teams of researchers, curriculum specialists, instructional technology specialists and teachers must be formed to embark upon research and development efforts geared specifically to vocational and technical education.
Viewed as a total system, instruction can be effectively designed only by the cooperative efforts of practitioners and researchers. The task is too complex and the system is too dynamic for implementation to be set apart from research (p. 69).
PROCEEDURES FOR THE STUDY

Introduction

The procedure utilized in conducting this investigation was that of experimental research. The study was also developmental in that the instructional formats, the slide-tape presentations, and the criterion tests were all researcher constructed.

The following observations by Baker and Shutz (1972) have been pertinent to the development of the instructional materials utilized in this study. These writers have suggested that any further pursuit of conceptual paradigms and generation of abstract interrelationships termed "theories" in educational research are probably unnecessary. Baker and Shutz have further pointed out the difficulty in translating educational research into a practically usable form; and, in a discussion regarding "instructional development," have recommended that we start viewing research as a means of reducing uncertainty by, stated simply, placing emphasis on "how" rather than "why" utility. This researcher has interpreted the foregoing discussion as a recommendation for educational researchers to utilize existing research proven instructional formats or techniques and to refine, combine, further develop, and/or reexamine the worth of these instructional methods.
In an attempt to design an improved instructional system, the materials which were developed for this study essentially evolved from the literature review, particularly from a number of experimental studies reviewed earlier in Chapter 2 and also from an investigation of current and proven learning strategies. More specifically, the design of the instructional materials generated for this study was at least initially influenced by the efforts of the following researchers:

1. (Earle, 1964) step method instruction sheet,
2. (Holland, 1973) slide quiz questions,
3. (Pressey, 1950 and Holland, 1975) a self-scoring response card, and
4. (Horne, 1977) learning objective sheets and criterion referenced testing.

The description of the procedures used in this study has been organized into a two-part discussion, and they are presented in this chapter and entitled as follows:

1. Development of the Media and Instruments and
2. Administration of the Study.

DEVELOPMENT OF THE MEDIA AND INSTRUMENTS

The Instructional System Rationale

The rationale underlying the development of all of the instructional materials was based upon a broad investigation of literature on current learning strategies in order to obtain a diversified view of current theory and practice. In conjunction with attempting to
combine features of certain research proven instructional formats, an attempt was made to select from the literature review an instructional system model for this study which would be as Herrscher (1971) has stated "at an operational level rather than at a theoretical level" (p. 4).

The model shown in Figure 1 was selected for this study because it is representative of the ideas of both current and proven learning theory. Herrscher has indicated that this instructional system is a synthesis of ideas gleaned from the writings of Ralph Tyler, W. James Popham, Bela Banathy, and Jerrold Kemp; and that "its proven capability of producing measurable learner achievement is its hallmark" (Herrscher, 1971, pp. 4 and 26).

![Figure 1: An Instructional System](image)
While this model served basically as a guide for the development of the instructional materials it was not adhered to rigidly in the experiment itself; for example, it was found in the pilot study, to be described later, that no student scored higher than 15 percentage points on the pretest. Therefore, for this reason and also to conserve time, the researcher elected to forego the pretesting of subjects in the actual experiment. This and other decisions will be described later in a discussion of the pilot study.

Selection of the Units of Instruction and Rationale

A number of articles and research studies in engineering education have cited the increased pressures to compress additional subject matter into existing course content. Graphical calculus, not traditionally offered in engineering graphics courses, has been one of several topics being added to many engineering graphics syllabi. The selection of graphical integration and graphical differentiation as the subject matter for the units of instruction to be developed for this experimental study was based upon a review of current engineering graphics texts, a review of course syllabi at several institutions, and a personal belief on the researcher's behalf that engineering and engineering technology students can benefit from instruction and in drawing practice in graphical integration and differentiation prior to or at least concurrently with their first college calculus course.

As suggested by the model in Figure 1, Herrscher has indicated to those of us engaged in the design of instructional materials the need
for communicating to students the reason that the material dealt with is important to be learned. The use of such a statement (rationale) should function to provide the students with motivation, cause the course work to seem relevant and/or to provide some evidence of how the material relates to a career interest. Such statements of rationale were included in this study on the learning objective sheets (Please refer to Appendix E, pp. 124-125) which were given to each participating student just prior to the beginning of each unit of instruction.

Additional informative statements clarifying the relevance of the subject matter were also included in the narrations of the 35mm slide programs as the students proceeded through the learning activities.

Development of the Learning Objectives

The learning objectives are the basic building blocks of each unit of a course. Herrscher believes that it is through the learning objectives that an instructor (a) communicates his expectations to his students, (b) affords direction to the students, (c) encourages learning, and ultimately (d) assesses the outcomes of the learning. He further notes that "Objectives dictate the test questions to be used so as to collect evidence of behavioral change in the student, thus verifying the effectiveness of instruction" (Herrscher, 1971, p. 6).

Popham (1975) has indicated that while no one can claim divine inspiration in the generation of acceptable kinds of learning objectives, he concludes that the objectives would usually state what the student will learn, under what conditions the student will demonstrate the learning, and how the student will be judged. (p. 44)
Once the subject matter, as described below, was thoroughly researched, an attempt was made to follow Popham's guidelines in the construction of the learning objectives.

Most every recently edited engineering graphics textbook has included a treatise on graphical calculus. In order to determine, among other things, important performance (learning) objectives to be presented to the students prior to their participation in the study, relevant subject matter content from each of the following engineering graphics textbooks and references was reviewed:


In an attempt to gather additional insight toward choosing appropriate learning objectives and learning activities, the researcher also reviewed a series of eight short super 8mm films, *Calculus in Motion*, available from Houghton Mifflin Company. Two of these, "The Definite Integral" and "Derivatives" were particularly helpful aids in isolating important concepts to be conveyed in the 35mm slides, and
thus they were therefore also helpful in the selection of the learning objectives.

The learning objectives which evolved from this review are included in Appendix E, page 125 and Appendix I, p. 146.

**Development of the Learning Activities**

**The Student Instructional Formats.** As stated previously the idea to utilize a step method in color format in the experimental and control groups was derived from a review of an experimental study done by Earle (1964) at Texas A & M University. The successful use of color to present sequential steps in descriptive geometry problems is documented in Earle's research and has subsequently been adapted in several recently published engineering graphics textbooks. Of the textbooks reviewed, Earle's *Engineering Design Graphics* was the first to incorporate the concept of using color as described above in conjunction with including the related script directly under each graphical step in the solution to a problem illustration (as opposed to presenting the related script on an entirely different page as was the frustrating case with many of the earlier texts).

In concluding (a) that student performance when using the step method in color was superior to the step method in black and white, as well as both the conventional textbook technique of presentation and the conventional lecture method, (b) that student comprehension time was decreased and (c) that students preferred this method to the others, Earle's study (1964) established conclusive evidence for the instructional merit of the step method in color format.
The decision was thus made by this researcher to develop a step method in color format for the instructional sheets to be utilized by members of both the experimental and control groups in this experiment.

The literature review which ultimately provoked the hypothesis that "sketching practice" (as the independent variable distinguishing the experimental and control instructional formats) could be added to the step method in color to provide an even superior instructional format can perhaps be traced to the fact that (a) Cozzens' (1965) study provided evidence that "practice" has a positive effect on student performance, (b) Herrscher's description of designing learning activities suggests that generous opportunities for appropriate practice in the learning activities must be provided as an essential part of the teaching process, and (c) many publishers of texts on programmed instruction have traditionally reserved specified space for notes and/or student practice in the margins of these textbooks.

After completing a review of the previously listed engineering graphics textbooks, the artwork and the design of the actual student step method instruction sheets was prepared by the researcher utilizing Rapidograph pens and Leroy lettering instruments. The artwork for each of these instruction sheets was done in two overlays for purposes of separating the black and red colors applied during the reproduction process. The final copies of these student instruction sheets were printed as a community service to the researcher and Thomas Nelson Community College by the printing office at the National Aeronautical and Space Administration Research Center at Hampton,
Virginia. The experimental and control step method instructional sheets have been reduced in size for their inclusion here and may be reviewed in Appendixes F, G, J, and K, pages 126-138 and 147-152.

Development of the 35mm Slide-Tape Programs. As previously specified, a review of engineering graphics textbooks and the 8mm films, Calculus in Motion, preceded the writing of the learning objectives for the units of instruction on graphical integration and graphical differentiation. From these materials, a better understanding of a proper selection and sequencing of the graphics for the 35mm slide programs was acquired. From these references, an effort was made to utilize easily comprehended example problems and illustrations and to relate these to practical applications of graphical calculus throughout the slide programs as often as possible. A number of references including (1) Production of 2 x 2 Inch Slides for School Use (1978) by Earnest F. Tiemann and (2) How to Design and Produce Individualized Instruction Programs, (1969) Visual Products Division of the 3M Company, were reviewed to obtain an understanding of recommended proportions, preparation of original material, and legibility of content in the slides.

Each slide program was ultimately to contain from 60 to 70 slides. After selecting the example problems and illustrations alluded to in the above paragraph, the idea for the artwork for each slide was initially conceived and sketched on the left side of a 5 inch by 8 inch file card. Adjacent to the sketch on each card a cursive version of the narrator's script was written. The artwork and
the narrative on these 5 x 8 cards was revised several times and finally, they were turned over to Ms. Pat McNichol and Ms. Vikki Burress, artist technicians employed by the Learning Resources Center at Thomas Nelson Community College; and, the final graphics were prepared for photography by these persons.

The graphics for the slide-quiz questions, as described by Holland (1976, p. 28), were prepared and included in the 5 x 8 card decks for the slide program in an attempt to increase student interest in the slide presentations. All students were required to respond to these questions immediately during the slide presentations on the Van Valkenburgh, et al. response card previously described on page 10.

After all of the artwork had been readied for photo-copying, Ms. Marlene Waters, a photographer who is also employed by the Learning Resources Center at Thomas Nelson, photographed all of the materials and subsequently took charge of seeing that the slides were developed and mounted in the frames.

The researcher then sequentially organized the slides into their respective carousel trays for the experimental and control treatments, and the scripts were narrated and recorded on high fidelity cassette tapes with the help of Assistant Professor Al Martin, of the Drafting and Design Department at Thomas Nelson Community College. Mr. Don Depoy, Supervisor of Audio-Visual Services of the Learning Resources Center at Thomas Nelson Community College coordinated the recording sessions and edited the narrations in order to produce the cassette tapes as clearly and concisely as possible.
A representative sample of the slides from each of the slide-tape programs may be reviewed in Appendixes M and N, pages 158-177.

Development of the Assessment Devices.

There were four measuring instruments devised for this study; a:

1. criterion test for the graphical integration instructional package,
2. criterion test for the graphical differentiation instructional package,
3. student opinionnaire, and
4. faculty opinionnaire.

The Criterion Tests. The aforementioned statement by Herrscher, (i.e., "Objectives dictate the test questions to be used so as to collect evidence of behavioral change in the student, thus verifying the effectiveness of the instruction.") was interpreted very literally in the construction of the criterion tests (Review Quizzes) for both the graphical integration and differentiation learning packages. Bush (1979) concurs with Herrscher and provides additional support to this relationship of the test and the objectives by simply asserting, "Criterion referenced testing closely connects with the objectives in learning" (p. 20). While the researcher's review did not unearth a statement such as, "there should be a one for one relationship between the objectives and the test questions," it does seem to be implied in the literature and this assumption was basically followed in the construction of the criterion tests (Appendixes H and I, pages 139 and 153 utilized in this study. A pilot study to be described later provided the researcher with information which was utilized in the revision of the
criterion tests (referred to as "Review Quizzes" on student handouts) prior to the conduction of the actual experiment reported in this study.

The Opinionnaires. Two survey forms, a "Student Opinionnaire and Background Survey Form" and a "Faculty Opinionnaire" (Appendixes O and Q, pages 178 and 183) were devised and utilized in this study. These instruments primarily functioned to gather data relative to the research hypotheses. The Student Opinionnaire and Background Survey Form was developed to obtain student biographical data and their opinions and attitudes regarding the two methods of instruction. The faculty opinionnaire was utilized to gather information regarding the value of the step method sheets and the slide-tape presentations in engineering graphics and/or drafting courses.

The Pilot Study

After the design of the media and instruments had been completed and sufficient copies of each had been prepared, a pilot study was conducted in the spring and summer quarters of 1976 for each of the units of instruction. A jury-panel of cooperating instructors at Thomas Nelson Community College and Rappahannock Community College participated in the pilot study (a) by utilizing students in their classes as subjects for the pilot study and (b) by submitting written critique regarding suggestions for revising and improving the slide-tape materials and the other learning activities. During the pilot study, cooperating faculty were encouraged to freely solicit student opinions. Instructor and student comments were then consolidated by
the researcher, analyzed, and, subsequently, (a) certain slides were omitted and/or modified, and (b) the narrations were modified and retaped accordingly.

During the pilot study, the cooperating faculty utilized the following procedural checklist as a guide for presenting the units of instruction:

General Instructions for Pilot Study

The purpose of this study is to compare the effectiveness of audio-visual presentations when sketching practice is introduced as the independent variable in the slide programs. The slides will be shown to two groups (1) an experimental group, and (2) a control group. The experimental group will be shown a series of slides which includes an instruction sheet with a sketching format. The control group will be shown the same series of slides but the accompanying instruction sheet and tape narration does not accommodate sketching practice. Please read all of the following instructions thoroughly before starting the slide program.

Procedural Checklist for Administering Both Experimental and Control Presentations:

1. Organize 35mm slide projector and cassette recorder for slide #1.

2. Give each student a learning objective sheet and instruct students to read it thoroughly. Discuss it briefly.

3. Handout Pre-posttest Part I.

4. Collect Part I when students finish.

5. Hand out Pre-posttest, Part II.

6. Collect Part II when students finish.

7. Give each student the step method instruction sheet and a response card.
8. Keep some light in the classroom for students to see their sketching material and response cards.

9. You may answer student questions during the presentation.

10. Stop the tape recorder only when instructed to do so. Allow sufficient time for students to sketch each step in the experimental groups and for all students to respond to the slide-quiz questions.

11. Start the program.

12. Encourage written comments and discussion from students.

13. At the end of the program, collect all of the step method instruction sheets and response cards.

14. Give each student a Review Quiz (Part I).

15. Collect Part I of the Review Quiz as each student completes it and give him Part II.

16. Collect Part II of the Review Quiz as each student completes it.

17. Give each student the Student Opinionnaire and Background form to complete.

18. Collect all Student Opinionnaire and Background Forms.

The members of the jury panel from the two community colleges are listed alphabetically as follows:

Mr. Robert Burnham, Instructor of Engineering, Thomas Nelson Community College, Hampton, Virginia.

Mr. Ralph D. Denton, III, Assistant Professor, Drafting and Design, Rappahannock Community College, Glenns, Virginia.

Mr. Jack G. Gardner, Instructor, Drafting and Design, Rappahannock Community College, Glenns, Virginia.
Dr. Thomas F. Kilduff, Professor of Mechanical Engineering Technology, Thomas Nelson Community College, Hampton, Virginia.

After the pilot study, the researcher scored the graphical integration criterion tests (Review Quizzes) and analyzed the results of this test statistically to ascertain its reliability with the Kuder-Richardson Formula 20. From this analysis, it was determined that the instrument possesses a reliability coefficient of +.85. Also, for their critique of the instruments the instructors were asked to scrutinize the learning objectives and researcher constructed tests and compare these to the content of the slide-tape programs. This procedure, the consolidation of these comments, and finally subsequent revisions of the instruments by the researcher functioned to document the content validity of the criterion tests.

The results of the graphical differentiation criterion test, for reasons explained on pages 13 and 14, were not analyzed statistically for purposes of determining the quality of student performances; therefore, no effort was made to document the reliability of this instrument.

At the beginning of the pilot study, as noted previously on page 37, the criterion test for graphical integration was given as a pretest to ascertain previous student knowledge of the subject matter. Due to the fact that no student was able to achieve a score of greater than 15 percentage points, it was decided to eliminate the pretest as a part of the experimental design utilized in the actual experiment. Furthermore, while the student opinionnaire was utilized in the pilot study as described above on the cooperating instructors' procedural
guidelines, the faculty opinionnaire, which was devised just prior to the actual experiment, was not utilized in the pilot study.

Following the completion of the pilot study and the revision of the learning materials, the investigator began making preparation for the coordination of the experiment itself. The remainder of this chapter will encompass a description of the decisions which were included in this coordination leading up to the study:

(1) how the participating schools were selected,
(2) the administration of the study,
(3) the statistical treatment
(4) the research design, and
(5) the pattern of instruction and testing.

Selection of Participating Colleges

After the pilot study was completed and the subsequent revisions were made on the learning activities, it was decided to conduct the study during the last part of the fall quarter, 1978. Instructors at three community colleges agreed to participate in the study. The three colleges were: Chesapeake College, Wye Mills, Maryland; Rappahannock Community College, Glenns, Virginia; and Thomas Nelson Community College, Hampton, Virginia. Since graphical calculus had normally been included in the syllabus for the third (spring) quarter, engineering graphics courses at these schools, it was necessary for the researcher to convince instructors at these schools of the potential merit of including it during the fall quarter. Primarily, this was based on a defensible personal belief that engineering students
can benefit from instruction in graphical calculus prior to their first college calculus course.

Once they had agreed to participate, the investigator contacted the instructors at Chesapeake College and Rappahannock Community College to gather information regarding class size and to ascertain convenient dates that the graphical integration and differentiation units could be included in their courses.

Random assignment of the treatments to the groups at the participating colleges was utilized; however, these schools were chosen primarily for convenience and, therefore, it was impossible for students to be randomly selected. Thus, no effort is made to generalize the inferences of this study beyond the subjects involved. All of the colleges selected for this study are either community or two-year institutions and therefore, the students' goals and the course offerings at each of these institutions were similar.

ADMINISTRATION OF THE STUDY

In describing the work of an experimental researcher, Van Dalen (1962) indicates that the experimental researcher does not merely chronicle past events but that:

Through manipulating an experimental variable under highly controlled conditions, he strives to ascertain how and why a particular condition or event occurs. Experimentation, as distinguished from observation, consists in the deliberate and
controlled modification of the conditions determining an event, and in the observation and interpretation of the ensuing changes in the event itself (p. 241).

In this study every effort was made to control all the conditions which might contribute to a confounding of the findings. A variation of the pilot study outline was utilized by the cooperating instructors as a guideline for the distribution of the learning objectives, step method instruction sheets, self-scoring response cards, review quizzes and opinionnaires. An example copy of the outline can be referred to in Appendix C, page 119. This procedural outline was necessary to ensure the uniformity of the control over the method in which the cooperating instructors administered their learning materials and coordinated them with the slide-tape presentations. Also, these procedures were orally explained to the individual instructors to further reduce their potential for introducing confounding influences. To further reduce this potential, student instructions were included at the beginning and throughout the cassette tape narrations so that, once the students had received the initial handouts from their instructor, he was not required to speak or participate except (a) to stop the cassette tape when instructed by the narrator to do so, and (b) to distribute the criterion tests at the end of the program.

As stated earlier, the independent variable in this study was "sketching practice." During the slide-tape presentations when the step method of instruction was utilized in explaining the example problem on graphical integration, for instance, students in the experimental group were given an opportunity to sketch each separate step. For
each step, a maximum of two minutes was allowed for this activity. The step method format in the control group, meanwhile, did not provide space for sketching practice (i.e., Appendix G, pages 136-138); however, instructors were instructed to keep each step method slide on the screen for two minutes so as not to introduce time as a variable between the methods. Also, for each step of the step method, the narrator in the experimental narration, for example, explained the step and then stated, "Please stop the program and sketch these constructions in the practice space for this step." Meanwhile, for each step method step on the control group narration, the narrator simply stated, "Please study these constructions for a few moments." The sketching practice, therefore, was the only independent variable in the study; and otherwise, the slide tape presentations for experimental and control groups were identical.

In order to eliminate prior study or classroom preparation from entering as a variable, students were given no advance notice regarding the nature of the subject matter to be covered on the day selected for presenting the experimental materials.

Research Design

The research design selected and utilized for this study was a Posttest-only Control Group Design. Gay (1976) explains that "there are two major classifications of experimental designs, single variable designs, which involve one independent variable (which is manipulated) and factorial designs which involve two or more independent variables" (p. 176). According to this description, the technique
for this experiment was that of a single variable design, and the research design itself may be represented graphically as follows:

\[
\begin{align*}
R & \quad X_1 & 0 \\
R & \quad X_2 & 0
\end{align*}
\]

This representation indicates that "one group is receiving a new, or unusual, treatment and one group is receiving the usual treatment." (Gay, 1976, p. 182) More specifically, in this study, treatment \( X_1 \) included manipulation of the independent variable, (sketching practice) as explained previously, and \( X_2 \) symbolizes the control treatment which is the same as \( X_1 \) except without sketching practice. (Please refer to page 10 for a complete description of the experimental and control treatments.)

In the symbolic representation of the design above, the \( R \) indicates that ideally in a true experiment, randomization procedures should include a random selection of subjects and random assignment of the treatments. However, as Gay points out, "to qualify as a true design, at least random assignment must be involved" (p. 179). Gay further describes the posttest-only control group design as a true experimental design and certifies that the combination of random assignment and the presence of a control group serves to control for all sources of invalidity except for mortality. He continues:

Mortality is not controlled for because of the absence of pretest data on subjects. However, mortality may or may not be a problem depending upon the study. If the study is relatively short in duration, for example, no subjects may be lost. In this case the researcher
may report that while mortality is a potential threat to validity with this design, it did not prove to be a threat in his or her particular study since the group sizes remained constant throughout the duration of the study. Thus, if the probability of differential mortality is low, the posttest-only (control group) design can be a very effective design. Of course if there is any chance that the groups may be different with respect to initial knowledge related to the dependent variable, the pretest-posttest control group design should be used. Which design is "best" depends upon the study. If the study is to be short, and if it can be assumed that neither group has any knowledge related to the dependent variable, then the posttest-only design may be the "best" (p. 132).

Having given due consideration to the above discussion, because of the short duration of the administration of the actual experimental and control treatments, the researcher elected to forgo (without ultimately, any disastrous results) a serious concern for the potential threats for differential mortality. With regard to other aforementioned assumptions underlying the proper use of the Posttest-Only Control Group Design, random selection of subjects was impossible due to the existence of intact class groups at the cooperating institutions. However, in order to be consistent with Gay's previously mentioned minimum qualifications for its use as a true experimental design, random assignment of the treatments to the groups was utilized in this study.

Finally, a decision was made to statistically control for any potential initial differences in the intact experimental and control groups by utilizing analysis of covariance as recommended by a number of individual authors including Gay (1976), Kerlinger (1973), Van Dalen (1962), and Huck (1972). The following review is an attempt to develop a rationale for the decision to use analysis of covariance.
Statistical Treatment

In conjunction with the frequent need for educational and psychological researchers to study intact groups, Kerlinger (1973) has cited the usefulness of analysis of covariance.

One of the major difficulties of educational and sociological research is our inability to set up experimental groups at will. Administrators and teachers, for example, are understandably reluctant to break up classes. The investigator often must use classes and other groups intact. Through the analysis of covariance it is often possible to control class or other group differences statistically. For example, three methods of teaching spelling, A₁, A₂, and A₃, are to be tested. The random assignment of subjects is not possible, but it is possible to use intact classes. It is known that intelligence is significantly related to spelling and that the classes will probably differ significantly in intelligence. The methods can be assigned to the intact classes at random, and intelligence test scores can be used as X measures in an analysis of covariance (p. 373).

A similar discourse, which squares with Kerlinger's thoughts on the analysis of covariance, is presented by Huck (1972), who initiates the discussion by asking, "Why use analysis of covariance?" (p. 42) The subsequent response to his own question was pertinent to this researcher's decision to use analysis of covariance to analyze the data in this experiment.

Why use the analysis of covariance? If asked this question, most educational researchers would answer by stating that the covariance procedure compares group means on Y, a dependent (criterion) variable, after these Y's have been "adjusted" for differences between the groups in terms of means on X, the concomitant variable (i.e., the covariate). Such an answer would be correct, but only partially correct. In addition to its ability to control for initial differences between groups, the analysis of covariance increases the sensitivity of the analysis, thus making it more likely that significant differences will be "picked-up" by the statistical test (p. 42).
A number of authors have pointed out that I.Q. scores, pretest scores, and other measures of achievement can be utilized in the analysis of covariance to equate groups. Basically, when test scores are utilized in this way, they conform to Huck's description of a concomitant variable or "covariate" in the discussion above. Gay points out that aptitude tests are frequently used this way in educational research.

Their most common use is probably to equate groups which are going to be compared on achievement after receiving different treatments. If groups are different in aptitude to begin with their final achievement differences might be attributable to this initial difference rather than differences in treatment effectiveness. Aptitude scores can be used to equate groups . . . through a statistical procedure called analysis of covariance (pp. 101-102).

Among a number of tests listed in this same reference, Gay recommends the Differential Aptitude Tests, a battery of individual aptitude tests which measure aptitude for mechanical reasoning, verbal reasoning, abstract reasoning, clerical speed, etc., for use as covariate measures. In conjunction with the decision to use the analysis of covariance statistical technique, the procedures for this study included the use of student scores on the Abstract Reasoning and the Verbal Reasoning tests of the Differential Aptitude Test as covariates. These two particular tests were selected by the researcher because of (a) the nature of the subject matter presented in the instructional materials (abstract reasoning) and (b) students were in fact required to interpret printed materials (Verbal Reasoning) relevant to the learning objectives, step method instruction sheets, and the other student handouts previously described in this report.
The reader will recall that (pages 13 and 14) the data gathered from the graphical differentiation criterion tests were not analyzed statistically for purposes of discerning the quality of student performance, but were only utilized for determining student preferences and opinions. The reason, as explained earlier, for not analyzing these tests statistically was due to the fact that the chordal method procedure for graphical differentiation is essentially the reverse of the graphical integration procedure which all of the students had been exposed to in the first slide presentation. Statistical analysis of the graphical differentiation criterion test data would perhaps, therefore, have been subject to a confounding influence by the knowledge that students had gleaned from the graphical integration treatment. Therefore, only the data gathered from the graphical integration criterion test (Review Quiz) was analyzed statistically to ascertain the superiority of the two treatments.

Finally then, these graphical integration criterion test scores were covaried, using student scores from the Verbal Reasoning and Abstract Reasoning Tests of the Differential Aptitude Test Battery as covariates, by the statistical procedure known as analysis of covariance in order to ascertain the superiority of the treatments in this study.

No attempt was made to analyze any of the data gathered from the slide quiz questions via the self-scoring response cards. These questions, as specified previously, were included in the slide presentations purely to sustain student interest and to provide
immediate reinforcement to their understanding of the material as they viewed the program.

**Pattern of Instruction and Testing**

The instructional packages in this experiment were designed to be administered in a single four-hour laboratory period in a beginning engineering graphics course. While the pattern of instruction and testing is implied on the Instructor's Procedural Checklist (Appendix C, page 119) a flowchart (Figure 2) was designed to graphically represent the sequence of the procedures explained on that checklist.

**FIGURE 2**

PROCEDURE FOR ADMINISTRATION OF A SLIDE-TAPE PRESENTATION
A second flowchart shown in Figure 3 offers a better perspective on the overall plan of the study. This diagram clarifies the chronological sequence of the events and the time lapses between the administration of the criterion tests, the retention tests, and Differential Aptitude Tests.

**Four-Hour Time Block**

- Slide program on Graphical Integration (50 minutes)
- Criterion test (review quiz) on Graphical Integration (50 minutes)
- 20 minute break
- Slide program on Graphical Differentiation (50 minutes)
- Criterion test (review quiz) on Graphical Differentiation (50 minutes)
- Administration of student Opinionnaire (20 minutes)

**Two-Hour Time Block**

- Retention test on Graphical Integration (60 minutes)
- Differential Aptitude Tests: Verbal Reasoning (30 minutes), Abstract Reasoning (30 minutes)

**FIGURE 3**

**CHRONOLOGICAL SEQUENCE OF THE STUDY**
Based upon the randomly assigned treatments (i.e., experimental or control), the graphical integration slide presentation was shown first in all of the participating classes. Table 1 illustrates the pattern of the randomly assigned treatments pertaining to each of the groups at the participating schools. There were a total of four classes of students who participated in the study—two groups from Thomas Nelson and a single group from each of the other participating colleges.

**TABLE 1**

<table>
<thead>
<tr>
<th>Colleges</th>
<th>Group</th>
<th>1st Treatment</th>
<th>2nd Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas Nelson</td>
<td>A</td>
<td>Control</td>
<td>Experimental</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>Chesapeake</td>
<td>C</td>
<td>Control</td>
<td>Experimental</td>
</tr>
<tr>
<td>Rappahannock</td>
<td>D</td>
<td>Experimental</td>
<td>Control</td>
</tr>
</tbody>
</table>

The cooperating instructors at each of these institutions were as follows:

Mr. Ralph D. Denton, III, Assistant Professor, Drafting and Design, Rappahannock Community College, Glenns, Virginia.

Mr. Jack Gardner, Instructor, Drafting and Design, Rappahannock Community College, Glenns, Virginia.

Dr. Ralph Horne, Professor and Chairman, Drafting and Design, Chesapeake College, Wye Mills, Maryland.
Mr. Al Martin, Assistant Professor of Drafting
and Design, Thomas Nelson Community College, Hampton, Virginia.

All of the completed materials were returned by the cooperating
instructors to the researcher at the completion of the study. In
order to maintain a high degree of uniformity, a grading key was
constructed and utilized by the researcher to score the graphical
integration criterion test. The Verbal Reasoning and Abstract
Reasoning tests were also marked by using the scoring forms avail­
able from the publisher (Psychological Corporation) of these tests.
Utilizing the procedures recommended in the Statistical Package for
the Social Sciences (SPSS), these data were then tabulated and
recorded on IBM Keypunch cards and sent to the computer processing
center at Thomas Nelson Community College to be analyzed.

SUMMARY

In the introduction to this chapter, an observation of authors
Baker and Shutz (1972) is quoted regarding the difficulty of translatir.
much educational research into practically usable forms. This kind of
awareness prompted these writers to prepare a kind of programmed text
which would equip the reader not only to more ably produce useful
instructional products but to also provide him with perhaps a more
mature understanding of the importance that research must play in
reducing uncertainty about natural phenomena and the development
of instructional products (p. xii).

The philosophies of writers Baker and Shutz are hopefully
indicative of the state of the art in educational research. As stated
previously, this writer believes these writers are recommending that educational researchers should be utilizing existing research tested instructional formats and/or techniques and refining, combining, further developing, and reexamining these strategies to determine their instructional worth.

This experiment, as stated earlier, was basically an effort to examine the combined features of several research proven instructional formats which were significant in terms of either student success or preference as instructional media.

This chapter provides a discussion of the units of instruction and the rationale for their choice, the development of the learning objectives for these units, and the learning activities which were developed for this study. A pilot study was conducted to improve these learning activities prior to the administration of the experiment itself. A discussion of the colleges selected to test the materials, the posttest-only control group research design, and the analysis of covariance statistical procedure is also provided. The Abstract Reasoning and Verbal Reasoning tests of the Differential Aptitude Test battery were selected as a source for covariate measures for use in this statistical procedure. Finally, in the SPSS computer program for analysis of covariance, regression procedures are used to remove variation in the dependent variable due to the covariates, and the results of these analyses are reported in Chapter 4.
Chapter IV

ANALYSIS OF THE DATA

The guidelines recommended by Nie, et al. in the second edition of the Statistical Package for the Social Sciences (SPSS) were utilized to analyze the data collected for this experiment. The analysis of variance (ANOVA) subprogram for covariance was used to evaluate the first two hypotheses:

First research hypothesis: The students who have been shown the slide-tape presentation, complete with slide-quiz questions and step method with color and with sketch format will score higher on the criterion test than students who have seen the slide-tape presentations with slide-quiz questions and step method with color format—without the sketch format.

\[ H_{01} \text{ (Null Form): There is no significant difference in the initial achievement favoring the experimental group.} \]

Second research hypothesis: The students who have been shown the slide-tape presentations, complete with slide-quiz questions and step method with color and with sketch format will score higher on the retention test than students who have seen the slide-tape presentations with slide-quiz questions and step method with color—but without the sketch format.

\[ H_{02} \text{ (Null Form): There is no significant difference in retention favoring the experimental group.} \]
The four remaining hypotheses regarding student or faculty preferences as listed below were analyzed on the basis of mean and standard deviation scores on each of the responses on the student and faculty opinionnaires.

Third research hypothesis: The students will prefer the slide-tape presentations complete with the step method in color and sketch format over the slide-tape presentations with the step method in color—but without the sketch format.

$H_03$ (Null Form): There is no significant difference in the students' preference favoring the experimental method of presentation.

Fourth research hypothesis: The cooperating instructors will prefer the slide-tape presentations complete with the step method in color and with the sketch format over the slide-tape presentations with the step method in color—but without the sketch format.

$H_04$ (Null Form): There is no significant difference in the instructors' preference favoring the experimental method of presentation.

Fifth research hypothesis: The instructors will prefer slide presentations of graphical methods (such as the chordal method) complete with slide quiz questions, step method with color instruction sheets, criterion referenced review quizzes, and taped narrations over the traditional lecture-chalkboard method of instruction as a means of initially introducing students to the concepts of differentiation and integration.
$H_{05}$ (Null Form): There is no significant difference in the instructors' preference favoring the experimental method, as presented in this study, versus the traditional method of instruction when initially introducing students to the math concepts of differentiation and integration.

Sixth research hypothesis: Students with previous formal classroom experience with differentiation and integration will prefer to have first been shown the slide-tape presentations on graphical integration and differentiation prior to that classroom experience.

$H_{06}$ (Null Form): There is no significant difference in the students' (with previous calculus experience) preference in favor of first receiving the experimental method of instruction as compared to their initial math (calculus) class experience.

With regard to the last four of these hypotheses, a graphical illustration of the mean and standard deviation scores on the student and faculty opinionnaire statements are shown on Figures 13 and 14 and further discussed on pages 88-89 and 95-96.

In this study, initial achievement, or the extent to which students were able to accomplish the learning objectives for graphical integration, was measured in terms of their scores on the criterion test for that unit of instruction. Student scores on the Verbal Reasoning and Abstract Reasoning batteries of the Differential Aptitude Test were introduced to adjust for differences in student ability levels. This was accomplished through the statistical procedure known as the analysis of covariance. While the rationale underlying the decision to use this statistical procedure is delineated on pages 54-56, the authors of the Statistical Package for the Social Sciences offer an
appropriate summary for analysis of covariance as it relates to the statistical method utilized in this study to evaluate the data regarding $H_{o1}$ and $H_{o2}$:

Most commonly, metric covariates (I.Q. scores, aptitude test scores, etc.) are inserted into a design to remove extraneous variation from the dependent variable, thereby increasing measurement precision. In such applications, the effects of the nonmetric factors (treatments) are of primary concern. Regression procedures are used to remove variation in the dependent variable due to one or more covariates, and a conventional analysis of variance is then performed on the "corrected" scores (Nie, et al., 1975, p. 409).

As described earlier (page 13) the data collected from the graphical integration criterion tests and retention tests are reported here two ways as follows:

(1) Using the classroom as the unit of analysis and

(2) Using the individual as the unit of analysis.

More specifically, in the case of using (1) the classroom (an intact class or group) as the unit of analysis, the performance of each experimental group was separately compared to the performance of each control group in this study.

Furthermore, with regard to utilizing (2) the individual as the unit of analysis in this study, an analysis was made comparing the performances of all experimental subjects to the performances of all control subjects as though these were separate intact groups. As recommended earlier, the results of these comparisons should be interpreted by the reader with due consideration to the qualities of each of the methods.
The results of randomly assigning the experimental and control treatments to the intact groups at the individual colleges are listed in Table 2. The number of subjects in each group is also included in Table 2, and it should be noted that there were two separate intact groups of students at Thomas Nelson while each of the other colleges had only a single group available to participate in the study.

The mean and standard deviation values on the scores of the students from each of the participating colleges on the Verbal Reasoning and Abstract Reasoning (Differential Aptitude Tests) are diagrammed in Figure 4. It is interesting to note that although random selection of students was not possible in this experiment, the mean scores of each group on these tests lends credibility to the corresponding equality of the participating groups, at least on the basis of abstract and verbal reasoning ability. Using analysis of covariance, the mean scores of each of the groups on these aptitude tests were utilized to adjust the group means on the graphical integration review quiz (criterion test) and retention test.

<table>
<thead>
<tr>
<th>COLLEGE</th>
<th>TREATMENTS</th>
<th>NUMBER OF SUBJECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chesapeake (Ches.C)</td>
<td>Control</td>
<td>14</td>
</tr>
<tr>
<td>Rappahannock (RCC)</td>
<td>Experimental</td>
<td>14</td>
</tr>
<tr>
<td>Thomas Nelson (TNCC)</td>
<td>Experimental</td>
<td>15</td>
</tr>
<tr>
<td>Thomas Nelson (TNCC)</td>
<td>Control</td>
<td>18</td>
</tr>
</tbody>
</table>

TABLE 2: RESULTS OF THE RANDOM ASSIGNMENT OF TREATMENTS TO GROUPS AT PARTICIPATING COLLEGES AND NUMBER OF SUBJECTS IN EACH GROUP
FIGURE 4: COMPARISON OF GROUP MEANS ON ABSTRACT REASONING AND VERBAL REASONING DIFFERENTIAL APTITUDE TESTS
ANALYSIS OF CRITERION TEST (REVIEW QUIZ) SCORES

Using the intact group as the unit of analysis, comparisons of the mean scores of each of these intact groups on the graphical integration Criterion Test (Review Quiz) are depicted in Figure 5. Figures 6 and 7 repeat the graphs of the individual college criterion test mean scores for the reader's convenience and also include the analysis of covariance report of the test data for the groups being compared.

It was mentioned earlier on page 67 and depicted graphically in Figure 4 that the participating groups evidenced very similar abilities on the Verbal Reasoning and Abstract Reasoning Differential Aptitude Tests which were used as covariates in this study. The similarity of these group means would suggest perhaps that not much was gained then by using these aptitude scores as covariates. For this reason the researcher felt that it is important to note the technical procedure utilized by the SPSS Computer Program to analyze the review quiz scores and covariates. According to Nie (1975, p. 409) in the SPSS computer program for analysis of covariance, regression procedures are used to remove variation in the dependent variable due to the abstract reasoning and verbal reasoning covariates, and then a conventional analysis of variance is performed on the "corrected" scores. The program also prints out an analysis of variance which has corrected for and removed the "combined" influence of both of the covariates in this case.
The SPSS subprogram ANOVA for analysis of covariance provides an optional statistic, that of Multiple Classification Analysis. This program yields the multiple R statistic, which can be utilized (multiple R squared) to determine the exact proportion or percentage of the variation in the test scores that can be explained by the additive influence of the treatments and covariates. A short discussion will be provided here to better enable the reader to interpret Figures 6 through 12.

The "Explained" sums of squares in Figures 6-12 is precisely the sum of (a) "Combined VR and AR" and (b) "Main Effects (Treat)." In Figure 6, for example, the sums of squares in the "Explained" row is 534.006; in other words, 345.023 + 188.983 = 534.006. This "Explained" sums of squares is directly and uniquely related to multiple $R^2$, which is also reported in Figures 6-12. A brief digression to explain the numerical relationship of Multiple $R^2$ and the "Explained" sums of squares is given by the following F test statistic which indicates that they should in fact both be statistically tested by the same F ratio (Nie, 1975, p. 335).

\[
F = \frac{SS_{reg}/K}{SS_{res}/N-K-1} = \frac{R^2 / K}{(1-R^2) / (N-K-1)}
\]
The numerical relationships of the tabled numerical values in Figures 6 through 12 can be more easily comprehended, as an example in this case, by using the values in Figure 6 and substituting them in the above equation. The purpose of showing these figures is to demonstrate the logic for placing multiple $R^2$ adjacent to the "Explained" variances in Figures 6-12.

Substituting the values from Figure 6 into the equation above we have:

$$
\frac{SS_{\text{reg}} / K}{SS_{\text{res}} / (N-K)} = \frac{534.006 / 3}{687.302 / 25} = 6.47
$$

and

$$
\frac{R^2 / K}{(1-R^2) / (N-K-1)} = \frac{.437 / 3}{(1-.437) / 25} = 6.47
$$

The multiple $R^2$ value is therefore uniquely related to the "Explained" sums of squares, and it is therefore listed in Figures 6 through 12 adjacent to the "Explained" variances. In the example above, one may conclude from the multiple $R^2$ value of .437 that the difference in the treatments and the adjustments for the covariates accounted for 43.7 percent of the differences in the test score analysis. In each of the Figures 6 through 12, the multiple $R^2$ value will be included along with the significance of $F$ test in order to in fact verify the reported results.

The SPSS program was designed to cope with unequal sample sizes, and derived $F$ ratios from the analysis were compared and checked with
appropriate tables to establish their significance. The .05 and .01 levels of significance were established as the probabilities required to reject the null hypotheses. Table 3 provides a list of abbreviations and symbols which apply to the interpretation of Figures 6-12.

**TABLE 5**

An interesting and significant difference at the .05 level was found between aptitude measures of the Thomas Nelson experimental and control groups on the basis of combined verbal and abstract reasoning abilities. As indicated in Figure 6, an F ratio of 4.475 was computed for the differences in these aptitudes. This was compared to a table of F statistics by Li (1969, p. 603). The tabled F value at the .05 level of significance was 3.327. Since the F value of 4.475 was greater than the tabled value of 3.327, it was concluded that a significant difference in the initial verbal and abstract reasoning abilities.
FIGURE 5: COMPARISON OF CRITERION TEST (REVIEW QUIZ) MEAN SCORES ON GRAPHICAL INTEGRATION BY SCHOOL
of the experimental and control groups at Thomas Nelson existed at the .05 probability level.

After these initial differences in ability were statistically removed, the SPSS program then computed an F ratio indicative of the actual effects of the treatments in the experiment. As indicated in Table 6 adjacent to "main effects (Treat)," this F value was 9.708. At the .01 probability level, the tabled F value for 1 and 29 degrees of freedom was 7.5976 (Li, 1969, p. 607). It was therefore concluded that at Thomas Nelson Community College, the experimental treatment group performed significantly better than the control group at the .01 level on the graphical integration criterion test.

With regard to the previously cited differences in combined abstract and verbal reasoning abilities of the groups at Thomas Nelson College, Figure 6 shows that a similar difference, except at the .01 level of significance was also found between the Thomas Nelson experimental group and the Chesapeake control group. The computed 6.275 F statistic shown in Figure 6 was compared to a tabled F value of 5.568 at the .01 level of significance, thus resulting in the conclusion that a significant difference did exist in the initial ability levels of these groups.

Again, after these initial differences were statistically controlled for, an F ratio was computed for purposes of ascertaining the actual effects of the treatments. As shown in Figure 6, this computed F value was 6.874. Upon following the procedure described above for comparing this figure to the tabled F values, it was determined that
### ANCOVA Table for TNCC Experimental and TNCC Control Groups

<table>
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<th>M.S.</th>
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<th>Signif. of F</th>
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<td>2.950</td>
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<td>NS</td>
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<tr>
<td>Combined VR and AR</td>
<td>198.825</td>
<td>2</td>
<td>99.413</td>
<td>4.475</td>
<td>* .05 level</td>
</tr>
<tr>
<td>Main Effects (Treat)</td>
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<td>1</td>
<td>215.671</td>
<td>9.708</td>
<td>** .01 level</td>
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<tr>
<td>Explained ($R^2$=.392)</td>
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<td>138.166</td>
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### ANCOVA Table for TNCC Experimental and Ches.C Control Groups

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<td>** .01 level</td>
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<tr>
<td>Total</td>
<td>1221.308</td>
<td>28</td>
<td>43.618</td>
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</tr>
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</table>

**Figure 6:** Comparison of Thomas Nelson Experimental Group to Thomas Nelson and Chesapeake Control Groups on the Graphical Integration Criterion Test (Review Quiz) Scores
the experimental treatment was more effective at the .05 level at Thomas Nelson than the control treatment was at Chesapeake College.

Again using the intact groups as the unit of analysis, comparisons of the performances of the experimental group at Rappahannock Community College were made to those of the control groups at Thomas Nelson and Chesapeake Colleges. These are shown in Figure 7. The reader may find it interesting to note that in both of these comparisons significant differences were found at (a) the .05 level when group aptitudes on verbal reasoning was compared and (b) the .01 level when the combined effects of both the verbal and abstract reasoning aptitudes were statistically compared.

After these group differences were controlled for and the main effects of the treatments were computed, significant differences favoring the experimental treatment were found to exist when comparing the Rappahannock experimental group to (a) the Thomas Nelson control group at the .01 level and (b) the Chesapeake control group at the .05 level. The corresponding F values may be reviewed in the Figure 7 analysis of covariance tables.

Figure 8 depicts a graphical comparison of the mean score of the performances of all experimental subjects to those of all the control subjects on the graphical integration review quiz. The data were analyzed utilizing the individual as the unit of analysis rather than intact groups, and the analysis of covariance data as well as the resulting F ratios and significance probabilities are also shown in Figure 8.
FIGURE 7: COMPARISON OF RAPPAHANNOCK EXPERIMENTAL GROUP TO THOMAS NELSON AND CHESAPEAKE CONTROL GROUPS ON THE GRAPHICAL INTEGRATION CRITERION TEST (REVIEW QUIZ) SCORES
FIGURE 8: COMPARISON OF ALL EXPERIMENTAL AND CONTROL SUBJECTS ON THE GRAPHICAL INTEGRATION CRITERION TEST (REVIEW QUIZ) SCORES
The analysis of covariance of these data indicated a significant difference at the .01 level when differences in verbal reasoning abilities were corrected for, at the .05 level when abstract reasoning variations were corrected for, and at the .01 level of significance when the combined effects of these group differences were analyzed.

Regarding the main effects of the treatments, the group analysis provided the largest source of variance in this experiment, an F ratio of 16.985 when the combined effects of the verbal and abstract reasoning differences were corrected for. The reader may find it interesting to note, as indicated in Figure 5, that both experimental groups scored an identical mean of 20.57 out of 26 possible points on the review quiz. Compared to the overall control group average of 19.20, this provided a 5.3 percent difference in group means. The 16.985 F value was compared at the .01 level of significance to the tabled F ratio of 7.113 for 1 and 57 degrees, and it was concluded that the experimental group scored significantly higher on the graphical integration criterion test than the control group. The reader may also want to review the variances reported in Figure 8, where the verbal reasoning and abstract reasoning have individually been corrected for and, as noted above, they were each also significant at the .01 and .05 levels respectively. As suggested previously, it is recommended that while these data have been reported by utilizing both (a) the intact classes and (b) the individuals as the unit of analysis that they be interpreted with all due regard to the merits of the methods.
ANALYSIS OF THE RETENTION TEST SCORES

The same analysis of covariance statistical procedure used on the criterion tests was also utilized for the retention test analysis. The retention test mean scores for each group are displayed in Figure 9. Of the four groups, students in the experimental group at Thomas Nelson had the highest mean score—19.5 out of 26 possible points or 75 percent. The experimental group at Rappahannock had the second highest retention test average, a score of 18.7 points or 72 percent. The Thomas Nelson and Chesapeake Colleges control groups scored percentages of 68.9 percent and 67.2 percent respectively.

Graphical comparisons of the retention test performances and the analysis of covariance reports for each of the possible comparisons between the experimental and control groups are reported here using exactly the same technique that was used previously for the criterion test reports. For the convenience of the reader, Figure 10 includes that part of Figure 9 which is immediately related to the groups being compared in the analysis of covariance tables under the graph of the mean scores.

As indicated in Figure 10, comparison of the Thomas Nelson experimental and control group performances on the retention tests revealed a significant difference at the .01 level. The tabled value for 1 and 29 degrees of freedom at the .01 probability level was 7.5976—compared to the computed value of 10.829. Neither of the variances due to group differences in verbal and/or abstract reasoning abilities were found to be significant in the computer analysis.
FIGURE 9: COMPARISONS OF RETENTION TEST MEAN SCORES ON GRAPHICAL INTEGRATION BY SCHOOL
### ANCOVA Table for TNCC Experimental and TNCC Control Groups

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<td>Abstract Reasoning</td>
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<td>0.361</td>
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<tr>
<td>Combined VR and AR</td>
<td>30.938</td>
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<td>15.469</td>
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<td>NS</td>
</tr>
<tr>
<td>Main Effects (Treat)</td>
<td>282.764</td>
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<td>282.764</td>
<td>10.829</td>
<td>** .01 level</td>
</tr>
<tr>
<td>Explained ($R^2=.293$)</td>
<td>313.702</td>
<td>3</td>
<td>104.567</td>
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<td>* .05 level</td>
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<td>Total</td>
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### ANCOVA Table for TNCC Experimental and Ches.C Control Groups

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<td>Main Effects (Treat)</td>
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<td>474.448</td>
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<td>Explained ($R^2=.603$)</td>
<td>606.775</td>
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<td>201.925</td>
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<td>399.534</td>
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<td>35.904</td>
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**FIGURE 10:** COMPARISON OF THOMAS NELSON EXPERIMENTAL GROUP TO THOMAS NELSON AND CHESAPEAKE COLLEGE CONTROL GROUPS ON GRAPHICAL INTEGRATION RETENTION TEST SCORES
Comparison of the Thomas Nelson experimental group to the Chesapeake control group showed evidence of significant variances due to combined verbal and abstract reasoning differences at the .05 probability level.

After the analytical adjustments were made for these aptitude differences, the resulting F ratio of 29.688 was compared to the tabled value of 7.5976 at the .01 level for 1 and 25 degrees of freedom, thus establishing a significance in retention favoring the Thomas Nelson experimental group.

Figure 11 shows the covariance report for the comparison of the Rappahannock experimental group to the control groups at Thomas Nelson and Chesapeake Colleges. Although the retention test performance of the Rappahannock experimental group was not found to be significantly better than that of the Thomas Nelson control group, it was significant when compared to the Chesapeake College control group performance. In fact, after significant differences (at the .01 level) due to (a) verbal reasoning and (b) combined verbal and abstract reasoning were corrected for, a significant difference in the main treatment effects was found to exist at the .01 level of probability. The reader may wish to refer to Figure 11 to review the variances and F ratios associated with this finding.

A comparison of the retention test performances of all of the experimental subjects to those in the control groups yielded mean scores of 73.6 percent versus 68.2 percent in favor of the experimental subjects. These data may be reviewed in Figure 12. The first two F ratios computed for the analysis in Figure 12 include corrections
### ANCOVA Table for RCC Experimental and TNCC Control Groups

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<tr>
<td>Combined VR and AR</td>
<td>37.778</td>
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<td>18.889</td>
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<td>Main Effects(Treat)</td>
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<td>2.377</td>
<td>NS</td>
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<tr>
<td>Explained(R^2=.121)</td>
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<td>32.966</td>
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<td>Total</td>
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### ANCOVA Table for RCC Experimental and Ches.C Control Groups

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**FIGURE 11: COMPARISON OF RAPPAHANNOCK EXPERIMENTAL GROUP TO THOMAS NELSON AND CHESAPEAKE COLLEGE CONTROL GROUPS ON THE GRAPHICAL INTEGRATION RETENTION TEST SCORES**
for verbal reasoning and abstract reasoning. These were 2.531 and 0.681 respectively. When these data were compared to the critical region for five percentage points of the F distribution for 1 and 57 degrees of freedom, neither of these ratios were found to be statistically significant.

When the combined effects of the variances of the verbal and abstract reasoning covariates were removed from the retention test scores, however, the computer yielded an F ratio of 3.553. At the .05 confidence interval, the critical region on the F distribution for 2 and 57 degrees of freedom begins at 3.162. The computed value is larger than this tabled value, thus resulting in the conclusion that this combined influence significantly affected the dependent variable (retention) at the five percent probability level. Regression procedures were used, as stated on page 66, to remove the variation in the dependent variable (retention) due to the effects of these covariates and a conventional analysis of covariance was performed on the "corrected" scores. The results of this procedure is reported in Figure 12 under "main effects (treat)." The F ratio of 18.412 was compared to a tabled value of 7.113 at the .01 level for 1 and 57 degrees of freedom, and found to be significant. It was therefore concluded that these data infer a significantly greater (.01 level) retention ability favoring the experimental treatment used in this study.
FIGURE 12: COMPARISON OF ALL EXPERIMENTAL AND CONTROL SUBJECTS ON THE GRAPHICAL INTEGRATION RETENTION TEST SCORES
ANALYSIS OF STUDENT AND FACULTY OPINIONNAIRES

Of the six hypotheses generated for this study, the purpose of four of them was to ascertain faculty and/or student preference regarding the experimental and control methods of instruction. More specifically, as stated on page 64, null hypotheses $H_0^4$ and $H_0^5$ were intended to evaluate faculty opinion and hypotheses $H_0^3$ and $H_0^6$ were utilized for evaluating student attitudes. Separate opinionnaires were constructed and may be reviewed in Appendix O (Student Opinionnaire) and Appendix Q (Faculty Opinionnaire). Both of the opinionnaires were designed to give the respondents a series of closed statements to which they could either agree, be neutral, or disagree according to the following rating continuum: 5 - agree; 4 - somewhat agree; 3 - neutral or no opinion; 2 - somewhat disagree; 1 - disagree.

As specified in the diagram depicting the chronological sequence for the study (Figure 3, page 59), the student opinionnaire was administered after students had completed both slide-tape programs on graphical integration and graphical differentiation and the criterion tests (review quizzes) which accommodated measurement of the objectives in each unit of instruction. This procedure was followed so that all students would be given an opportunity to participate as a member of both a control and experimental section prior to responding to the opinionnaire. The responses of the students from the three participating institutions were pooled for this analysis. Each of the items on the student opinionnaire are discussed below with Figure 13 depicting a graphical display of the mean and standard deviation of each item.
Item 1: I prefer the slide program including the step method with sketching practice to the slide program without sketching practice.

(n=61)

Item 2: The slide program which included the step method instruction sheet with sketching practice and slide-quiz questions with response card was more interesting than a lecture-chalkboard method of presentation.

(n=61)

Item 3: The slide program which included the step method instruction sheet without sketching practice and the slide-quiz questions with response card was more interesting than a lecture-chalkboard method of presentation.

(n=61)

Legend:

Mean and Standard Deviation

5-Agree
4-Somewhat Agree
3-Neutral or 2-Somewhat Disagree
1-Disagree

FIGURE 13: SUMMARY OF STUDENT OPINIONNAIRE
Item 4: The review quiz at the end of each slide program provided a thorough review of the information presented.

(n=61)

Item 5: Slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cards, taped narrations, and review quizzes should become a permanent part of drafting and engineering graphics courses.

(n=61)

Item 6: I would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in a calculus course.

(n=30)

Legend:

Mean and Standard Deviation

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<th>Mean</th>
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<tr>
<td>5</td>
<td>Agree</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat Agree</td>
<td>No Opinion</td>
</tr>
</tbody>
</table>

FIGURE 13: SUMMARY OF STUDENT OPINIONNAIRES (cont.)
Item No. 1: I prefer the slide program including the step method with sketching practice to the slide program without sketching practice.

The pooled responses on this item averaged 3.98 and had a standard deviation of 1.34, indicating that participants in the study showed a definite preference for the instructional slide-tape programs which provided space for students to practice sketching the sequential steps on the step method instruction sheets.

Item No. 2: The slide program which included the step method instruction sheet with sketching practice and slide-quiz questions with response card was more interesting than a lecture chalkboard method of presentation.

The students rated this item with a mean of 3.17 and a standard deviation of 1.54. These figures suggest that the students were basically undecided and that if anything, they found the slide-tape programs with sketching practice only slightly more interesting than a traditional lecture chalkboard method of presentation.

Item No. 3: The slide program which included the step method instruction sheet without sketching practice and the slide-quiz questions with response card was more interesting than a lecture-chalkboard method of presentation.

The mean score of 2.375 and standard deviation of 1.36 on this item indicates that the students actually rated a lecture-chalkboard presentation in preference to the control method. A comparison of Item No. 2 and Item No. 3 interestingly suggests that while students showed only a slight favoritism for the experimental method over a traditional lecture-chalkboard presentation, they did, in fact, favor the experimental method more decisively than the control method.
Item No. 4: The review quiz at the end of each slide program provided a thorough review of the information presented.

Item No. 4 received a mean of 3.95 and a standard deviation of 1.23 indicating that students basically agreed that the review quizzes (criterion tests) did provide a thorough review of the concepts presented in the experimental and control slide-tape presentations.

Item No. 5: Slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cards, taped narrations, and review quizzes should become a permanent part of drafting and engineering graphics courses.

The students rated this statement with a mean of 3.74 and a standard deviation of 1.39. By generally agreeing with the statement, the students indicated that the experimental instructional strategy should become a permanent part of drafting and engineering graphics courses.

Item No. 6: I would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in a beginning calculus course.

Responses on this statement were limited to only those students who had previously taken a calculus course. Item 6 was rated with a pooled mean of 4.07 and a standard deviation of 1.14. The mean score of 4.07 indicates that the students felt that it would be advantageous to have been exposed to graphical integration and differentiation prior to taking a first calculus course.
Null hypotheses $H_0^3$ and $H_0^6$ regarding student preferences were analyzed on the basis of the responses to student opinionnaire items Number 1 and 6 respectively. The conclusions resulting from these evaluations are reported in the summary to this chapter and also in Chapter 5. Also, recommendations made by students under "additional comments or suggestions" are listed in Appendix P.

ANALYSIS OF FACULTY OPINIONNAIRE

The following discussion describes the faculty responses to the statements on the faculty opinionnaire. Figure 14 shows a diagram of the mean and standard deviation scores adjacent to the statements which the cooperating instructors responded to on the opinionnaire.

**Item No. 1:** I prefer the slide program including the step method with sketching practice to the slide program without sketching practice.

The participating faculty members rated Item 1 with a mean 4.75 and a standard deviation of .433. These figures suggest a very positive faculty preference toward the program which included the step method sheets that provided space for sketching practice on the material presented in each step versus the step method sheets which did not provide this space.

**Item No. 2:** I prefer the slide-tape presentations complete with the step method in color with sketch format as the instructional method by which to best initially present the math concepts of differentiation and integration over the traditional lecture-chalkboard method of instruction.
The pooled responses of the faculty members to Item 2 averaged for a mean of 4.25 and a standard deviation of .433. This indicates an agreement on the part of the faculty members that perhaps the best way to introduce students to the concepts of differential and integral calculus is to present the concepts graphically by utilizing slide-tape presentations complete with the step method sheets in color which provide space for practice sketching on each sequential step.

Item No. 3: The photographic slides used were an effective means of presenting the subject material.

The faculty members rated Item 3 with a mean of 4.5 and a standard deviation of .5. The 4.5 mean suggests an affirmative agreement on the statement that the photographic slides utilized in this study were in fact, an effective means of presenting the concepts of graphical integration and graphical differentiation.

Item No. 4: Each slide series was comprehensive enough for the student to meet the objective(s) of the unit.

A mean of 4.25 and a standard deviation of .433 on Item 4 indicated that the cooperating instructors did agree that students were able to meet the objectives of each unit as a result of being exposed to the slide-tape programs utilized in this experiment.

Item No. 5: Slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cards, taped narrations, and review quizzes should be incorporated as a permanent part of drafting and engineering graphics courses.
This item received a mean rating of 4.75 and a standard deviation of .433 which when considered in conjunction with the pooled responses to Items 2, 3, and 4 is again a very favorable inference on the part of the faculty members that the experimental method could be advantageously included as a permanent part of instruction in drafting and engineering graphics courses.

**Item No. 6:** The example curves utilized on the step method instruction sheets were effective in illustrating the practical aspects of the topics covered.

Faculty members rated this item with a mean of 4.25 and a standard deviation of .829. This mean verifies the instructors' agreement that the curves selected for illustrating the graphical integration and differentiation concepts were instructionally effective examples.

**Item No. 7:** Less class time is consumed when using slide presentations, complete with review quizzes and taped narrations, than by the traditional lecture-chalkboard method of instruction.

Faculty response to Item 7 yielded a pooled mean of 4 and a standard deviation of .707. The instructors therefore agreed that less class time is consumed when using slide presentations with review quizzes and taped narrations than by the traditional lecture-chalkboard method of instruction.

**Item No. 8:** I personally would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in my first calculus course.
Item 1: I prefer the slide program including the step method with sketching practice to the slide program without sketching practice.

Item 2: I prefer the slide-tape presentations complete with the step method in color with sketch format as the instructional method by which to best initially present the math concepts of differentiation and integration over the traditional method of instruction.

Item 3: The photographic slides used were an effective means of presenting the subject material.

Item 4: Each slide series was comprehensive enough for the student to meet the objective(s) of the unit.

Mean and Standard Deviation

<table>
<thead>
<tr>
<th>Opinion Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-Agree</td>
</tr>
<tr>
<td>4-Somewhat Agree</td>
</tr>
<tr>
<td>3-Neutral or No Opinion</td>
</tr>
<tr>
<td>2-Somewhat Disagree</td>
</tr>
<tr>
<td>1-Disagree</td>
</tr>
</tbody>
</table>

FIGURE 14: SUMMARY OF FACULTY OPINIONNAIRE
Item 5: Slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cards, taped narrations, and review quizzes should be incorporated as a permanent part of drafting and engineering graphics courses. (n=4)

Item 6: The example curves utilized on the step method instruction sheets were effective in illustrating the practical aspects of the topics covered. (n=4)

Item 7: Less class time is consumed when using slide presentations, complete with review quizzes and taped narrations, than by the traditional lecture-chalkboard method of instruction. (n=4)

Item 8: I personally would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in my first calculus course. (n=4)

Legend:

Mean and Standard Deviation Opinion Scale
1-Disagree 2-Somewhat Disagree
2-Somewhat Agree 3-Neutral or No Opinion
3-Agree 4-Somewhat Agree

FIGURE 14: SUMMARY OF FACULTY OPINIONNAIRE (cont.)
A mean score of 4.5 and standard deviation of .50 on this statement indicates that faculty members strongly agree that it would be instructionally beneficial and effective for students to have viewed the slide programs, as designed for this study before entering their first calculus course. Considering their enthusiastic agreement to Items 2 and 8, which were intended to evaluate related attitudes, the cooperating instructors demonstrated notable confidence that exposing students to the chordal method of integration and differentiation (which are not traditionally taught in mathematics courses) would improve their ultimate performance.

The faculty opinionnaire instrument may be reviewed in Appendix Q. Also, a summary of faculty recommendations in response to "additional comments or suggestions" on the opinionnaire are included in Appendix R. Null hypotheses $H_{o4}$ and $H_{o5}$ were analyzed on the basis of faculty preferences expressed in response to Item 1 ($H_{o4}$) and Items 2 and 8 ($H_{o5}$) on this same opinionnaire. The results of these and other pertinent conclusions derived as a result of the data analysis reported in this chapter are summarized below.

SUMMARY

This chapter has presented the results of the data analysis for an experimental study performed to evaluate the instructional benefits of including "sketching practice" as a potentially improved method for teaching graphical integration in engineering drawing and drafting courses. This study was conducted during the winter quarter at the following two-year colleges: Thomas Nelson Community College,
Hampton, Virginia; Rappahannock Community College, Glenns, Virginia; and Chesapeake College, Wye Mills, Maryland. With regard to the null hypotheses which were formulated for this experiment and stated previously, the results of the analyses reported in this chapter indicated that:

\( H_{o1} \): There is no significant difference in the initial achievement favoring the experimental group.

When initial achievement, as measured on the graphical integration criterion test (Appendix H) was compared between treatment groups, it was determined that the experimental group scored significantly higher than the control groups. Therefore, null hypothesis \( H_{o1} \) was rejected in both cases on the basis of the data which were evaluated (a) using the intact groups as the unit of analysis and (b) using the individual subjects as the unit of analysis. (Please refer to Figures 6, 7, and 8 on pages 75, 77, and 78.)

\( H_{o2} \): There is no significant difference in retention favoring the experimental group.

When the same graphical integration criterion test shown in Appendix H was given a second time two weeks after the conclusion of the slide-tape presentations, it was determined that there was a significant difference in group performances favoring the experimental group. When the main effects of the treatments were analyzed, three out of the four analysis of covariance comparisons suggested significant differences in retention ability when these analyses were made using the intact groups as units of analysis. However, the analysis of covariance data indicated significance at the .01 level of confidence.
when these same retention test scores were analyzed using the individual subjects as units of the analysis. It was therefore concluded that this analysis provided sufficient evidence for rejection of the null hypothesis stating that no significant difference in retention between the groups existed. (These data may be reviewed in Figures 10, 11, and 12 on pages 82, 84, and 86.)

\[ H_{03} : \text{There is no significant difference in the students' preference favoring the experimental method of presentation.} \]

The null hypothesis \( H_{03} \) was evaluated by means of Item 1 on the student opinionnaire. These opinionnaires were distributed in the experiment after the second slide-tape presentation as described earlier, thus giving each student the opportunity to participate both as a member of an experimental group and a control group. Item 1 on the opinionnaire read, "I prefer the slide program including the step method with sketching practice to the slide program without sketching practice." The student responses to this closed statement were rated such that the respondent could agree (5), somewhat agree (4), remain neutral—no opinion (3), somewhat disagree (2), or disagree (1). The pooled responses from all of the groups to Item 1 averaged 3.98 with a standard deviation of 1.34, a very positive indication of student preference favoring the experimental method.

Digressing just briefly for a short discussion on statistical decision theory, Li (1969) has stated that while it is not unusual in statistics to estimate the population parameter (mean) on the basis of a sample mean, the sample mean is very seldom equal to the population
mean (p. 157). Subsequently, both Li and Guilford (1965) recommend the use of a confidence interval, based on calculations involving the sample mean and standard derivation scores, as a means of strengthening the inferences for rejection or acceptance of the null hypothesis. Guilford (1965) recommends a procedure in terms of standard z scores in which the arithmetic for a confidence interval at the .95 level can be set up by applying the following formula (p. 152):

\[ CI_{.95} = M - 1.96 \sigma_m \text{ to } M + 1.96 \sigma_m \]

where \( M \) = hypothesized population mean

\( \sigma_m = \text{standard error of the mean estimated by} \)

\[ \frac{\text{Standard Deviation of Sample}}{\sqrt{\frac{\text{Sample Size}}{n}}} - 1 \]

Regarding Item 1 on the student opinionnaire, if one assumed that (a) an hypothetical population mean response equivalent to 4 (somewhat agree), and (b) a 95 percent confidence interval were satisfactory and justifiable levels at which to reject the null hypothesis \( H_0 \), then the results of the following arithmetic could be interpreted to determine the significance of the sample mean of 3.98 and standard deviation of 1.34. (It was decided to analytically assess the sampling responses associated with Item 1 on the student opinionnaire and to report the results in terms of the procedures outlined above by Guilford.)
On the basis of conclusions drawn from the discussion above, the null hypothesis $H_{03}$ was rejected.

$H_{04}$: There is no significant difference in the instructors' preference favoring the experimental method of presentation.

This item was evaluated on the basis of faculty responses to Item 1 on the faculty opinionnaire which was stated in exactly the same words as Item 1 on the student opinionnaire which was cited above. As indicated on Figure 14 page 95 and also stated on page 92, the participating faculty rated Item 1 with a mean of 4.75 and a standard deviation of 0.433. Since the sample size was so small (4 instructors), a confidence interval was not computed for this item, as Guilford (1965) indicated that a sample size of at least 30 is required for this kind of analysis (p. 151). However, the mean and standard deviation figures alone suggest a very decisive preference for the experimental method on the part of the cooperating instructors, thus leading to the rejection of the null hypothesis.
\( H_{05} \): There is no significant difference in the instructors' preference favoring the experimental method, as presented in this study, versus the traditional method of instruction when initially introducing students to the math concepts of differentiation and integration.

The statements on Items 2 and 8 on the Faculty Opinionnaire were utilized to evaluate this particular hypothesis. These statements were written as follows:

Item 2: I prefer the slide tape presentations complete with the step method in color with sketch format as the instructional method by which to best initially present the math concepts of differentiation and integration over the traditional lecture chalkboard method of instruction.

Item 8: I personally would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in my first calculus course.

The pooled faculty responses on Item 2 averaged for a mean of 4.25 and a standard deviation of .433. Item 8 received a mean score of 4.5 and a standard deviation of .50. Considering their enthusiastic support for Items 2 and 8, the cooperating instructors demonstrated decisive preference for first introducing students to the concepts of integration and differentiation via the experimental method utilized in this study. These inferences were considered to be decisively sufficient data in favor of the fifth research hypothesis, thus resulting in the rejection of \( H_{05} \).

\( H_{06} \): There is no significant difference in the students' (with previous calculus experience) preference in favor of first receiving the experimental method of instruction as compared to their initial math (calculus) experience.

On the opinionnaire, students were asked to respond to Item 6, page 176 only if they had previous calculus experience. Of the total of 61 students participating in the study, 30 respondents marked this
item on their opinionnaire. These pooled responses had a mean score of 4.07 and a standard deviation of 1.14. These scores indicated that the students felt that it would be advantageous to have been exposed to graphical integration and differentiation subject matter via the experimental method prior to their first calculus course.

The same z score statistical rationale as that which was utilized in evaluating $H_{03}$ above was utilized in evaluating this null hypothesis. It was again sub-hypothesized that the population mean was equal to 4 ($M = 4$). Using the procedure outlined earlier by Guilford for the .95 confidence interval, the appropriate calculations using the sample mean (4.07) and standard deviation (1.14) scores were made as follows:

$CI_{.95} = M - 1.96 \sigma_m$ to $M + 1.96 \sigma_m$

$CI_{.95} = 4 - 1.96(.21)$ to $4 + 1.96(.21)$

$CI_{.95} = 4 - .41$ to $4 + .41$

$CI_{.95} = 3.59$ to $4.41$

On the basis of inferences drawn from these calculations, the null hypothesis $H_{06}$ was rejected.
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The problem of this investigation was the lack of experimental evidence with regard to the relative effectiveness of two programmed audio-visual methods for presenting graphical differentiation and graphical integration subject matter to pre-engineering and engineering technology students.

The rationale underlying the instructional materials developed for this study was based upon combining the following research proven instructional formats and/or techniques:

1. Step method instruction sheet (Earle, 1964),
2. Slide-quiz questions (Holland, 1973),
3. Self-scoring response card (Pressey, 1950 and Holland, 1975),

By combining these features and including "sketching practice" as an added instructional strategy, this experiment consisted of an attempt to design and test an improved instructional system for engineering graphics and drafting courses.

Each slide-tape presentation developed for this experiment consisted of the following materials: a sheet of learning objectives, a series of 60 to 70 35mm slides, a recorded narration, a step method instruction sheet with sketching practice (experimental) or without
sketching practice (control), a self-scoring response card for slide-quiz responses, and a criterion test at the end of the slide program.

The null hypotheses for this study stated that there was no significant difference in (1) initial achievement favoring the experimental group, (2) retention favoring the experimental group, (3) the students' preference favoring the experimental method, (4) the instructors' preference favoring the experimental method, (5) the instructors' preference favoring the experimental method versus the traditional method for introducing students to the math concepts of differentiation and integration, and (6) the students' (with previous calculus experience) preference in favor of first receiving either the experimental method of instruction as compared to their initial math (calculus) class experience.

The sample of subjects (n=61) utilized in this experiment consisted of groups of engineering and engineering technology students enrolled at the following two-year colleges during fall quarter, 1978: Thomas Nelson Community College, Hampton, Virginia; Rappahannock Community College, Glenns, Virginia; and Chesapeake College, Wye Mills, Maryland. Experimental and control treatments were randomly assigned to each of the four intact groups.

The research design utilized in this experiment was a posttest-only control group design. The criterion test data were analyzed by utilizing the analysis of covariance (Subprogram Anova) statistical technique described in the Statistical Package for the Social Sciences (Nie, et al., 1975). Student scores on the Verbal Reasoning and Abstract Reasoning batteries of the Differential Aptitude Test were
utilized as covariates to adjust for differences in student ability levels. Data were subsequently collected via the criterion tests, retention tests, and separate student and faculty opinionnaires which were administered at the conclusion of the study.

CONCLUSIONS

Within the assumptions and limitations as prescribed for this experiment, the six null hypotheses of this study were rejected. The analysis of the data subsequently warrants the following conclusions:

1. Students in the experimental treatment groups who were shown the slide-tape presentation, complete with slide-quiz questions and the step method with color and with sketch format, scored significantly higher on the graphical integration criterion test than students receiving the same treatment but without the sketching format.

2. When the data were analyzed utilizing the individual subjects (rather than intact groups) as units of analysis, students in the experimental group demonstrated significantly greater retention ability on the criterion test two weeks after the completion of the slide-tape presentations.

3. Analysis of the student opinionnaire indicated that participants in the study showed a definite preference for the slide programs and experimental step-method formats which provided for sketching practice between the steps on the step method instruction sheets versus the control method which did not make provisions for sketching.
(4) Analysis of the faculty opinionnaire indicated that the instructors also demonstrated a decisive preference for the experimental slide presentations which provided for sketching practice.

(5) Faculty participants demonstrated a definite preference for the experimental method over the traditional lecture-chalkboard as a means of first introducing students to the concepts of integration and differentiation.

(6) The pooled responses of students who had previous calculus experience indicated that these individuals felt that it would have been advantageous to have seen the experimental materials on graphical integration and differentiation prior to their first calculus course.

DISCUSSION

In regards to using color instructional presentations for solving graphical problems in engineering drawing, Chance (1960) and Earle (1964) both reported more efficient student performances from those who had been instructed by systems incorporating color presentations as compared to those instructed by presentations without color.

Utilizing the research proven "step method in color" format therefore, as an accepted "more effective" presentation technique, this study sought to improve upon it by including a specified space and format for "practice sketching" for each step of the step method. In this study, the step method in color with sketching practice was found to be more effective as regarding student comprehension (initial learning), retention, and preference than the step method in color format without provision for sketching practice.
Cozzens (1965) and Holland (1973), utilized different techniques and documented the effectiveness of immediate feedback and reinforcement on student performance. Students also preferred the treatments utilized by these researchers which provided for immediate reinforcement as compared to those which did not. Therefore, on this research proven assumption, this study sought to include the reinforcement-feedback phenomena in a manner similar to that used by Holland. This provision for reinforcement was in relation to student slide-quiz question responses during the 35mm slide presentations.

Other researchers who found 35mm slides and other audio-visual instructional technology to be more effective means of presenting engineering drawing concepts are included here as follows:

Wilkes (1966): Experimental 35mm slide presentations versus conventional lecture method (control)

Nystrom (1969): Experimental 16mm sound film (animated) versus conventional lecture-demonstration method (control)

Horne (1977): Experimental individualized instructional systems approach utilizing silent and sound super 8mm filmloops versus traditional methods control group.

To summarize, please consider the appropriateness of Baker and Shutz' appeal for educational researchers to involve themselves in an "instructional product research" effort (p. xix) which would encourage researchers in both academic and industrial education to continually utilize research and practitioner efforts in order to create new knowledge and products which will be useful in reducing the uncertainty associated with the effectiveness of instructional products.
The findings of this study additionally suggested:

(1) Students were basically undecided regarding whether or not the slide programs with sketching practice were any more interesting than a traditional lecture-chalkboard presentation.

(2) Students indicated a slight preference for a traditional lecture chalkboard presentation as compared to the control method utilized in this study.

(3) Students basically agreed that the review quizzes provided a thorough review of the information presented in the slide-tape presentations.

(4) Students generally agreed that the experimental instructional strategy should become a permanent part of engineering graphics and drafting courses.

(5) The participating instructors enthusiastically agreed that the photographic slides were an effective means of presenting the subject material in this experiment.

(6) The instructors also generally agreed that each slide series was comprehensive enough for students to meet the objectives of the units.

(7) The instructors agreed that slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cards, taped narrations, and review quizzes should be incorporated as a permanent part of drafting and engineering graphics courses.
(8) The participating faculty demonstrated confidence that the example curves selected for the step method instruction sheets were effective in illustrating the practical aspects of integration and differentiation.

(9) Finally, with regard to usage of classroom time, faculty members generally agreed that less class time is consumed when utilizing slide presentations with taped narrations and review quizzes than by the traditional lecture-chalkboard method of instruction.

RECOMMENDATIONS

Based on the assumption that effective instructional systems do not simply appear but that they must evolve as a result of the cooperative efforts of practitioners and researchers, the following recommendations are suggested:

(1) Further research should be conducted to ascertain the effectiveness of step-method formats which accommodate sketching practice as an instructional technique in other subject areas in drafting, engineering graphics, as well as in other forms of industrial education.

(2) This research should be repeated to involve a broader sample of college and/or university students to verify the findings of this study.

(3) Additional research should be conducted to ascertain the value of independent study of these experimental materials as compared to the results obtained as a result of the group presentations as in this experiment.
(4) Since the students' major criticism of the instructional materials developed for this study was that there was no opportunity provided for asking questions, more research and development needs to be done to determine a more effective technique for student-teacher interaction during the slide presentations.

(5) Additional research should be conducted to ascertain the predictive validity of student performances on graphical integration and differentiation problems as compared to subsequent math class performance in these subject areas.
Alpren, Morton and Baron, Bruce. The death of the behavioral objectives movement. *Intellect*, November 1974, 105, 103-104.


Tiemann, Ernest P. *Production of 2x2 inch slides for school use* (Rev. ed.). Austin, Texas: Visual Instruction Bureau, Division of Extension, The University of Texas, 1970.


APPENDIX A

List of Jury Panel Members and Credentials
Mr. Robert Burnham  
Assistant Professor, Engineering, Thomas Nelson Community College, Hampton, Virginia.  
B.S., Civil Engineering, 1973, University of Maine, Orono, Maine.  
M.E., Civil Engineering, 1979, Old Dominion University, Norfolk, Virginia.

Mr. Ralph Denten, III, Assistant Professor, Drafting and Design,  
Rappahannock Community College, Glenns, Virginia.  
B.S., Industrial Arts, 1973, Old Dominion University, Norfolk, Virginia.  
M. Ed., Industrial Education, 1977, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Mr. Jack G. Gardner, Instructor, Drafting and Design, Rappahannock Community College, Glenns, Virginia.  
B.S., Mechanical Engineering, 1966, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.  

Dr. Thomas F. Kilduff, Professor of Mechanical Engineering Technology,  
Thomas Nelson Community College, Hampton, Virginia.  
B.S., Electrical Engineering, 1948, U.S. Naval Academy, Annapolis, Maryland.  
APPENDIX B

List of Cooperating Instructors in the Experiment and Their Credentials
Mr. Ralph Denton, III, Assistant Professor, Drafting and Design, 
Rappahannock Community College, Glenns, Virginia.
Four-year Apprenticeship Diploma, Machinist, 1970, Newport News 
Shipbuilding and Drydock Company Apprentice School, Newport News, 
Virginia.
B.S., Industrial Arts, 1973, Old Dominion University, Norfolk, 
Virginia.
M. Ed., Industrial Education, 1977, Virginia Polytechnic Institute 
and State University, Blacksburg, Virginia.

Mr. Jack G. Gardner, Instructor, Drafting and Design, Rappahannock 
Community College, Glenns, Virginia.
B.S., Mechanical Engineering, 1966, Virginia Polytechnic Institute 
and State University, Blacksburg, Virginia.
M.A., Adult Education, 1978, Virginia Commonwealth University, 
Richmond, Virginia.

Dr. Ralph Horne, Professor and Chairman, Drafting and Design, Chesapeake 
College, Wye Mills, Maryland.
B.S., Industrial Education, 1970, University of Tennessee, 
Knoxville, Tennessee.
M.A., Industrial Education, 1971, University of Tennessee, 
Knoxville, Tennessee.
D.Ed., Vocational and Technical Education, 1977, Virginia Polytechnic 
Institute and State University, Blacksburg, Virginia.

Mr. Al Martin, Assistant Professor of Drafting and Design, Thomas 
Nelson Community College, Hampton, Virginia.
B.S., Chemical Engineering, 1960, Cornell University, Ithaca, 
New York.
M.A., Higher Education, 1977, The George Washington University, 
Washington, D. C.
APPENDIX C

General Instructions for Presenting the Slide Presentations
The purpose of this study is to compare the effectiveness of audio-visual presentations when sketching practice is introduced as the independent variable in the slide programs. The slides will be shown to two groups (1) an experimental group, and (2) a control group. The experimental group will be shown a series of slides which includes an instruction sheet with a sketching format. The control group will be shown the same series of slides but the accompanying instruction sheet and tape narration does not accommodate sketching practice. Please read all of the following instructions thoroughly before starting the slide program.

Procedural Checklist for Administering Both Experimental and Control Presentations:

1. Organize 35mm slide projector and cassette recorder for slide #1.

2. Give each student a learning objective sheet and instruct students to read it thoroughly.

3. Give each student the step method instruction sheet and a response card.

4. Keep some light in the classroom for students to see their sketching material and response cards.

5. Please do not answer any student questions during the presentation and brief them beforehand that they should be attentive and make their own best possible effort.

6. Stop the tape recorder only when instructed to do so. Allow sufficient time for students to sketch each step in the experimental groups and for all students to respond to the slide-quiz questions.

7. Start the program.

8. At the end of the program, collect all of the step method instruction sheets and response cards.

9. Give each student a Review Quiz (Part I).

10. Collect Part I of the Review Quiz as each student completes it and give him Part II.

11. Collect Part II of the Review Quiz as each student completes it.

12. Please allow a 20-break period.
13. Repeat steps 1-12 for next slide presentation.

14. Give each student the Student Opinionnaire and Background form to complete.

15. Collect all Student Opinionnaire and Background Forms.
APPENDIX D

Self-scoring Response Card
Direction—Variable Alphabetical Response Mode:

Erase the area where you think correct answer is. Preferably use clean, firm, non-plastic pencil eraser, with a reasonably sharp edge.

Your instructor will designate the correct answer's response for a particular exercise, for example:

**Correct Answer Designated:** Then other responses are:

- "T" = Right
- "H", "E" or "L" = Wrong

If your instructor wishes you to learn the correct answer, continue erasing until the response designated as correct is revealed; make as few erasures as possible. For self-teaching, grading and item-of-difficulty identification see Directions Sheet.
APPENDIX E

Learning Objectives for
Graphical Integration
LEARNING OBJECTIVES
Graphical Integration

Rationale: Students in technical drawing courses sometimes initially wonder whether graphical solutions or methods to math problems are really necessary or useful. Actually, formal calculus is an advanced form of algebra that can be applied whenever a known equation is available. Ordinarily, however, a mathematical approach is not practical when the data being considered has been gathered from some sort of experimental testing and thus, no equations are readily available. It is in these circumstances then, when the plot of the data does not follow a known equation, that the real significance of graphical techniques can be appreciated.

1. Given a list of terms normally associated with semigraphical and graphical methods of integration, students will specify which of these terms should be associated with each of the methods.

2. Given a list of example situations, students will identify those cases in which either the planimeter or the chordal method would provide the most satisfactory solution.

3. Students will identify the maximum numerical height for the ordinate axis for a given integral curve.

4. Given an example "given data curve," and the axis for its integral curve, students will select an appropriate scale for the ordinate axis of that integral curve.

5. In conjunction with solving for a solution by the chordal method of integration, students will describe, in writing, the relationship between the shape of the given data curve and the width of the required strips (rectangles) which are used to divide the area under that curve.

6. Given an example integral curve and specifically stated limits of X along with X axis of that curve, students will demonstrate an understanding of the Area Law by designating the numerical value of the area which exists between those limits under the curve from which the integral curve was derived.

7. Students will recall and express in writing two key factors which specifically affect the usefulness of a solution generated by the chordal method of integration.

8. Given a curve to be integrated graphically, students will utilize drafting instruments and apply from memory, the principles of the chordal method in order to accurately locate a pole point within an accuracy tolerance level of three percent.

9. Using drafting instruments, students will solve a practical integration problem using the chordal method, by carefully applying, from memory, the principles presented in the step method to delineate a solution which is accurate within three percent.
APPENDIX F

Experimental Step Method Instruction
Sheet for Graphical Integration
STEP METHOD INSTRUCTION SHEET

NAME

COLLEGE

COURSE NO.

IN EACH OF THE PRACTICE SPACES BELOW, PLEASE SKETCH THE CONSTRUCTIONS EXPLAINED FOR THAT STEP.

PRACTICE SPACE 1

STEP 1:

Draw in the mean ordinate line PQ in order to estimate the total area (5 x 4 = 20).

Use a convenient scale and graduate the ordinate axis to accommodate the 20 units.

PRACTICE SPACE 2

STEP 2:

Locate point M at X=5, G=20. Theoretically, point M will be the highest point on the integral curve.

Draw line MO.

Extend the X axis to the left as shown, and draw line 4P parallel to line MO.

PRACTICE SPACE 3

STEP 3:

Construct vertical lines which divide the area under the curve into strips.

Draw a mean ordinate line at the top of each strip.

Project the top of each rectangle to the Y axis as shown at points A,B,C,D.
STEP 4:
Draw lines that connect pole point P to points A, B, C, and D where the extensions of the mean ordinates intersect the Y axis. Extend vertical construction lines upward to establish the width of the strips on the integral curve axis.

STEP 5:
Begin at the origin of the integral axis and construct line AP parallel to line PA. Line AP ends at the point where it intersects the projector from the first strip. Begin at this point and draw BP parallel to PB, construct CP and DP parallel to their respective lines in the appropriate intervals, as shown.

STEP 6:
Fair in a smooth integral curve through the ends of the chords. Please note that the maximum ordinate value shown at the end of chord DP accurately designates the calculated area of 19.6.

\[ \text{Area} = \frac{1}{2} \pi r^2 \]
\[ \text{Area} = \frac{1}{4} \times 3.1416 = 5^2 \]
\[ \text{Area} = 19.6 \]
GRAPHICAL INTEGRATION (CHORDAL METHOD)

GIVEN: A CURVE WHICH IS AN ARC OF A CIRCLE WITH ITS CENTER LOCATED AT X=5, Y=0; AND THE AXIS FOR THE INTEGRAL CURVE.

REQUIRED: USING THE CHORDAL METHOD OF GRAPHICAL INTEGRATION, SOLVE FOR THE INTEGRAL CURVE.

NAME _______________________

COLLEGE ____________________

COURSE NO. _________________

IN EACH OF THE PRACTICE SPACES BELOW, PLEASE SKETCH THE CONSTRUCTIONS EXPLAINED FOR THAT STEP.
STEP I:
Draw in the mean ordinate line PQ in order to estimate the total area \(5 \times 4 = 20\).

Use a convenient scale and graduate the ordinate axis to accommodate the 20 units.
STEP 2:
Locate point M at X=5, 
G=20. Theoretically, point 
M will be the highest 
point on the integral 
curve.

Draw line MO.

Extend the X axis to 
the left as shown, and 
draw line 4P parallel 
to line MO.
STEP 3:
Construct vertical lines which divide the area under the curve into strips.

Draw a mean ordinate line at the top of each strip.

Project the top of each rectangle to the Y axis as shown at points A, B, C, & D.
STEP 4:
Draw lines that connect pole point P to points A, B, C, and D where the extensions of the mean ordinates intersect the Y-axis.
Extend vertical construction lines upward to establish the width of the strips on the integral curve axis.
STEP 5:
BEGIN AT THE ORIGIN OF THE INTEGRAL AXIS AND CONSTRUCT LINE AP PARALLEL TO LINE PA. LINE AP ENDS AT THE POINT WHERE IT INTERSECTS THE PROJECTOR FROM THE FIRST STRIP. BEGIN AT THIS POINT AND DRAW BP PARALLEL TO PB, CONSTRUCT CP AND DP PARALLEL TO THEIR RESPECTIVE LINES IN THE APPROPRIATE INTERVALS, AS SHOWN.
STEP 6:
Fair in a smooth integral curve through the ends of the chords. Please note that the maximum ordinate value shown at the end of chord DP accurately designates the calculated area of 19.6.

\[
\text{Area} = \frac{1}{4} \pi r^2
\]

\[
\text{Area} = \frac{1}{4} \times 3.1416 \times 5^2
\]

\[
\text{Area} = 19.6
\]
APPENDIX G

Control Step Method Instruction
Sheet for Graphical Integration
STEP METHOD INSTRUCTION SHEET

NAME ____________________

COLLEGE __________________

COURSE NO. ________________

GRAPHICAL INTEGRATION
(CHORDAL METHOD)

GIVEN: A curve which is an arc of a circle with its center located at (5,0); and the axis for the integral curve.

REQUIRED: Using the chordal method of graphical integration, solve for the integral curve.

STEP 1:
Draw in the mean ordinate line PQ in order to estimate the total area (5 x 4 = 20).
Use a convenient scale and graduate the ordinate axis to accommodate the 20 units.

STEP 2:
Locate point M at X=5, G=20. Theoretically, point M will be the highest point on the integral curve.
Draw line MO.
Extend the X axis to the left as shown, and draw line 4P parallel to line MO.

STEP 3:
Construct vertical lines which divide the area under the curve into strips.
Draw a mean ordinate line at the top of each strip.
Project the top of each rectangle to the Y axis as shown at points A, B, C, & D.
STEP 4:
Draw lines that connect pole point P to points A, B, C, and D where the extensions of the mean ordinates intersect the Y axis, extend vertical construction lines upward to establish the width of the strips on the integral curve axis.

STEP 5:
Begin at the origin of the integral axis and construct line AP parallel to line PA. Line AP ends at the point where it intersects the projector from the first strip. Begin at this point and draw BP parallel to PB, construct CP and DP parallel to their respective lines in the appropriate intervals, as shown.

STEP 6:
Fair in a smooth integral curve through the ends of the chords. Please note that the maximum ordinate value shown at the end of chord DP accurately designates the calculated area of 19.6.

\[ \text{Area} = \frac{1}{4} \times 3.1416 \times 5^2 \]

Area = 19.6
APPENDIX H

Criterion Test (Review Quiz) and "Retention Test" for Graphical Integration
The document is a quiz on graphical integration. The questions ask the student to select the correct term associated with each method. Here are the questions and answers:

1. Which of the following would most likely be associated with semigraphical integration?
   a. Integral curve
   b. Simpson's Rule
   c. Planimeter
   d. Trapezoidal Rule
   e. Pole Point

2. Which of the following would most likely be associated with the Chordal Method of integration?
   a. Planimeter
   b. Integral curve
   c. Mean ordinate
   d. Simpson's Rule
   e. Pole point

(OVER)
3. Given the "given curve" and the integral curve axis as shown, what numerical value would most likely be assigned to the highest point on the ordinate axis of the integral curve?
   a. 50 feet
   b. 100 feet
   c. 150 feet
   d. 200 feet
   e. 250 feet

4. Referring to question No. 3 and the given information above, which of the following would be the most appropriate scale to use for the ordinate axis of the integral curve?
   a. $\frac{1}{4}$ inch = 75 feet
   b. $\frac{1}{2}$ inch = 60 feet
   c. 1 inch = 100 feet
   d. $\frac{1}{8}$ inch = 20 feet
5. In each of the following situations, if the planimeter would provide the most satisfactory solution, write the word "Planimeter" in the blank next to it; if the chordal method would provide the best solution, write the words "Chordal Method" in the blank; if neither of them seem necessary, write the word "Neither."

________ A naval architect needs to determine cross-sectional areas on a ship's hull design drawing.

________ Data were collected in terms of the cubic feet per minute discharge from a flood control dam in order to determine the volume discharged at various intervals.

________ The X and Y variables on a given curve conform to the equation $X = 3y^3 + 2y^2$.

________ An experimental structures test has been conducted to determine the Bending Moment Diagram for a loaded beam.

________ A surveyor has to determine the acreage from a plot plan drawing of an irregular plot of land.

Please decide whether the following statement is True or False. Circle your answer and then explain your selection, regardless of whether it was true or false.

TRUE FALSE 6. When utilizing the chordal method for graphical integration, the strips (rectangles) which one uses to divide the area under the given data curve should all be of equal width.

(Please Explain)

In the following question, please write the correct answers in the spaces provided.

7. As in all graphical solutions, the usefulness of the results obtained by the chordal method of integration are directly determined by two key factors.

They are:

1. __________________________________________________________________________

2. __________________________________________________________________________

(OVER)
8. Based on what you have learned about the area law, study this integral curve and determine the numerical value of the following:

(a) The area under the original curve (from which this integral curve was derived) and above the X axis between the limits of X=0 and X=25

(b) The area under the original curve (from which this integral curve was derived) and above the X axis between the limits of X=15 and X=50.

(c) With what unit calibration should one label the ordinate axis on the "given curve" from which this integral curve was derived.

When you have completed this part of your exam, please hand it to your instructor and ask for Part II of this exam.
The given curve of volume versus pressure is characteristic of data often encountered in science and technology.

(a) Please utilize the principles of the chordal method and solve first for the pole point. Use your drafting instruments and strive for an accuracy within three percent.

(b) Please utilize the principles of the chordal method to draw the integral curve. Use your drafting instruments and strive for an accuracy within three percent. Add the appropriate labeling and calibration to the integral ordinate axis.
APPENDIX I

Learning Objectives for
Graphical Differentiation
LEARNING OBJECTIVES
Graphical Differentiation

Rationale: From Part I of this slide series, you will recall that graphical differentiation was briefly defined as a process of determining the rate of change of one variable with respect to another. This is basically a reverse operation of the integration process. The same statements regarding the usefulness of graphical techniques when a known equation is unavailable apply also for graphical differentiation, just as you learned in Part I of this program on graphical integration. Furthermore, most authors of textbooks on graphical methods generally agree that these methods better enable students to comprehend the numerical aspects of differentiation and integration. Please read the objectives below carefully prior to starting Part II of this slide-tape presentation.

1. Given an example "given data curve," students will determine the approximate maximum numerical value for the ordinate axis of a derivative curve to be derived from that given curve.

2. In conjunction with chordal method solutions, students will describe, in writing, the relationship between the shape of a "given data curve" and the suggested lengths of the required chords to be drawn on it.

3. Given a curve to be differentiated graphically, students will utilize drafting instruments and apply, from memory, the principles of the chordal method in order to accurately locate a pole point within an accuracy tolerance level of three percent.

4. Given a curve to be differentiated graphically, students will utilize drafting instruments and apply, from memory, the principles of the chordal method in order to delineate a derivative curve solution which is accurate within a tolerance level of three percent.

5. Students will express in writing their own interpretation of the "Slope Law."

6. Given a tangent line drawn to a curve at a designated point, students will utilize drafting instruments to establish the slope value at that point.

7. Given two points on an example "given data curve," students will identify their slope direction and specify whether their corresponding ordinate on a subsequent derived curve would be increasing or decreasing and/or positive or negative.

8. Given an displacement and a velocity curve, students will interpret designated distance and time values.
APPENDIX J

Experimental Step Method Instruction Sheet
for Graphical Differentiation
STEP METHOD INSTRUCTION SHEET

NAME ____________________________
COLLEGE __________________________
COURSE NO. ________________________

IN EACH OF THE PRACTICE SPACES BELOW, PLEASE SKETCH THE CONSTRUCTIONS EXPLAINED FOR THAT STEP.

STEP 1:
Draw a chord where the given curve appears to be steepest.
The maximum slope is 5.
Use a convenient scale and allow for an ordinate of 5 units on the derivative curve.

STEP 2:
Draw any line of known slope on the given curve.
The line shown here has a slope of 4.
Draw line 4P parallel to the known slope to locate pole point P.

STEP 3:
Construct a series of chords on the given curve as shown.
(Use short chords for sharp curves and longer chords for flatter curves)
Draw lines through pole point P parallel to each chord as shown.

GRAPHICAL DIFFERENTIATION
(CHORDAL METHOD)

GIVEN: The "given curve" is the curve which was derived by chordal method of integration in Part 1, integration.
REQUIRED: Using the chordal method of differentiation, solve for the "derivative" curve.

NAME ____________________________
COLLEGE __________________________
COURSE NO. ________________________

STEP 1:
Draw a chord where the given curve appears to be steepest.
The maximum slope is 5.
Use a convenient scale and allow for an ordinate of 5 units on the derivative curve.

STEP 2:
Draw any line of known slope on the given curve.
The line shown here has a slope of 4.
Draw line 4P parallel to the known slope to locate pole point P.

STEP 3:
Construct a series of chords on the given curve as shown.
(Use short chords for sharp curves and longer chords for flatter curves)
Draw lines through pole point P parallel to each chord as shown.
STEP 4:
Construct vertical lines downward as shown through the end points of each chord.

Draw horizontal lines through points A, B, and C to define the height of each "strip".

STEP 5:
Carefully draw the derivative curve through these intervals near the midpoint at the top of each strip.

Construct the curve to have approximately equal areas under and over the "mean ordinate" at the top of each strip.
APPENDIX K

Control Step Method Instruction Sheet
for Graphical Differentiation
STEP METHOD INSTRUCTION SHEET

NAME __________

COLLEGE __________

COURSE NO. __________

GRAPHICAL DIFFERENTIATION
(CHORDAL METHOD)

GIVEN: The "GIVEN CURVE" is the curve which was derived by chordal method of integration in Part I, Integration.

REQUIRED: Using the chordal method of differentiation, solve for the "DERIVATIVE" curve.

STEP 1:

Draw a chord where the given curve appears to be steepest.

The maximum slope is 5.

Use a convenient scale and allow for an ordinate of 5 units on the derivative curve.

STEP 2:

Draw any line of known slope on the given curve.

The line shown here has a slope of 4.

Draw line 4P parallel to the known slope to locate pole point P.

STEP 3:

Construct a series of chords on the given curve as shown.

(Use short chords for sharp curves and longer chords for flatter curves)

Draw lines through pole point P parallel to each chord as shown.
**STEP 4:**

Construct vertical lines downward as shown through the end points of each chord.

Draw horizontal lines through points A, B, C to define the height of each "strip".

**STEP 5:**

Carefully draw the derivative curve through these intervals near the midpoint at the top of each strip.

Construct the curve to have approximately equal areas under and over the "mean ordinate" at the top of each strip.
APPENDIX L

Criterion Test (Review Quiz) and "Retention Test" for Graphical Differentiation
1. Please describe the relationship between the shape of a given curve and the suggested lengths of the chords to be drawn when using the chordal method of differentiation.

2. Please state or describe the meaning of the "Slope Law."

3. (a) Define an "inflection point."

   (b) Describe the derivative of an inflection point.

4. Assuming a particle to be moving from left to right along the curve below, the slopes at points P and Q would be:
   A. increasing positive
   B. decreasing positive
   C. increasing negative
   D. decreasing negative
   E. none of the above
5. In question 4 above, the ordinates for points P and Q at their corresponding points on a derivative curve would be:
   A. positive and increasing
   B. positive and decreasing
   C. negative and increasing
   D. negative and decreasing
   E. none of the above

6. Given the velocity and acceleration curves below, please interpret for the following values:
   - A. Maximum velocity in FPS
   - B. Point of maximum acceleration
   - C. Point where acceleration is minimum
   - D. Acceleration after 65 seconds
7. Please determine the mathematical slope, value of the tangent at point Q.

8. Assuming that the chordal method of differentiation is to be applied to the given data curve below, please determine the approximate maximum numerical value that would be assigned to the ordinate axis of the derived curve.

When you have completed this part of your exam, please hand it to your instructor and ask for Part II of this exam.
A cam has been designed that will cause a follower to rise at each interval of its constant revolution as plotted in the graph. Connect these points with a smooth curve.

(a) Please utilize the principles of the chordal method and solve first for the pole point. Use your drafting instruments and strive for accuracy within three percent.

(b) Please utilize the principles of the chordal method and solve for the velocity curve of this follower by the chordal method of graphical differentiation. Strive for accuracy within 3 percent. Label the axes and give a title in the block provided.
APPENDIX M

Examples of Slides and Script for Experimental and Control Graphical Integration Units
Script: Graphical Calculus Part I is a slide-sound program designed to introduce students in engineering graphics and engineering technology courses to the principles of graphical integration. Before proceeding with the program please make sure that you have the following materials in front of you.

Script: You should have a No. 2 lead pencil, a "step-method instruction sheet," and the self-scoring response card shown here. You should also have 2 available drafting triangles, an engineer's scale and a French curve. If you do not have all of these, please stop the program and arrange to get the materials that you are missing before you proceed.
Script: The two basic forms of calculus are the differential and the integral calculus. The following definitions will provide some helpful background. Broadly speaking, one way of thinking of integration is that it is basically the process of determining an area under a given curve.

Script: Differentiation, as you may know, can be defined as the process of determining the rate of change of one variable with respect to another variable. Mathematically, these variables usually pertain to the X and Y variables in a given equation.
Script: It is important to realize that mathematically each of these processes is really the reverse of the other. This is also true of the graphical solutions, as you will see in Part II of this program—each graphical procedure can be worked backwards to give the solution to the other.

Script: Please read Slide Question No. 1: (10 second pause—narrator does not read it.) As you know, the answer to this question is "B." The simplicity of this question is partly to demonstrate how to use the response card.
Script: As the slide shows, you should erase the mark where you think the answer is. In this example, you erase "B." When you do this, you will uncover a hidden code letter which should match the red circled letter "L" on the slide. In this case, the code letter "L" confirms that you have answered correctly. If your answer was wrong, please select the next answer you think is correct and try again.

Script: Determining the area under a curve is sometimes considered the easiest procedure for students to understand at first. Therefore, Part I of this presentation deals with graphical integration. Most students will find that these graphical solutions are helpful because they actually show a graphical picture of the fundamental process of integration.
If you would, at this time, please take out your step method instruction sheet. The next few slides will relate to this sheet until we have completed our discussion of the chordal method for deriving an integral curve.

Experimental Narrative: (The program will be stopped after each step and you will be asked—for practice purposes—to sketch, in the designated space—that part of the solution which was just explained in that step.)

Control Narrative: (The program will be stopped after each step to give students time to consider the concepts which have just been presented.)

After we have finished this series of slides, you will be asked to solve—from memory—a similar problem using your drafting equipment, so please pay particular attention to each step.

The usefulness of your solution will be determined by:
A. The accuracy of the original data plot
B. The care used in drafting.

Please keep in mind that as we proceed, in reality for solutions to be useful, that the accuracy of the original data plot and the care used in drafting practices are extremely important.
In this example problem we use a circular arc which has a radius of 5 units. The center is located at $X = 5$ on the axis. We can easily calculate the area of $\frac{1}{4}$ of a circle and this curve will help us to check the accuracy of the chordal method. Please note that as the solution develops, the information presented in each new step is printed in red in order to visually clarify that material from that which has already been described.

**Step 1:**

- **Draw in the mean ordinate line PQ in order to estimate the total area ($5 \times 4 = 20$).**
- **Use a convenient scale and graduate the ordinate axis to accommodate the 20 units.**

Step 1: The range of the integral curve is estimated to be 20 units by drawing the mean ordinate line PQ. You may then use a convenient scale to graduate the G axis to accommodate 20 units.

(Control Narrative Only: (Please stop the program and study this slide for a few moments.)
The following slide was not included in the control treatment series.

**Experimental Narrative Only:** (At this time, in the practice space provided for Step 1, please sketch in a mean ordinate line as shown in Step 1 and use a convenient scale to calibrate the G axis. Please stop the tape while you do this.)

In each of the practice spaces below, please sketch the constructions explained for that step.
In order to avoid drawing a "Flat" integral curve, one should normally make the ordinate axis at least as long as the ordinate axis on the original curve. Please keep in mind that the numerical values on the integral ordinate will be larger numbers than those on the original curve.

Please locate point M at X=5, G=20. Theoretically, point M will be the highest point on the integral curve.

**STEP 2:**
Locate point M at X=5, G=20. Theoretically, point M will be the highest point on the integral curve.

Draw line MO.

Extend the X axis to the left as shown, and draw line 4P parallel to line MO.

Please locate point M on the integral grid at the point where X=5 and G=20. Theoretically, point M will be the highest point on the integral curve. Now draw line MO as shown. Extend the X axis to the left as shown and construct line 4P parallel to the slope of line MO. The Pole Point P will be used in determining the integral curve.
As a matter of drafting technique, sliding one triangle against another is a good technique for drawing one line parallel to another.

Experimental Narrative: (Please stop the program and sketch these constructions in Practice Space 2.)

Control Narrative: (Please stop the program and study these constructions for a few moments.)

Please construct vertical lines which divide the area under the curve into strips. Then draw a mean ordinate line at the top of each strip. Finally, project the top of each rectangle to the Y axis as shown at points A, B, C, and D.
As a general rule of thumb, it is good to remember that steep slopes should have narrower strips and that curves with flatter slopes should have wider strips.

Experimental Narrative: (Please stop the program and sketch these constructions in Practice Space 3.)

Control Narrative: (Please stop the program and study these constructions for a few moments.)

**STEP 4:**

Draw lines that connect pole point P to points A, B, C, and D, where the extensions of the mean ordinates intersect the Y axis. Then extend the vertical construction lines upward to establish the width of the strips on the integral curve.

Experimental Narrative: (Please stop the program and sketch these constructions in Practice Space 4.)

Control Narrative: (Please stop the program and study these constructions for a few moments.)
Begin at the origin of the integral axis and construct line AP parallel to line PA. Line AP ends at the point where it intersects the projector from the first strip. Begin at this point and draw line BP parallel to PB. Construct CP and DP parallel to their respective lines in the appropriate intervals, as shown. These sloping lines are drawn to represent the chords of the integral curve, which gives rise to the name "chordal method" by which it is known.

Experimental Narrative: (Please stop the program and sketch these chords parallel to their respective lines as described, as accurately as possible.)

Control Narrative: (Please stop the program and study this slide for a few moments.)
Use a French curve and fair in a smooth integral curve through the ends of the chords. Please note that the maximum ordinate value shown at the end of chord DP accurately designates the calculated area of 19.6. Briefly, as you will recall, we used the original curve with a radius of 5 units so that we could easily calculate its area and check our results against that of the chordal method.

**Experimental Narrative:** (Please stop the program and fair in a smooth curve through these points—preferably with an irregular curve.)

**Control Narrative:** (Please stop the program and study this slide for a few moments.)
Finally, as a parting reminder to any student using drafting equipment in the construction of any graphical solution, it is extremely important to realize that the accuracy and usefulness of his graphical results will be determined directly by the accuracy of the original data plot and the care which he exercises in the handling of his drafting instruments.
APPENDIX N

Examples of Slides and Script for Experimental and Control Graphical Differentiation Units
It is advisable, as a reminder, for you to have the materials shown here in front of you for this next sequence of slides. If you do not, please stop the program and arrange to get them together.

**STEP 6:**

**FAIR IN A SMOOTH INTEGRAL CURVE THROUGH THE ENDS OF THE CHORDS.**

Please note that the maximum ordinate value shown at the end of chord DP accurately designates the calculated area of 19.6.

\[ \text{Area} = \frac{1}{4} \pi r^2 \]

\[ \text{Area} = \frac{1}{4} \times 3.1416 \times 5^2 \]

\[ \text{Area} = 19.6 \]

As we mentioned early in this program, we have elected to demonstrate that differentiation is basically the reverse of integration by graphically differentiating the same curve—as shown here—which we derived in Part I by using the chordal method of integration. As our given curve then...
Given: The "given curve" is the curve which was derived by chordal method of integration in Part I, Integration.

Required: Using the chordal method of differentiation, solve for the "derivative" curve.

... let's begin by using this familiar curve, hopefully then,—if in fact differentiation is really the reverse of integration—our derivative curve should resemble an arc of a \( \frac{3}{4} \) circle.

Step 1: Draw a chord where the given curve appears to be steepest. The purpose of this is to determine the numerical value of the ordinate axis on the derivative curve. In this case the maximum slope is about 5 units. Use a convenient scale and allow for an ordinate of 5 units on the derivative curve.

Control Narrative Only: (Please stop the program and study these constructions for a few moments.)
The following slide was not included in the control treatment series.

At this time, in the practice space provided for Step 1, please sketch the construction called for in Step 1. Please stop the tape while you do this.

\[ \text{In each of the practice spaces below, please sketch the constructions explained for that step.} \]
Step 2: Draw any line of known slope on the given curve. The slope shown here has a slope of 4. Draw line 4P parallel to the known slope to locate pole point P.

Experimental Narrative: (Stop the program and sketch these constructions in Practice Space 2.)

Control Narrative: (Please stop the program and study these constructions for a few moments.)

Step 3: Construct a series of chords on the given curve as shown. (Use short chords for sharp curves and longer chords for flatter curves.) Draw the lines through pole point P parallel to each chord as shown.

Experimental Narrative: (Please stop the program and sketch these constructions in Practice Space 3.)

Control Narrative: (Please stop the program and study this slide for a few moments.)
Step 4: Construct vertical lines downward as shown through the end points of each chord. Now draw horizontal lines through points A, B, and C to define the height of each strip.

**Experimental Narrative:** (Please stop the program and sketch these constructions.)

**Control Narrative:** (Please stop the program and study this slide for a few moments.)

Step 5: Finally, use an irregular curve and carefully draw the derivative curve through these intervals near the midpoint at the top of each strip. Construct the curve to have approximately equal areas under and over the "mean ordinate" at the top of each strip.

**Experimental Narrative:** (Please stop the program and sketch these constructions in Practice Space 5.)

**Control Narrative:** (Please stop the program and study this slide for a few moments.)
APPENDIX O

Student Opinionnaire
STUDENT OPINIONNAIRE AND BACKGROUND SURVEY FORM

PART I

1. Name
   (Last) (First) (Middle Initial)

2. Age

3. Instructor's Name

4. Academic Classification:
   Freshman
   Sophomore

5. Major:

6. High School Last Attended:
   (City) (County) (State)

7. Number of Semesters of High School Mechanical Drawing: (Circle One)
   0 1 2 3 4 5 6 7 8

8. Number of Semesters of High School Mathematics:
   Algebra I 0 1 2 (Circle One)
   Plane Geometry 0 1 2 (Circle One)
   Algebra II 0 1 2 (Circle One)
   Solid Geometry 0 1 2 (Circle One)
   Trigonometry 0 1 2 (Circle One)
   Analytic Geometry 0 1 2 (Circle One)
   Calculus 0 1 2 (Circle One)

9. College Math Course Currently or Most Recently Enrolled in:
   (Course Number) (Course Title)
PART II - Directions:

In cooperation with your instructor, an effort is being made to improve the quality of this course. Your assistance in responding to the following items will help to provide this improvement. For each of the following statements, please select the response which best describes your opinion, and record it in the appropriate blank. If you have no opinion about a particular statement, record a "3" (neutral).

Rating Scale:

5—Agree
4—Somewhat Agree
3—Neutral or No Opinion
2—Somewhat Disagree
1—Disagree

Statements:

1. I prefer the slide program including the step method with sketching practice to the slide program without sketching practice.

2. The slide program which included the step method instruction sheet with sketching practice and slide-quiz questions with response card was more interesting than a lecture-chalkboard method of presentation.

3. The slide program which included the step method instruction sheet without sketching practice and the slide-quiz questions with response card was more interesting than a lecture-chalkboard method of presentation.

4. The review quiz at the end of each slide program provided a thorough review of the information presented.

5. Slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cards, taped narrations, and review quizzes should become a permanent part of drafting and engineering graphics courses.

6. I would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in a calculus course.

******* Additional Comments or Suggestions:
APPENDIX P

Summary of Student Recommendations and
Reactions to the Slide-Tape Presentations
SUMMARY OF STUDENT RECOMMENDATIONS AND REACTIONS TO THE SLIDE-TAPE PRESENTATIONS

1. In reference to slide-quiz question No. 6, I feel that this program could be beneficial to many high school calculus courses.

2. Personally, I do not like the slide program at all.

3. I feel that after the presentation and before the criterion test that it would be helpful to have a question and answer period with the instructor to eliminate any uncertainties.

4. A thorough introduction and explanation of a new method of instruction being tried should be presented at the beginning of such an activity.

5. The slide show would be better if assisted by actual instruction where questions could be asked.

6. Please add more practice sketching during the program.

7. The slide show would be alright if we had an opportunity to ask questions after the slide show was presented.

8. Better to use not in class but maybe as a review in the library.

9. The slides move too fast to comprehend the information to have a test at the end.

10. It's pretty good, but students still need personal contact with an instructor to ask questions and such.
APPENDIX Q

Faculty Opinionnaire
FACULTY OPINIONNAIRE

Part I

DIRECTIONS: For each of the following statements, please select the response which best describes your opinion and record it in the appropriate blank. If you have no opinion about a particular statement, record a 3 (neutral).

RATING SCALE

5—Agree 3—Neutral or 2—Somewhat Disagree
4—Somewhat Agree No Opinion 1—Disagree

1. I prefer the slide program including the step method with sketching practice to the slide program without sketching practice.

2. I prefer the slide-tape presentations complete with the step method in color with sketch format as the instructional method by which to best initially present the math concepts of differentiation and integration over the traditional lecture-chalkboard method of instruction.

3. The photographic slides used were an effective means of presenting the subject material.

4. Each slide series was comprehensive enough for the student to meet the objective(s) of the unit.

5. Slides, complete with step method instruction sheets, sketching practice, slide-quiz questions and response cords, taped narrations, and review quizzes should be incorporated as a permanent part of drafting and engineering graphics courses.

6. The example curves utilized on the step method instruction sheets were effective in illustrating the practical aspects of the topics covered.

7. Less class time is consumed when using slide presentations, complete with review quizzes and taped narrations, than by the traditional lecture-chalkboard method of instruction.

8. I personally would prefer to have seen the slide programs on Graphical Integration and Graphical Differentiation prior to enrolling in my first calculus course.

Part II

Additional Comments or Suggestions: (use back side of this sheet)
APPENDIX R

Summary of Faculty Recommendations for Slide-Tape Presentations
SUMMARY OF FACULTY RECOMMENDATIONS FOR SLIDE-TAPE PRESENTATIONS

1. Students need more practice, preferably with more instructor interaction.

2. I felt that your program was well thought out and thoroughly covered graphical integration and differentiation.

3. I would, if teaching this material, integrate the slide program as an integral part of the overall instruction.

4. The programs are comprehensive enough but not repetitious enough.

5. Your methodology shows potential and can be expanded upon.