72-5209

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AUDIO-TUTORIAL VERSUS CONVENTIONAL METHODS OF TEACHING SLIDE RULE.

Iowa State University, Ph.D., 1971
Education, general

University Microfilms, A XEROX Company, Ann Arbor, Michigan

Audio-tutorial versus conventional
methods of teaching slide rule

by

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A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Education

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Area

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1971

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INTRODUCTION

Background

The task of teaching engineering technology students at Iowa State University how to use the slide rule has historically been accomplished by using the conventional method of "lecture and practice." However, this method of teaching the use of the slide rule leaves much to be desired when one evaluates it in terms of

(1) Individual differences among students with different levels of past achievement, in the rate at which they learn, and in manual dexterity and muscular control capabilities,

(2) Efficient use of students' and instructors' time,

(3) Efficient use of available classroom facilities, and

(4) The cost of offering the slide rule course in terms of the number of students per instructor.

Good (4) defines teaching in the following manner: "the act of providing situations, conditions, or activities designed to facilitate learning on the part of those formally engaged in attending school or informally engaged in learning activities."

Most instructors who teach the conventional slide rule course follow the same basic plan, and each one provides approximately the same situations, conditions, and/or activities designed to facilitate learning how to use the slide rule.

It seems that it might be possible to design an audio-tutorial slide rule course in which appropriate situations, conditions, and/or activities are provided to facilitate learning how to use the slide rule. In addition, it seems that in an audio-tutorial slide rule course it might be possible to eliminate, or at least minimize, the shortcomings of the conventional slide rule course.

This study is concerned with the design of an audio-tutorial slide rule course, and a comparison of actual student performance in such a course versus student performance in a conventional slide rule course.

The Conventional Slide Rule Course

Engineering technology students enrolled in the conventional slide rule course at Iowa State University are scheduled to attend three two-hour sessions each week. Since six hours of classtime are required each week, and since it is only a two quarter credit course, the students have very little, if any, slide rule homework assigned between class meetings. The instructor of a conventional slide rule class usually starts a two-hour class period by lecturing on the material to be covered that day. Then he solves a few example problems using a large demonstration slide rule which hangs on the front wall of the classroom. Each student is encouraged to use his own slide rule to duplicate each step of the solution of each example problem while the instructor is doing it (and also talking about it) on the demonstration slide rule. This procedure requires that the student simultaneously watch the demonstration, listen to the instructor, and duplicate the solution using his own slide rule. These three activities are in addition to any note-taking activity the student may wish to do, or need to do.

Eventually the instructor decides that he has demonstrated the proper method of solution of a sufficient number of example problems (or the time allocated to demonstrations runs out), and the students indicate (by not asking any more questions) that they understand the procedures. At this time the instructor distributes to each member of the class one or more drill sheets which consist of several problems of the type that he just finished discussing. The students are informed of the number of minutes they have to solve all the problems on the drill sheets, and at the end of the specified time interval the papers are collected. In most cases, no special arrangements are made for those students who finish the work in less than the allowed time nor for those students who are unable to finish before the time limit expires.

If the two-hour class period has not expired by the time the drill sheets are collected, the students are either dismissed or the remaining time is spent repeating the above described procedures on a new problem type.

The instructor usually makes an honest attempt to assure that the paper grader gets the papers scored before the next class meeting. If he is successful, the students get their papers back in 48 hours, and each paper is marked with a numerical grade for accuracy of answers and an additional grade for neatness and quality of workmanship. The slow student is penalized for not solving all the problems since a blank answer space is treated as an incorrect answer. The student who hurried through the problems, and did in fact obtain an answer for each problem, is penalized for his inaccuracy and the poor workmanship which may have resulted from his careless haste.

The conventional slide rule course does not adjust to individual differences among students. Some students come into the course with a rather strong background in using the slide rule. Many students learn the rudiments of the slide rule, and its various scales in high school. Also many students have had a rather rigorous exposure to the slide rule in the technical training programs offered by the various branches of the armed forces. On the other hand, many students who enter the conventional slide rule course have had no previous training or exposure to the slide rule. In spite of this heterogeniety of student population, the conventional slide rule class effectively forces all members of the class to proceed at the same pace. As a result, some students get bored with what seems to be a slow pace while others get frustrated with what they see as a rapid pace.

Need for the Study

The audio-tutorial method of teaching has been proven effective in subjects involving the assimilation of ideas and the orderly presentation of the fundamental concepts of biology, agronomy, etc., but very little evidence is available to prove or disprove that audio-tutorial methods of instruction are effective in subjects that require the cultivation of both mental discipline and certain manipulative skills.

Problem

This study was designed to investigate and also evaluate the effectiveness of audio-tutorial methods of teaching in a slide rule course in which the student is required to develop certain manipulative and mental skills.

The ultimate goal of the study was to provide evidence to test the notion that audio-tutorial methods might be positively effective in teaching the use of the slide rule. In order to accomplish this goal it was necessary to

(1) Develop audio-tutorial instructional material which could be used to teach the use of the slide rule,

(2) Design an experiment in which a control group took the slide rule course in the conventional manner and an experimental group took the slide rule course in

the audio-tutorial format,

(3) Develop and administer measurement instruments, i.e. examinations, to both groups, and

(4) Evaluate the performance of the experimental group versus the performance of the control group.

Objectives

The objectives of this study were to answer the following broadly stated questions:

(1) Do students who receive slide rule instruction in the audio-tutorial format achieve the same as students who receive slide rule instruction in the conventional format?

(2) Does audio-tutorial slide rule instruction benefit some students more than others? If so, what are the characteristics of these students?

Selection of the Population of Students

The study was conducted during the fall quarter, 1970, at Iowa State University. The engineering technology students enrolled in the course entitled Technical Problems I constituted the population of the experimental and control groups.

About ninety percent of the content of this course is concerned with teaching the proper use of the slide rule in the solution of technical problems. The remaining ten percent of the course content is concerned with teaching proper workmanship standards for the presentation of problem solutions on standard engineering problems paper, fundamentals of unit conversion techniques, and dimensional analysis. This division of the course content results in the final course grade for each student being determined almost entirely by his performance on examinations over the slide rule material.

Assignment of Students to Groups

Six sections of the slide rule course were offered fall quarter 1970. Each student was classified into one of the sections by the departmental secretary without any regard whatsoever as to the personal desires or characteristics of the student. The only objective in the process of classifying a student into a particular section was to maintain an equal number of students in all sections. For all practical purposes, this procedure corresponds to random assignment of students to sections.

Three of the six sections were selected by a random process to form the experimental group, and the remaining three sections formed the control group. The number of students in each group was approximately equal.

Sources of Data

The statistical analysis of data was based on data which were obtained from two sources. These sources of data were:

(1) Examinations over the slide rule course material and

(2) Independent variables selected to describe the academic characteristics of the students in both groups.

Each of these two sources of data is discussed below.

Examinations over the slide rule course material

The following examinations were administered:

(1) Three one-hour examinations which were administered at appropriate times during the course.

(2) A post-test which was administered at the conclusion of the course.

Independent variables

Seven independent variables which were selected to provide a description of the academic characteristics of the students in both groups are listed below. The list is followed by a brief discussion of each one.

(1) The Minnesota Scholastic Aptitude Test

(2) The College Level Mathematics Placement Examination score

(3) The percentile rank in high school graduating class

(4) The final grade in Applied Mathematics I (Math 50)

(5) The Otis-Gamma IQ test score

(6) The Spatial Relations test score

(7) The pre-test score

Minnesota Scholastic Aptitude Test This is one of a series of tests administered to all incoming students at Iowa State. Each student's raw score was used in this study. Hereinafter, this item of data will be referred to as "MSAT".

College Level Mathematics Placement Examination This examination is also one of a series of tests administered to all incoming students at Iowa State. Each student's raw score was used in this study. Hereinafter, this item of data will be referred to as "Math Placement".

Percentile rank in high school graduating class Each student admitted to Iowa State University is required to supply accurate information about his percentile rank in his high school graduating class. A large percentile rank is indicative of low class rank, whereas, a small percentile rank is indicative of high class rank. Hereinafter, this item of data will be referred to as "Percentile HSR".

Final grade in Applied Mathematics I This is a five quarter credit algebra-trigonometry course that most of the students were taking concurrently with the slide rule course. Letter grades were converted to numerical scores according to the following scale: A = 6, B = 5, C = 4, D = 3 and F = 2. Hereinafter, this item of data will be referred to as "Math

50 grade".

<u>Otis-Gamma IQ test</u> This standard ability test was administered to the students in both groups late in the quarter. Hereinafter, this item of data will be referred to as "Otis-Gamma".

<u>Spatial Relations test</u> This is one part of a Multiple Aptitude Test devised by David Segal and Evelyn Raskin. It was administered to the students late in the quarter. Hereinafter, this item of data will be referred to as "Space Relations".

<u>Pre-test</u> The pre-test was a one hour examination administered at the outset of the quarter. It was designed to measure each student's ability to use the slide rule to solve various problems similar to those that were to be encountered throughout the quarter. A copy of the pre-test is included in Appendix E.

Hypotheses

Three groups of null hypotheses were formulated and tested in the statistical analysis of data at the conclusion of the study. The three groups were:

(1) Null hypotheses in regard to performance on examinations.

(2) Null hypotheses in regard to the independent variables.

(3) Null hypotheses in regard to several two-factor analyses in which the group classifications

(experimental and control) were used as the subdivisions of one factor, and high and low classifications of the independent variable data were used as the subdivisions of the other factor.

Each group of null hypotheses is presented below.

Null hypotheses in regard to performance on examinations

The following null hypotheses were formulated and tested in regard to performance on examinations.

(1) There is no difference between the mean scores of the experimental group and the control group on the first one-hour examination.

(2) There is no difference between the mean scores of the experimental group and the control group on the second one-hour examination.

(3) There is no difference between the mean scores of the experimental group and the control group on the third one-hour examination.

(4) There is no difference between the mean scores of the experimental group and the control group on the post-test.

The raw scores on each of the three one-hour examinations and the post-test were converted to standard scores, and then a "total score" datum point was calculated for each student by summing his standard scores on the three one-hour examinations plus twice his post-test standard score. The following null hypothesis was tested.

(5) There is no difference between the mean total score of the experimental group and the control group.

Null hypotheses in regard to the seven independent variables

The following null hypotheses were formulated and tested in regard to the independent variables.

(1) There is no difference between the mean MSAT scores of the experimental group and the control group.

(2) There is no difference between the mean Math Placement scores of the experimental group and the control group.

(3) There is no difference between the mean Percentile HSR of the experimental group and the control group.

(4) There is no difference between the mean Math 50 grades of the experimental group and the control group.

(5) There is no difference between the mean Otis-Gamma scores of the experimental group and the control group.

(6) There is no difference between the mean Space Relations scores of the experimental group and the control group.

(7) There is no difference between the mean pre-test scores of the experimental group and the control group.

Null hypotheses in regard to the two-factor analyses

Three null hypotheses were formulated and tested in each of seven two-factor analyses performed for the first one-hour examination. In each two-factor analysis, the group classifications (experimental and control) were used as the subdivisions of one factor (called factor A), and high and low classifications of an independent variable were used as the subdivisions of the second factor (called factor B).

Each two-factor analysis performed for the first one-hour examination is described below, and then the three null hypotheses for it are stated. A total of 21 null hypotheses in regard to the two-factor analyses performed for the first one-hour examination are stated below.

1. Factor A: Group

   Factor B: MSAT

   Null hypotheses:

   1.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the MSAT scores.

   1.2 There is no difference between the mean scores on the first one-hour examination for both classifications of MSAT over both classifications of the group factor.

   1.3 There is no interaction between the group factor and the MSAT factor on the first one-hour examination.

2. Factor A: Group

   Factor B: Math Placement

   Null hypotheses:

   2.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the Math Placement scores.

   2.2 There is no difference between the mean scores on the first one-hour examination for both classifications of Math Placement over both classifications of the group factor.

   2.3 There is no interaction between the group factor and the Math Placement factor on the first one-hour examination.

3. Factor A: Group

   Factor B: Percentile HSR

   Null hypotheses:

   3.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of Percentile HSR.

   3.2 There is no difference between the mean scores on the first one-hour examination for both classifications of Percentile HSR over both classifications of the group factor.

3.3 There is no interaction between the group factor and the Percentile HSR factor on the first one-hour examination.

4. Factor A: Group

Factor B: Math 50 grade

Null hypotheses:

4.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of Math 50 grade.

4.2 There is no difference between the mean scores on the first one-hour examination for both classifications of Math 50 grade over both classifications of the group factor.

4.3 There is no interaction between the group factor and the Math 50 grade factor on the first one-hour examination.

5. Factor A: Group

Factor B: Otis-Gamma

Null hypotheses:

5.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the Otis-Gamma scores.

5.2 There is no difference between the mean scores on the first one-hour examination for both classifications of Otis-Gamma over both classifications of the group factor.

5.3 There is no interaction between the group factor and the Otis-Gamma factor on the first one-hour examination.

6. Factor A: Group

Factor B: Space Relations

Null hypotheses:

6.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the Space Relations scores.

6.2 There is no difference between the mean scores on the first one-hour examination for both classifications of Space Relations over both classifications of the group factor.

6.3 There is no interaction between the group factor and the Space Relations factor on the First one-hour examination.

7. Factor A: Group

Factor B: Pre-test

Null hypotheses:

7.1 There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the pre-test scores.

7.2 There is no difference between the mean scores on the first one-hour examination for both classifications of pre-test over both classifications of the group factor.

7.3 There is no interaction between the group factor and the pre-test factor on the first one-hour examination.

All of the above described two-factor analyses were also performed for the second one-hour examination, the third one-hour examination, the post-test and, finally, for the total score.

The null hypotheses (21 in all) which were formulated and tested in the seven two-factor analyses for the second one-hour examination are identical to those listed above except that the words "second one-hour examination" are inserted in place of the words "first one-hour examination".

In a similar fashion the null hypotheses which were formulated and tested in the two-factor analyses for the third one-hour examination, the post-test and the total score are identical to those stated above except that the words "third one-hour examination" or "post-test" or "total score" are appropriately inserted for the words "first one-hour examination".

A grand total of 105 null hypotheses were formulated and tested in the course of performing the 35 two-factor analyses.

REVIEW OF THE LITERATURE

Pressey (16) pioneered in the field of individualized instruction in 1926, but the concept of this type of instruction is much the same today as it was then. The equipment available for individualized instruction is more sophisticated and more plentiful today than it was then, and contemporary educators know more about individualized instruction today than did the educators of that day. Individualized instruction has the capability of integrating and appropriately sequencing the use of learning media and materials. It can be readily adapted to the great variation in students' backgrounds, aptitudes and interests, while it still places control of learning with the student.

One type of individualized instruction is audio-tutorial instruction. Audio-tutorial methods of instruction are currently being employed in many fields in a wide variety of subjects.

Pullias (17) describes the characteristics of effective teachers and effective teaching, and he makes the observation that the teacher must perform four basic, closely related tasks in his role in the educative process. First, the teacher must define his objectives with great care. He must know precisely what he expects the student to learn and what levels of achievement he expects the students to attain. The objectives should be clear to the teacher and also to the student. They should be adjusted to the student's ability level, his background and maturity, and they should be reasonably attainable. Second, the teacher must assure that the student engages in activities that will produce learning and thereby achieve the objectives. Third, the teacher must impart life and imagination to the materials which are the means of learning. He should employ imagination in the process and relate the learning to the needs and interests of the students. Fourth, the teacher must evaluate the student's progress in learning and help the student develop the habit of self-evaluation.

Pullias declares that the quality of the teacher's work is largely determined by his personality and character traits. Six qualities which give the teacher special power, according to Pullias are:

1. Integrity or authenticity: a freedom from falseness or pretense.
2. Enthusiasm or zest: an ardent belief in the significance of what one is doing and the energy to put life into it.
3. Perspective or length and breadth of view: manifested frequently in a sense of humor, patience, freedom from the scourge of perfectionism.
4. Freedom of mind and especially freedom of imagination: a trait that encourages ideas to flow freely, an

eagerness to consider many alternatives.

5. Breadth of interest or sensitivity to a wide spectrum of life: manifested in wide reading and varied concern.

6. An abiding concern for the individual learner: an ability to feel and communicate the notion that the individual learner is significant, that he has potential of great worth, and that it can be realized.

The principles presented by Pullias are applicable to all levels and types of teaching.

In 1926 S. L. Pressey (16), of the Ohio State University, expressed his opinion that he could design and build a simple machine for automatic testing of intelligence or information. He felt that the modern objective test lent itself quite naturally to an automated procedure by virtue of the systematic and strictly objective manner in which it is administered and scored.

In addition to automating a testing procedure, Pressey felt that the machine could, with minor modification, be used as a teaching device. He felt that if this could be accomplished, the teacher could spend more time in pursuing"... those inspirational and thought stimulating activities which are, presumably, the real function of the teacher."

Pressey's device operated in a manner such that the questions were presented to the students one at a time in the multiple choice format. The student would read a question and select one of the answers and then depress the appropriate key to record his selection. The act of depressing the key would cause the machine to present a new question and also keep track of the number of correct responses by incrementing a counting device. At the conclusion of the testing period the instructor determined the number of correct responses by simply reading the counter dial.

Pressey modified his machine to enable him to use it as a teaching device as well as a testing mechanism. The mechanism was modified in such a fashion that the student had to depress the key for the correct answer to the current question before the machine would present the next question. Consequently, if the student made an incorrect response to a question, he would have to select other answers until he finally selected the correct one which would automatically advance the machine to the next question. The machine kept track of the number of incorrect responses for each question.

There were a number of advantages to the student and also to the instructor when the device was used in this fashion. The most obvious advantage for the student was that he knew immediately when he had made a mistake. He did not have to wait one day or perhaps several days before he knew where he was right and where he was wrong since he had to answer each question correctly before he was allowed to proceed.

S. N. Postlethwait (15), a botany professor at Purdue University, is one of the foremost modern pioneers in the field of audio-tutorial instruction. He observed that students with essentially equal capacities could not perform at equal levels in his botany class which primarily served freshman students in fields other than botany. To assist the students with poor background, a plan was initiated whereby he (Postlethwait) would record a special lecture on tape each week and then file it in a location of convenient access to the students. Students listened to the supplementary taped lecture on a voluntary basis. Postlethwait soon discovered that he could just as well have the students refer to sections in the text book while they were listening to the lecture in order to facilitate relating textual subject matter to the lecture subject matter. The laboratory manual was soon included in the process in order that the laboratory manual subject matter could easily be related to the text subject matter and also to the subject matter in the tape lecture. The next logical step was to provide the students with plants and other experimental materials so that these too could be used in conjunction with the laboratory manual, the text, and the tape recorded lecture. In Postlethwait's words "...the discussion on tape was no longer a lecture but rather a discussion on a one-to-one basis, one-teacher-one-student, in which I was tutoring the student through a sequence of learning events."

Being encouraged by student response to this first informal experiment, Postlethwait arranged to offer the course for an entire semester to 36 students using the audio-tutorial format. At the end of the semester it was found that students learned just as much one way as they did the other. At the end of the semester the 36 students were interviewed, and their comments were considered during the process of restructuring the entire course. Restructuring the course was accomplished with complete disregard of any traditional limitation, and total emphasis was placed on student learning. The new, restructured botany course was permanently established utilizing audio-tutorial instruction.

The original modification of the botany course was to simply include an optional Independent Study Session in the old course. The new, restructured course consisted of the Independent Study Session (variable hours per week), the General Assembly Session (one hour per week), and a Small Assembly Session (one hour per week). Later the Small Assembly Session was replaced by an Integrated Quiz Session (IQS) which consisted of a modified seminar and an oral quiz. In the IQS, students would gather around a conference table in groups of eight and the instructor would display physical material from the previous week's experiments. Each student in turn orally discussed different portions of the materials and the instructor recorded a subjective grade for each student based on his initial solo discussion and his subsequent contributions to the group discussions. The IQS became a useful vehicle to accomplish several goals, and it also served as an effective tool to prevent procrastination on the part of the students.

The question always comes up about whether or not the audio-tutorial system eliminates the personal contact between student and instructor which is so important for motivation. Postlethwait declares that the audio-tutorial system actually enhances personal contact. The opportunities for personal contact are as follows:

1. The senior instructor is available at the General Assembly Session.
2. An instructor is available during the Independent Study Session to give direct attention to individual needs on a one-to-one basis for any problem requiring instructor assistance.
3. The IQS provides an opportunity for every student to become well known by at least one instructor in the course, and every student to know at least one instructor very well. Additional opportunity is available for every student to know many instructors well, but there is no alternative but to become well acquainted with at least one instructor.

In a recent issue of The Journal of Engineering Education, Hurst et al. (6), describe a system currently in use at Purdue University which is actually an extension of the method used by Postlethwait. Introductory biology and zoology courses are being taught in small conceptual units called minicourses. The minicourse approach coupled with the flexibility of audio-tutorial teaching permits the student some freedom in selecting a schedule compatible with his interest and his self-determined achievement level.

Each student is told at the outset of the course that he will receive at least a C if he completes the course, and that if he does not complete the course, no grade will be submitted for him.

Subject matter is divided into minicourses and each minicourse is assigned a unit value which indicates the estimated study time required in the learning center by the average student.

The format for the conduct of the course follows the plan of the General Assembly Session, the Independent Study Session (ISS), and the Integrated Quiz Session (IQS) with the major changes being in the ISS and IQS. If a student's performance in these two sessions does not equal or exceed some predetermined level of acceptance, then the student is required to do supplementary work until he achieves the acceptable level of performance.

Students who complete the course and do only the minimum required work receive a C grade at the end of the semester. If a student wishes to get an A or B grade in the course, then he must do extra work. He may select his extra work from a list of written suggestions which is made available to all students. Students earn A and B points by performing the extra work. Each suggestion is worth a specific number of points, so a student can earn an A in the course by collecting enough points to equal the predetermined number of points required for the A. When extra work is finished, and before points are awarded, the students are required to answer some A-B type questions. These questions require more from the student than rote memorization which would probably suffice for the C level. The questions "...are designed to cause the student to synthesize, hypothesize, and apply concepts and principles learned from his Independent Study Session experience, and, therefore, to demonstrate clearly his A-B level of learning."

In the interest of improving his teaching effectiveness in a metallurgy course, Sidney H. Avner (1), Chairman of Mechanical Technology at New York City Community College, embarked on a program of audio-visual self-instruction. Recognizing that a wide variation existed among his students in the ability to absorb and understand material, Avner felt that some means must be made available for student self-instruction in order that each could proceed at his own pace in preparation for class and/or for reinforcement and review.

Sixteen tape recorded lectures, each with a coordinated series of slides, were prepared and placed in a learning center which contained individual study booths. The students were informed that they were required to use the audio-visual materials since they contained all of the lecture material. No class time was used for lecturing, but rather was devoted entirely to discussing applications of the subject matter. After listening to one of the tape-slide programs, the student would obtain, from the attendant, a question sheet on the program material. If the student wished to review some part or all of the program material while answering the questions, he was free to do so. Upon request, the attendant would provide the student with the correct answers so the student could have immediate feedback on his degree of success with the material.

At the outset of the course the students were told how the course would be conducted, the objectives were explained, and a list of the programs and their running times was distributed. Also distributed at the outset of the course was a complete assignment sheet which included the textbook assignment and the appropriate program number to be studied prior to each session of the class. At the beginning of each classroom session a ten minute quiz was given over the program material. Questions by the students were fielded, and these often served as the starting point for a discussion on applications of the theory.

At the end of the course Avner observed that the students were more enthusiastic about metallurgy than previous classes had been. He also observed that he gave more high grades than he had given in previous classes.

Avner surveyed his class at the end of the semester and found that: 70% considered the tape-slide system to be very effective or above average in effectiveness as a medium for instruction; 67% thought that the classroom sessions helped them learn to think; 85% felt that the questions and answers for each program did provide adequate feedback; 93% would like to take another metallurgy course. Apparently most students liked the idea of having audio-visual material available for self-instruction.

Earl T. Ratledge (19), Assistant Professor of Engineering Graphics at the University of Wisconsin, Milwaukee, developed a system of individualized instruction in his freshman graphics course. His primary objectives were to reduce student time loads, promote more efficient learning and understanding, and to reduce the number of instructor hours needed for teaching the introductory graphics courses.

The material was presented to the students through reading assignments, tape-slide presentations, 16 mm sound movies, 8 mm single concept films, laboratory drawing plates, and single topic work sheets. Eighteen instructional units were prepared. Each one included behavioral objectives statements, study assignments, assignment of visual presentation, a list of problem assignments, and a list of procedures to follow after completing the study and laboratory work.

The instructional materials were made available to the students at stated hours during the day under the supervision of a student helper. The instructor provided individual help and checked drawings, and each student could take an examination whenever he felt he was ready. It was scored immediately, and if his performance was not satisfactory, he was required to review the unit material and then take a second alternate examination.

Two groups of students were organized -- a control group and an experimental group. Accurate records of student performance on all major examinations were kept. Also kept was a record of the time required for students in both groups to complete the course. Students in the experimental group were allowed to proceed at their own pace within each week so both groups maintained essentially the same rate of progress throughout the course. No limit was set on the number of hours a student in the experimental group could spend in completing a week's material whereas students in the control group were effectively limited, by normal class scheduling, in the number of hours they had available to absorb the instruction.

The two groups were given identical unit examinations and on these the experimental group had less than 2% failing grades while the control group had just short of 30%. The two groups were comparable in terms of grade span on the major examinations, but the experimental group had fewer failing grades.

The students in the experimental group spent 25% less time on the course than students in the control group did.

Instructor contact time was reduced by about 25% in the experimental group. The instructor time spent was almost 100% in direct personal contact with individual students. Each student was in direct personal contact with the instructor at least twice during each unit. Instructors in the experimental group were more intimately familiar with the capabilities of individual students than were their counterparts in the control group.

Audio-tutorial instruction is being employed in a senior level electrical engineering communications laboratory course at Purdue University by Professor John C. Lindenlaub (10, 11, 12). He uses audio-tutorial tapes to replace the conventional set of mimeographed notes and the laboratory preparation session.

Before the introduction of audio-tutorial techniques into the communications laboratory course, each student attended a scheduled three-hour laboratory period each week. This rigidly structured period was eliminated when audio-tutorial teaching techniques were introduced and an accompanying "open-shop" laboratory policy was implemented. Students were permitted to come to the laboratory at their convenience, to spend as much or as little time as they needed. Upon completion of each experiment each student was examined orally. This plus the individual help during the experiment served to offset any impersonal impression or sense of remoteness that might be associated with the tape recorder.

Lindenlaub made no attempt to analyze any data statistically, but he felt that the students learned just as much under the new system as they did under the old.

If one of the instructional objectives is to develop skills, audio-tutorial instruction is particularly valuable according to Lindenlaub. Effective teaching takes place if one can activate the senses of sight, touch, and hearing simultaneously. By using audio tapes the instructor can describe the function of a control knob on a piece of electronic test equipment and simultaneously instruct the student how to properly manipulate it to produce desirable results. This immediately illustrates the operation of the control knob and avoids the tedious reference to written instructions.

Audio-tutorial instruction coupled with the "open-shop" laboratory policy allowed the student to proceed at his own pace in a relaxed fashion and with a receptive mind. Using the tape recorder the student could easily rewind the tape and listen to any part of the lecture again. This advantage is not available if the lecture is live. Lindenlaub feels that the instructor has more opportunity for meaningful interaction with his students. He can tailor his teaching activities to meet individual needs.

Lindenlaub uses cassette tapes and tape recorders. They are relatively inexpensive and simple for the students to operate. Another advantage he sees in using this equipment is that "branch points" can be included in the taped lecture. At any point in the lecture the instructor can have the student stop to remove the main tape lecture from the recorder, and insert another tape which simply expands upon, and provides more detail on, the topic being discussed in the main lecture. The use of the extra material can either be required or optional.

Student reaction to the audio-tutorial laboratory course was essentially 100% in favor of the method. All but one of the 57 students expressed a desire to continue the method in the subsequent laboratory course. Lindenlaub wasn't sure whether the overwhelming positive reaction was due to the audio-tutorial method itself, the open laboratory policy, the individual attention of the oral examinations, the novelty of the approach, or some combination of these factors.

The Department of Electrical Technology at Purdue University uses audio-tutorial teaching techniques in selected laboratory courses (18). These are called "Learner Controlled Laboratories" to distinguish them from those laboratory courses which are taught in the traditional manner. The techniques used in these laboratory courses are essentially parallel to those used by Lindenlaub in his communications laboratory. The major difference is that colored slides are used in conjunction with the audio-tape whereas Lindenlaub used only the audio tape and some coordinated printed material.

Lindenlaub (12) suggests a four step procedure for the preparation of audio-tutorial materials.

(1) "List the objectives of the unit of instruction... Answers are needed to such questions as: What do you expect the students to accomplish? What level of achievement do you expect? What do you expect the student to be able to do after completing the lesson? The objectives must be expressed in behavioral terms",

(2) "...the points to be taught should be put in logical order and studied as to the best way to teach them." Material to be used in conjunction with the tape recorded lecture should be prepared prior to the act of recording the lecture.

(3) "...make a rough draft tape". This can be accomplished in any one of several ways -- use a written outline, make the tape while actually talking to a student, or perhaps prepare a written script.

Lindenlaub found that the third alternative resulted in the smoothest tape, but it was expensive in terms of the amount of time required, and

(4) Finalize all the materials that the students are to have in hand before they start a lesson. A set of notes which includes an outline or a flow chart of the lesson should accompany the tape to enable students to get a quick overview. The notes should also include an estimate of the time required to complete the lesson in order that the student can plan his activities and his study schedule. The notes used in conjunction with the body of the tape recorded lecture should contain figures, formulas, block diagrams, etc. Neither the tape recorded lecture nor the notes should be complete in themselves, rather they should complement one another.

Hamelink (5) observed that laboratory work and measurement engineering have traditionally had a minor role and low prestige in engineering education at Western Michigan University. Conversations with practicing engineers revealed that one of industry's greatest problems is obtaining graduate engineers who have some knowledge and skill in measurements and some active interest in experimental work. Hamelink adapted audio-tutorial teaching methods in his measurement engineering course in an effort to up-grade the quality and status of the course and improve student interest in it. The course was structured according to the following allocation of time: a one-hour lecture per week devoted to discussing experimental design, data acquisition, and data evaluation; a one-hour recitation per week devoted to discussing experimental engineering concepts, instrument theory, and general laboratory procedures; and one laboratory session of one to four hours per week (scheduled individually according to student convenience) in which each student is individually involved with a variety of instruments and practice with experimental design and execution. Self-instructional tapes were used to teach the student the operation of basic laboratory equipment such as oscilloscopes and strip chart recorders. The students followed the instructions on the tape, operated the test equipment, and performed basic operations and experiments. A lab assistant was available at all times to answer questions and supervise equipment.

No attempt was made to analyze data to evaluate the success of the procedures used in the conduct of the course, but student reaction was generally enthusiastic. At the conclusion of the course the students were asked to submit their written comments and observations in a follow-up study. In general, the comments and observations were constructive and were useful in the revision of the tape recorded material.

Summary

The review of the literature has attempted to provide an overview of the usage of audio-tutorial methods of instruction at institutions of higher learning. S. N. Postlethwait became the modern pioneer of audio-tutorial instruction when he used the method in his botany course at Purdue University. Since Postlethwait's first experiment with audio-tutorial instruction, the method has been, or is being, used in a variety of subjects at virtually every level of higher education.

Articles which describe the use of audio-tutorial instruction in the fields of botany, biology, zoology, metallurgy, engineering graphics, electrical engineering communicatio laboratory and measurement engineering laboratory are revie d

Without exception the authors of the articles felt that the use of the audio-tutorial method of instruction led to better student performance, improvement of student attitudes and, finally, to better and more personal instructor-student relationships than had been experienced when the more conventional methods of instruction were used.

METHOD OF PROCEDURE

Introduction

This study was conducted at Iowa State University during the fall quarter 1970 to investigate and also evaluate the effectiveness of modern audio-tutorial teaching techniques in a slide rule course as compared to the conventional methods of teaching slide rule. The engineering technology students enrolled in the course entitled Technical Problems I were divided into two approximately equal size groups using the procedure described in Chapter I. One group (control) took the course in the conventional manner, while the other group (experimental) took the course in the audio-tutorial format.

The course content for the experimental group and the control group was identical. Also, examinations administered to both groups were identical, and all examinations were scored in the same manner. Both groups covered the material at the same pace insofar as all students took examinations on the same day.

Organization of the content of the course and schedule preparation

The topics to be covered during the course were grouped into categories according to the scales on the slide rule, and then a schedule for the quarter was planned.

A detailed list of the topics which were covered and the schedule for fall quarter 1970 appear in Appendix A.

Preparation of Materials for the Experimental Group

This investigator prepared the audio-tutorial materials for the experimental group. The material for each lesson consisted of a tape recorded lecture, notes to supplement the lecture, and practice sheets. A total of 46 audio-tutorial lessons were prepared.

Tape recorded lecture

The majority of the tape recorded lectures were less than 20 minutes long. Each lecture followed the same basic format although minor variations in style and organization occurred occasionally to minimize the aspect of monotony. The general outline of the lectures was as follows:

I. A statement of the lesson number

II. A brief description of the topic of the upcoming lecture

III. A statement of the objective of the lesson in behavorial terms, i.e., of what the student should be able to do at the conclusion of the lesson

IV. The main body of the lecture making frequent reference to the information provided in the supplementary notes

V. A few example problems which utilize the information discussed in the main body of the lecture

VI. The conclusion which summarizes the lecture and instructs the student to solve the problems on the practice sheet(s). The conclusion also reminds the student of the objective of the lesson, and it encourages him to try to achieve the objective

The master tape recording of each lecture was recorded on a reel-to-reel tape recorder. The lectures were then reproduced onto cassette tapes which were used by the students in individual study booths as discussed later in this chapter.

A manuscript of the lecture for lesson number 11 is included in Appendix B. This lecture was approximately 16 minutes long and is representative of all 46 lectures in terms of the outline presented above.

<u>Notes to supplement the tape recorded lectures</u>

Each tape recorded lecture was supplemented by a set of notes prepared simultaneously with the preparation of the lecture. Included in the notes were pictures of the slide rule showing the proper settings for the solution of the example problems given in the lecture, and other information such as step-by-step procedures for problem solution which the student could read as well as hear in the lecture. All of the notes were on 11x14 inch paper and were assembled in the form of a manual. The pages in the manual were numbered sequentially and each page was also cross referenced with the appropriate lesson number.

Included in Appendix C is a copy of each page of notes which supplemented the lecture for lesson number 11. These examples of the notes are representative of the notes for the other lessons except that for several lessons the notes included pictures of the slide rule showing appropriate settings to solve example problems given in the lecture.

Practice sheet

Each lesson had associated with it one or more practice sheets which consisted of several problems of the type dealt with in the lecture. The student was encouraged to solve the problems in a manner that would lead to his achievement of the objectives of the lesson.

Included in Appendix D is a copy of each practice sheet for lesson number 11. These practice sheets are representative of the practice sheets for all the lessons in that they illustrate the content of the practice sheet as a collection of problems of the type discussed in the lecture.

Examinations during the quarter

Three one-hour examinations were administered during the quarter. These were designed to measure each student's level of understanding of the subject matter. A copy of each of the three one-hour examinations is included in Appendix F.

Post-test

The post-test was a two-hour examination designed to measure each student's ability to use the slide rule at the conclusion of the course. It was administered at the regularly scheduled time during Final Examination Week. A copy of the post-test is included in Appendix G.

Materials Used in the Control Group and Conduct of the Course for the Control Group

Since the instructors in the control group were teaching the course in the conventional manner (as described in Chapter I) they used the conventional materials. The practice (or drill) sheets used in the control group were virtually identical to the practice sheets used in the experimental group.

The only requirement of the control group instructors in addition to covering the same topics that were covered in the experimental group (as outlined in Appendix A) was to administer examinations on the same day that examinations were administered in the experimental group.

Conduct of the Course for the Experimental Group

The audio-tutorial laboratory where the students listened to the tape recorded lectures and did the assigned work on the practice sheets in individual study booths was open from 8:00 A.M. to 6:00 P.M. weekdays and from 8:00 A.M. to noon on

Saturday. The students were free to come to the audio-tutorial laboratory at their convenience during the week. An attendant was on duty during the open hours. The attendant was one of a group of four instructors which included this writer and three others hired specifically for this purpose. The duties of the attendant included providing individual instruction and assistance to students who had questions and to check all completed work for correctness. When students finished their practice sheets for a particular lesson, they would submit them to the attendant for immediate evaluation. Each student whose performance on any practice sheet did not equal or exceed a predetermined minimum satisfactory level, was required to revise it until his performance met or exceeded the minimum. He was not allowed to continue to the subsequent lesson until he performed satisfactorily on the current one.

Students in the experimental group attended a 50 minute (or shorter) meeting each week in which this writer was present to answer questions and provide any information necessary for the proper administration of the course. The examination week meetings were given over to the administration of the examinations. The weekly meetings provided some contact between the student and the instructor, but the primary purpose of holding weekly meetings was to answer any questions that the students had, and to provide them with a preview of the material for the upcoming week.

FINDINGS

Introduction

The objectives of this study were to answer the following questions:

(1) Do students who receive slide rule instruction in the audio-tutorial format achieve the same as students who receive slide rule instruction in the conventional format?

(2) Does audio-tutorial slide rule instruction benefit some students more than others? If so, what are the characteristics of these students?

The findings are presented in two sections in order to fulfill the above stated objectives. These sections are:

(1) Analysis of performance on examinations

(2) Two-factor analyses

The two sections of findings are preceded by two sections in which the number of students in each group and the independent variable data which describe the academic characteristics of the student population of both groups are analyzed and compared.

Number of Students in Each Group

Forty-seven students were enrolled in the experimental group when the study began, but only 40 of these finished the course. The seven students who dropped out of the experimental group were not included in the statistical analysis of data since none of them took all of the one-hour examinations, and, of course, none of them took the post-test. Also, several independent variable data points were unavailable for these students.

Forty-two students were enrolled in the control group when the study began, and all 42 finished the course. That is, there were no dropouts from the control group during the quarter.

The following question arises: Did the audio-tutorial method of instruction have something to do with the fact that seven students dropped out of the experimental group and none dropped out of the control group? It is not possible to answer the question with absolute certainty, but the answer seems to be no. Justification of this follows.

One of the seven students who dropped out of the experimental group was performing exceptionally well until he withdrew from school and would not provide any reason for this action. It was apparently for a very personal reason, and he just did not wish to discuss it. He tied with two other students in the experimental group for the high score on the first one-hour examination, and only nine other students in the group earned higher scores than he did on the second one-hour examination. He dropped out before the third one-hour examination was given. This student apparently would have dropped out of the control group had he been in that group rather than the experimental group.

The remaining six students who eventually dropped out of the experimental group all earned at least a C mark on the first one-hour examination. Two of these students dropped out before the second one-hour examination was given, and the other four students did considerably poorer on this examination than they had on the first. No one of these six dropouts took the third one-hour examination.

Four of the last six students who dropped out of the experimental group either formally withdrew from Iowa State giving "lack of interest" as their reason, or they merely left the area without formally withdrawing from school. At any rate, these four dropouts did not attend any of their classes during the latter portion of the quarter.

The remaining two dropouts from the experimental group continued to attend classes until the end of the quarter (with the exception of the slide rule class), but they apparently did no work and consequently received virtually all F grades.

Analysis of the Independent Variable Data

Seven independent variables were selected to describe the academic characteristics of the students in both groups. These seven variables were listed and described in Chapter I, and are presented here also for the sake of convenience.

(1) The Minnesota Scholastic Aptitude Test score (referred to as MSAT).

(2) The College Level Mathematics Placement Examination score (referred to as Math Placement).

(3) The percentile rank in high school graduating class (referred to as Percentile HSR).

(4) The final grade in Applied Mathematics I (referred to as Math 50 grade).

(5) The Otis-Gamma IQ test score (referred to as Otis-Gamma).

(6) The Spatial Relations test score (referred to as Space Relations).

(7) The pre-test score.

The data for each of these independent variables were collected for each student in the experimental group and also for each student in the control group. The purpose of collecting and analyzing the independent variable data was to determine whether or not there were any meaningful differences in ability and/or aptitude among the students in the experimental and control groups which might tend to affect the outcome of the study.

Table 1 contains a summary of the group means and the group standard deviations of the independent variable data. Subscript "1" refers to the experimental group, and subscript "2" refers to the control group. This convention of subscripts will be used throughout the remaining portion of this writing.

Table 1. Summary of the group means and standard deviations of the independent variable data

Variable	N_1[a]	N_2[a]	$\bar{X}_1$[b]	$\bar{X}_2$[b]	s_1[c]	s_2[c]
MSAT	40	42	39.53	40.28	8.39	10.83
Math Placement	40	42	16.75	16.07	6.48	7.89
Percentile HSR	40	42	50.95	51.69	21.80	19.14
Math 50 grade	40	42	4.75	4.57	0.95	1.08
Otis-Gamma	40	42	119.70	119.14	6.26	7.72
Space Relations	40	42	15.67	16.64	4.47	4.70
Pre-test	40	42	5.25	4.95	3.43	4.68

[a]Number of students.

[b]Group means.

[c]Group standard deviations.

There were a few missing data points among the independent variables for individuals in both groups. Multiple regression techniques were used to estimate values for these missing data points with as much reliability as possible. This was done in order to avoid having to delete these students from the statistical analysis of data since each of them did in fact take the pre-test, all three of the one-hour examinations and the post-test.

It can be seen from Table 1 that the group means of the independent variables were very nearly equal in all cases.

The procedure described below was used to determine whether or not the differences were statistically significant. The purpose of this procedure was to test the null hypotheses in regard to the independent variables which were stated in Chapter I and are repeated in this section.

Two equations are available to calculate a t statistic to test for a significant difference between the means of two groups of data. The first of these is shown in Equation 1 below. This equation utilizes the pooled variance, and the underlying assumption for its use is that both groups of data come from a single, homogeneous, normally distributed population. That is, the group variances are the same.

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{\sqrt{S_p^2\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}} \tag{1}$$

where $\bar{X}_1$ is the experimental group mean

$\bar{X}_2$ is the control group mean

N_1 is the number of students in the experimental group

N_2 is the number of students in the control group

S_p^2 is the pooled variance using the data from both groups.

The following equation is used to calculate the pooled variance.

$$S_p^2 = \frac{\Sigma(X_{1i} - \overline{X}_1)^2 + \Sigma(X_{2i} - \overline{X}_2)^2}{N_1 + N_2 - 2}$$

where N_1, N_2, $\overline{X}_1$ and $\overline{X}_2$ are as defined above

X_{1i} is the i^{th} datum point in the experimental group; $i = 1,2,...,40$

X_{2i} is the i^{th} datum point in the control group; $i = 1,2,...,42$.

The second equation which can be used to calculate a t statistic to test for a significant difference between two group means is shown as Equation 2 below. This equation is used if the underlying assumption for Equation 1 is not met. That is, the group variances are significantly different.

$$t = \frac{|\overline{X}_1 - \overline{X}_2|}{\sqrt{S_1^2(\frac{1}{N_1}) + S_2^2(\frac{1}{N_2})}} \qquad (2)$$

where $\overline{X}_1$, $\overline{X}_2$, N_1, N_2 are as defined for Equation 1

S_1^2 is the experimental group variance

S_2^2 is the control group variance.

The following equation is used to calculate the group variance. The equation is shown as it would be used for the experimental group data.

$$S_1^2 = \frac{1}{N_1 - 1} \Sigma(X_i - \overline{X}_1)^2$$

where N_1 is the number of students in the experimental group

X_i is the i^{th} datum point in the experimental group; $i = 1,2,\ldots,40$

$\overline{X}_1$ is the experimental group mean.

This equation would be used to calculate the control group variance by inserting N_2 in place of N_1, $\overline{X}_2$ in place of $\overline{X}_1$ and, of course, using the control group X_i datum points.

The task of choosing the appropriate equation for the calculation of the t statistic to test the null hypotheses in regard to the independent variables was accomplished by following the procedure described below.

Equation 3 below was used to calculate a group variance ratio F statistic for each independent variable.

$$F = \frac{S^2_{large}}{S^2_{small}} \quad (3)$$

The calculated group variance ratio F statistic for each independent variable was compared to the appropriate tabulated value of F to test for significantly different group variances.

The results of these calculations and tests are shown in Table 2 below.

Table 2. Results of the group variance ratio F tests of the independent variables

Variable	F[a]	Level of significance
MSAT	1.665	Not significant
Math Placement	1.482	Not significant
Percentile HSR	1.297	Not significant
Math 50 grade	1.293	Not significant
Otis-Gamma	1.519	Not significant
Space Relations	1.106	Not significant
Pre-test	1.855	Significant at the 0.10 level

[a]Compared with the tabulated value of F with 40 degrees of freedom in both numerator and denominator (F = 1.69) at the 0.10 level.

The pre-test was the only independent variable for which the calculated group variance ratio was larger than the tabulated value of F. Therefore Equation 2 was used to calculate the t statistic to test the null hypothesis in regard to the pre-test and Equation 1 was used to calculate the t statistic to test the null hypotheses in regard to the other six independent variables. The calculated t statistics were compared to the appropriate tabulated value of t, and Table 3 contains the

Table 3. Results of the t tests on the group means of the independent variables

Variable	t^a	Degrees of freedom	Level of significance
MSAT	0.354	80	Not significant
Math Placement	0.424	80	Not significant
Percentile HSR	0.164	80	Not significant
Math 50 grade	0.792	80	Not significant
Otis-Gamma	0.358	80	Not significant
Space Relations	0.955	80	Not significant
Pre-test	0.330^b	40	Not significant

[a]Compared with the tabulated value of t for 80 degrees of freedom at the 0.05 level ($t = 1.99$).

[b]Compared with the tabulated value of t for 40 degrees of freedom at the 0.05 level ($t = 2.021$).

results of these calculations and tests.

The null hypotheses which were formulated for the independent variables, and the result of the t test for each one are stated below.

Null hypothesis in regard to MSAT:

There is no difference between the mean MSAT scores of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to Math Placement:

There is no difference between the mean Math Placement scores of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to Percentile HSR:

There is no difference between the mean Percentile HSR of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to Math 50 grade:

There is no difference between the mean Math 50 grades of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to Otis-Gamma:

There is no difference between the mean Otis-Gamma scores of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to Space Relations:

There is no difference between the mean Space Relations scores of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to the pre-test:

There is no difference between the mean pre-test scores of the experimental group and the control group.

Result of t test: Fail to reject the null hypothesis.

Since these t tests did not reveal any significant differences between the group means of any of the independent variables, the implication was that the composition of the groups was essentially the same and that any differences in performance between the two groups on the examinations could be attributed to the differences in methods of instruction.

Analysis of Performance on Examinations

Four examinations were administered to all the students in both groups during the course of the study. These examinations were described in Chapter III and are also listed here for sake of convenience. They were:

(1) The first one-hour examination

(2) The second one-hour examination

(3) The third one-hour examination

(4) The post-test.

Table 4 contains a summary of the group means and standard deviations of the scores on the four examinations and the total score. ("Total score" was an artificial variable generated in the manner described in the Hypotheses section of Chapter I). The experimental group mean was greater than the control group mean in all cases.

Table 4. Summary of the group means and standard deviations of the scores on the four examinations and the total score

Examination	N_1[a]	N_2[a]	$\bar{X}_1$[b]	$\bar{X}_2$[b]	s_1[c]	s_2[c]
First one-hour examination	40	42	75.73	65.86	14.44	17.30
Second one-hour examination	40	42	53.58	44.83	12.66	12.03
Third one-hour examination	40	42	48.78	43.41	16.37	16.44
Post-test	40	42	104.20	89.38	23.64	22.17
Total score	40	42	265.08	236.71	41.26	40.27

[a]Number of students.

[b]Group means.

[c]Group standard deviations.

The purpose of analyzing performance on examinations was to test the five null hypotheses in regard to the examinations and thereby provide evidence to decide the question about whether or not students who receive slide rule instruction in the audio-tutorial format learn at least as much as students who receive slide rule instruction in the conventional format. The five null hypotheses in regard to the examinations were stated in Chapter I and are repeated later in this section along with the result of the test of each one.

Since the test of each null hypothesis involved the comparison of the means of two groups of data, the t test was used. The choice of which Equation, 1 or 2, to use for the calculation of the t statistic to be used in the test of each null hypothesis was based on the results of the following calculations and tests of group variance ratio F statistics.

A group variance ratio F statistic was calculated using Equation 3 for the first, second and third one-hour examinations, the post-test, and the total score variable. Each of the calculated group variance ratio F statistics was compared to the appropriate tabulated value of F to determine whether or not the group variances were significantly different. The results of these calculations and tests are shown in Table 5 below.

Table 5. Results of the group variance ratio F tests of the four examinations and total score

Examinations	F[a]	Level of significance
First one-hour examination	1.436	Not significant
Second one-hour examination	1.108	Not significant
Third one-hour examination	1.009	Not significant
Post-test	1.137	Not significant
Total score	1.050	Not significant

[a]Compared with the tabulated value of F with 40 degrees of freedom in both numerator and denominator ($F = 1.69$) at the 0.10 level.

None of the calculated group variance ratio F statistics was larger than the tabulated value of F, so Equation 1 (using the pooled variance) was used to calculate the t statistics to test the five null hypotheses in regard to performance on the examinations. Table 6 contains the results of these t tests.

Table 6. Results of the t tests on the group means of the four examinations and the total score

Examination	t	Degrees of freedom	Level of significance
First one-hour examination	2.798[a]	80	Significant at 0.01 level
Second one-hour examination	3.206[a]	80	Significant at 0.01 level
Third one-hour examination	1.482[b]	80	Not significant
Post-test	2.929[a]	80	Significant at 0.01 level
Total score	3.151[a]	80	Significant at 0.01 level

[a]Compared with the tabulated value of t with 80 degrees of freedom (t = 2.640) at the 0.01 level.

[b]Compared with the tabulated value of t with 80 degrees of freedom (t = 1.990) at the 0.05 level.

The five null hypotheses in regard to the examinations and total score and the result of the t test of each one are stated below.

Null hypothesis in regard to the first one-hour examination:

There is no difference between the mean scores of the experimental group and the control group on the first one-hour examination.

Result of t test: Reject the null hypothesis.

Null hypothesis in regard to the second one-hour examination:

There is no difference between the mean scores of the experimental group and the control group on the second one-hour examination.

Result of t test: Reject the null hypothesis.

Null hypothesis in regard to the third one-hour examination:

There is no difference between the mean scores of the experimental group and the control group on the third one-hour examination.

Result of t test: Fail to reject the null hypothesis.

Null hypothesis in regard to the post-test:

There is no difference between the mean scores of the experimental group and the control group on the post-test.

Result of t test: Reject the null hypothesis.

Null hypothesis in regard to total score:

There is no difference between the mean total scores of the experimental group and the control group.

Result of t test: Reject the null hypothesis.

All else being considered equal, the implication that can be drawn from this analysis of performance on examinations is that the students who received slide rule instruction in the audio-tutorial format learned at least as much as the students who received slide rule instruction in the conventional format. In the cases of the first and second one-hour examinations, the post-test and the total score, sufficient statistical evidence is available to support the claim that students who receive audio-tutorial slide rule instruction learn more than students who receive conventional slide rule instruction.

In the case of the third one-hour examination, the difference between the group means did not prove to be significant, but it is interesting to note that the experimental group mean was larger than the control group mean.

Two-Factor Analyses

Several two-factor analyses were performed for the purpose of determining whether or not audio-tutorial slide rule instruction tends to benefit some students more than others, and, in the event that it does, to determine the academic characteristics of the students who tend to receive the most benefit.

The mathematical model for the design of the two-factor analyses is given below.

$$X_{ijk} = M + A_i + B_j + AB_{ij} + e_{ijk}$$

where X_{ijk} is the observation for the k^{th} student in the i^{th} classification (or level) of factor A in the j^{th} classification (or level) of factor B

M is the overall mean

A_i is the effect of the i^{th} level of factor A; $i = 1,2$

B_j is the effect of the j^{th} level of factor B; $j = 1,2$

AB_{ij} is the effect of interaction of the i^{th} level of factor A with the j^{th} level of factor B

e_{ijk} is the experimental error associated with the k^{th} observation for the $(ij)^{th}$ combination of the levels of factors A and B.

Factor A in the mathematical model represents "group" and it has two classifications (or levels) -- experimental and control. Factor B in the mathematical model represents an independent variable, and it also has two classifications (or levels) -- high and low. As was discussed in the Hypotheses section of Chapter I, seven two-factor analyses were performed for the first one-hour examination, seven for the second one-hour examination, seven for the third one-hour examination, seven for the post-test and, finally, seven for the total score.

Following is a description of each set of seven two-factor analyses.

1. Factor A: Group

   Factor B: MSAT

2. Factor A: Group

   Factor B: Math Placement

3. Factor A: Group

   Factor B: Percentile HSR

4. Factor A: Group

   Factor B: Math 50 grade

5. Factor A: Group

   Factor B: Otis-Gamma

6. Factor A: Group

   Factor B: Space Relations

7. Factor A: Group

   Factor B: Pre-test

For the purpose of these two-factor analyses the data for each of the independent variables were subdivided into two classifications (or levels). The levels were "high" and "low". It was not possible to make the subdivision in a manner which would result in an equal number of students in both levels for both groups, however, an attempt was made to achieve this as nearly as possible. Table 7 contains the results of the sub-

Table 7. Results of the subdivision of the data for each independent variable into high and low classifications

Variable	Break point	Number of low scores		Number of high scores	
		Experimental group	Control group	Experimental group	Control group
MSAT	40	21	20	19	22
Math Placement	16	18	20	22	22
Percentile HSR	50[a]	19	21	21	21
Math 50 grade	13	17	21	23	21
Otis-Gamma	119	15	16	25	26
Space Relations	16	17	18	23	24
Pre-test	5	20	25	20	17

[a]A large Percentile HSR indicates that the student ranked low in his high school graduating class. Percentile HSR's of 50 or larger are considered to be in the low classification since these students were in the lower half of their respective high school graduating classes.

division of the data for each independent variable into high and low classifications.

The basic design of the two-factor analyses is shown in Figure 1 below.

	Factor A: Group		
	Experimental	Control	
Factor B: MSAT[a]			
High	$\bar{X}_{11}$[b]	$\bar{X}_{21}$[b]	$\bar{X}_{.1}$[c]
Low	$\bar{X}_{12}$[b]	$\bar{X}_{22}$[b]	$\bar{X}_{.2}$[c]
	$\bar{X}_{1.}$[c]	$\bar{X}_{2.}$[c]	

[a]MSAT is used as an example.

[b]Cell means.

[c]Margin means.

Figure 1. The basic design of the two-factor analyses

Since it was not possible to subdivide the independent variable data into high and low classifications in a manner which would result in an equal number of observations at both levels for both groups, the two-factor analyses were non-orthogonal, and the cell means of each two-factor analysis had to be calculated using unequal numbers of examination scores. Also, the margin means had to be calculated by averaging the appropriate cell means. Tables 8 through 12 show the cell and margin means for each two-factor analysis performed for the first, second and third one-hour examinations, the post-test and the total score.

Least squares methodology was used to prepare an analysis of variance table for each two-factor analysis. The analysis of variance table for the first two-factor analysis performed for the first one-hour examination is given in Table 13.

The calculated F ratios shown in Table 13 were used to test the three null hypotheses in regard to this two-factor analysis. These F ratios were compared to the tabulated values of F with 1 and 78 degrees of freedom. The tabulated value of F at the 0.01 level was 6.96, and the tabulated value of F at the 0.05 level was 3.96. In the analysis of variance shown in Table 13, the calculated F ratio for factor A (group) was greater than the tabulated value of F at the 0.01 level. Therefore, this calculated F ratio was said to be "highly significant beyond the 0.01 level", and the null hypothesis was

Table 8. Cell and margin means for each two-factor analysis performed for the first one-hour examination

	Factor A: Group		Margin
	Experimental	Control	mean
Factor B: MSAT			
High	77	67	72
Low	74	64	69
Margin mean	75.5	65.5	
Factor B: Math Placement			
High	75	66	70.5
Low	77	66	71.5
Margin mean	76	66	
Factor B: Percentile HSR			
High	77	72	74.5
Low	74	60	67
Margin mean	75.5	66	
Factor B: Math 50 grade			
High	81	72	76.5
Low	69	60	64.5
Margin mean	75	66	
Factor B: Otis-Gamma			
High	78	69	73.5
Low	72	60	66
Margin mean	75	64.5	
Factor B: Space Relations			
High	76	79	75
Low	76	49	62.5
Margin mean	76	64	
Factor B: Pre-test			
High	82	67	74.5
Low	69	65	67
Margin mean	75.5	66	

Table 9. Cell and margin means for each two-factor analysis performed for the second one-hour examination

	Factor A: Group		Margin mean
	Experimental	Control	
Factor B: MSAT			
High	55	45	50
Low	52	45	48.5
Margin mean	53.5	45	
Factor B: Math Placement			
High	55	46	50.5
Low	52	43	46.5
Margin mean	53.5	44.5	
Factor B: Percentile HSR			
High	55	50	52.5
Low	51	40	45.5
Margin mean	53	45	
Factor B: Math 50 grade			
High	60	50	55
Low	45	40	42.5
Margin mean	52.5	45	
Factor B: Otis-Gamma			
High	55	45	50
Low	51	44	47.5
Margin mean	53	44.5	
Factor B: Space Relations			
High	55	55	55
Low	51	31	41
Margin mean	53	43	
Factor B: Pre-test			
High	56	44	50
Low	51	45	48
Margin mean	53.5	44.5	

Table 10. Cell and margin means for each two-factor analysis performed for the third one-hour examination

	Factor A: Group		Margin
	Experimental	Control	mean
Factor B: MSAT			
High	50	46	48
Low	47	40	43.5
Margin mean	48.5	43	
Factor B: Math Placement			
High	49	48	48.5
Low	49	38	43.5
Margin mean	49	43	
Factor B: Percentile HSR			
High	52	49	50.5
Low	45	37	41
Margin mean	48.5	43	
Factor B: Math 50 grade			
High	55	51	53
Low	40	36	38
Margin mean	47.5	43.5	
Factor B: Otis-Gamma			
High	49	46	47.5
Low	48	39	43.5
Margin mean	48.5	42.5	
Factor B: Space Relations			
High	51	53	52
Low	46	31	38.5
Margin mean	48.5	42	
Factor B: Pre-test			
High	52	46	49
Low	45	42	43.5
Margin mean	48.5	44	

Table 11. Cell and margin means for each two-factor analysis performed for the post-test

	Factor A: Group		Margin
	Experimental	Control	mean
Factor B: MSAT			
High	104	97	100.5
Low	104	80	92
Margin mean	104	88.5	
Factor B: Math Placement			
High	107	92	99.5
Low	101	86	93.5
Margin mean	104	89	
Factor B: Percentile HSR			
High	106	99	102.5
Low	102	80	91
Margin mean	104	89.5	
Factor B: Math 50 grade			
High	111	100	105.5
Low	94	79	86.5
Margin mean	102.5	89.5	
Factor B: Otis-Gamma			
High	107	96	101.5
Low	99	79	89
Margin mean	103	87.5	
Factor B: Space Relations			
High	107	108	107.5
Low	100	65	82.5
Margin mean	103.5	86.5	
Factor B: Pre-test			
High	118	91	104.5
Low	90	88	89
Margin mean	104	89.5	

Table 12. Cell and margin means for each two-factor analysis performed for total score

	Factor A: Group		Margin
	Experimental	Control	mean
Factor B: MSAT			
High	268	246	257.5
Low	262	226	244
Margin mean	265	236	
Factor B: Math Placement			
High	268	244	256
Low	262	229	245.5
Margin mean	265	236.5	
Factor B: Percentile HSR			
High	271	256	263.5
Low	258	218	238
Margin mean	264.5	237	
Factor B: Math 50 grade			
High	283	257	270
Low	241	216	228.5
Margin mean	262	236.5	
Factor B: Otis-Gamma			
High	271	247	259
Low	255	221	238
Margin mean	263	234	
Factor B: Space Relations			
High	270	286	278
Low	258	171	214.5
Margin mean	264	228.5	
Factor B: Pre-test			
High	274	240	257
Low	256	235	245.5
Margin mean	265	237.5	

Table 13. Analysis of variance table for the two-factor analysis for the first one-hour examination using group as factor A and MSAT as factor B

Source of variation	Degrees of freedom	Corrected sum of squares	Mean square	F[a]
A: Group	1	2,044.94	2,044.94	7.882**
B: MSAT	1	144.47	155.47	< 1[b]
AXB: Group X MSAT	1	0.11	0.11	< 1[b]
Error	78	20,235.65	259.43	
Total	81	22,386.11[c]		

[a]The F ratio is calculated as the quotient of mean squares with the error mean square always being the denominator.

[b]The F ratio is less than unity (also in subsequent tables).

[c]The total corrected sum of squares is not equal to the summation of the corrected sum of squares from the four sources of variation due to the non-orthogonality of the two-factor analysis.

**The F ratio is significant beyond the 0.01 level.

rejected as untenable.

Calculated F ratios which exceeded the tabulated value of F at the 0.05 level, but not at the 0.01 level, were said to be "significant at the 0.05 level" and the null hypothesis is rejected as untenable at the 0.05 level.

A total of 35 two-factor analyses were performed, and the analysis of variance for each one was identical in format to that shown in Table 13. The calculated F ratios from each of the 35 analysis of variance tables are shown in Table 14.

Table 14. Tabulation of the calculated F ratios from the two-factor analysis of variance tables

Line	Source of variation	One-hour examinations First F	Second F	Third F	Post-test F	Total score F
1.1	Group	7.882**	10.296**	2.350	9.499**	10.416**
1.2	MSAT	< 1	< 1	1.388	2.882	1.995
1.3	Group X MSAT	< 1	< 1	< 1	3.150	< 1
2.1	Group	7.888**	9.941**	2.428	8.314**	9.859**
2.2	Math Placement	< 1	1.481	1.989	1.225	1.320
2.3	Group X Math Placement	< 1	< 1	1.838	< 1	< 1
3.1	Group	8.107**	10.772**	2.200	9.149**	10.807**
3.2	Percentile HSR	4.963*	6.645*	7.579**	5.941*	9.082**
3.3	Group X Percentile HSR	1.400	1.118	< 1	2.484	2.053
4.1	Group	7.259**	10.247**	1.665	8.384**	10.247**
4.2	Math 50 grade	12.403**	26.427**	20.034**	16.506**	27.499**
4.3	Group X Math 50 grade	< 1	< 1	< 1	< 1	< 1
5.1	Group	8.078**	8.777*	2.539	9.839**	10.491**
5.2	Otis-Gamma	5.009**	1.248	1.449	6.879*	5.441*
5.3	Group X Otis-Gamma	< 1	< 1	< 1	< 1	< 1
6.1	Group	6.444*	9.885**	1.866	6.988**	8.463**
6.2	Space Relations	< 1	1.661	< 1	< 1	< 1
6.3	Group X Space Relations	< 1	< 1	< 1	< 1	< 1
7.1	Group	7.339**	10.238**	1.863	8.116**	9.436**
7.2	Pre-test	< 1	< 1	2.153	< 1	1.559
7.3	Group X Pre-test	< 1	1.211	< 1	< 1	< 1

**Significant beyond the 0.01 level.

*Significant at the 0.05 level.

Each null hypothesis and an explicit statement of the result of the test of each one are provided later in this section.

In the Hypotheses section of Chapter I, twenty-one null hypotheses in regard to the seven two-factor analyses performed for the first one-hour examination were stated. These twenty-one null hypotheses were made applicable to the seven two-factor analyses performed for the second one-hour examination by inserting the words "second one-hour examination" in place of the words "first one-hour examination" in each one. In a similar manner, the twenty-one null hypotheses were made applicable to the two-factor analyses performed for the third one-hour examination, the post-test and the total score by appropriately inserting the words "third one-hour examination", or "post-test" or "total score" in place of the words "first one-hour examination".

Following is a restatement of all twenty-one null hypotheses along with the result of the test of each one as it, i.e. the null hypothesis, applied to each of the three one-hour examinations, the post-test and the total score.

Null hypothesis 1.1 (tested by the F ratios on line 1.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the MSAT scores.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 1.2 (tested by the F ratios on line 1.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of MSAT over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 1.3 (tested by the F ratios on line 1.3 of Table 14):

There is no interaction between the group factor and the MSAT factor on the first one-hour examination.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 2.1 (tested by the F ratios on line 2.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the Math Placement scores.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 2.2 (tested by the F ratios on line 2.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of Math Placement over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 2.3 (tested by the F ratios on line 2.3 of Table 14):

There is no interaction between the group factor and the Math Placement factor on the first one-hour examination.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 3.1 (tested by the F ratios on line 3.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of Percentile HSR.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 3.2 (tested by the F ratios on line 3.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of

Percentile HSR over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 3.3 (tested by the F ratios on line 3.3 of Table 14):

There is no interaction between the group factor and the Percentile HSR factor on the first one-hour examinations.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 4.1 (tested by the F ratios on line 4.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of Math 50 grade.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 4.2 (tested by the F ratios on line 4.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of Math 50 grade over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 4.3 (tested by the F ratios on line 4.3 of Table 14):

There is no interaction between the group factor and the Math 50 grade factor on the first one-hour examination.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 5.1 (tested by the F ratios on line 5.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the Otis-Gamma scores.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 5.2 (tested by the F ratios on line 5.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of Otis-Gamma over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 5.3 (tested by the F ratios on line 5.3 of Table 14):

There is no interaction between the group factor and the Otis-Gamma factor on the first one-hour examination.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 6.1 (tested by the F ratios on line 6.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the Space Relations scores.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 6.2 (tested by the F ratios on line 6.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of

Space Relations over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 6.3 (tested by the F ratios on line 6.3 of Table 14):

There is no interaction between the group factor and the Space Relations factor on the first one-hour examination.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 7.1 (tested by the F ratios on line 7.1 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the group factor over both classifications of the pre-test.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Reject

As applicable to the second one-hour examination: Reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Reject

As applicable to the total score: Reject

Null hypothesis 7.2 (tested by the F ratios on line 7.2 of Table 14):

There is no difference between the mean scores on the first one-hour examination for both classifications of the pre-test over both classifications of the group factor.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

Null hypothesis 7.3 (tested by the F ratios on line 7.3 of Table 14):

There is no interaction between the group factor and the pre-test factor on the first one-hour examination.

Results of the tests of the hypothesis:

As applicable to the first one-hour examination: Fail to reject

As applicable to the second one-hour examination: Fail to reject

As applicable to the third one-hour examination: Fail to reject

As applicable to the post-test: Fail to reject

As applicable to the total score: Fail to reject

The null hypotheses numbered 1.1, 2.1, 3.1, 4.1, 5.1, 6.1 and 7.1 are, in effect, saying that there is no difference between the two margin means shown at the bottom of each two-factor analysis in Tables 8 through 12. By definition, the difference between these margin means represents the "main effect" of the group factor in each two-factor analysis. Now, using this terminology, each of the null hypotheses mentioned above is, in effect, saying that the main effect of the group factor is not significant. The statistical analysis has shown that the main effect of the group factor is, in fact, significant in all cases except for the third one-hour examination. Since the experimental group margin means were greater than those of the control group in all cases, the obvious implication is that the experimental group performed significantly better on the first and second one-hour examinations, the post-test and the total score than did the control group. This bears out the conclusion drawn in the previous section (where the t test was used): the audio-tutorial instruction had a significant positive effect toward increased learning.

The difference between the margin means shown on the right hand side of each two-factor analysis in Table 8 through 12 by definition represents the "main effect" of the independent variable in each case. The null hypotheses numbered 1.2, 2.2, 3.2, 4.2, 5.2, 6.2 and 7.2 are, in effect, saying that the main effect of the independent variable is not significant in any of the two-factor analyses. The statistical analysis has shown that this is true in some cases and not in others. The main effect of Percentile HSR and Math 50 grade was either "significant at the 0.05 level" or "highly significant beyond the 0.01 level" in all cases. The conclusion here is that, in general, the students who ranked in the upper half of their high school graduating class did well in the slide rule course no matter which group (experimental or control) they were in. Also, students who earned high grades in Applied Mathematics I (Math 50) did well in the slide rule course regardless of which group they were in. The main effect of Otis-Gamma was significant at the 0.05 level in the cases of the first one-hour examination, the post-test and the total score. No other independent variable displayed significant main effects.

No significant interaction of group and independent variable was found in any of the 35 two-factor analyses.

The cell and margin means of the two-factor analysis for the post-test using Percentile HSR as factor B are extracted from Table 11 and shown in Figure 2 below.

	Factor A: Group		
	Experimental	Control	Margin mean
Factor B: Percentile HSR			
High	106	99	102.5
Low	102	80	91
Margin mean	104	89.5	

Figure 2. Cell and margin means for the post-test two-factor analysis using Percentile HSR as factor B

For the purpose of the two-factor analysis the break point between high and low Percentile HSR was made at the fiftieth percentile. Figure 2 indicates that students in the experimental group who were in the lower half of their respective high school graduating classes received higher post-test scores, on the average, than control group students who were in the upper half of their respective high school graduating classes.

A conclusion that can be drawn from Figure 2 is that the audio-tutorial instruction apparently benefited students in both levels of high school class rank, but the percentage gain by students in the experimental group over students in the control group at the same high school class rank level was greater for low rank than for high.

Cell and margin means of the two-factor analysis for the post-test using Math 50 grade as factor B are extracted from Table 11 and shown in Figure 3 below.

	Factor A: Group		
	Experimental	Group	Margin mean
Factor B: Math 50 grade			
High (A or B)	111	100	105.5
Low (C or below)	94	79	86.5
Margin mean	102.5	89.5	

Figure 3. Cell and margin means for the post-test two-factor analysis using Math 50 grade as factor B

Figure 3 indicates that the percentage gain of students in the experimental group over students in the control group at the same level of Math 50 grade are greater for the low Math 50 grade level than for the high Math 50 grade level.

The general conclusion that can be drawn from Figures 2 and 3 is that the audio-tutorial slide rule instruction seemed to benefit all students, but students who exhibited a low profile in Percentile HSR and Math 50 grade tended to benefit the most.

A matrix of correlation coefficients was generated for each group (experimental and control) to investigate whether there was evidence of strong correlation between the independent variables and the four examinations and also between the independent variables and the total score. The correlation coefficients for the experimental and control groups are shown in Tables 15 and 16 respectively. Scrutiny of these two tables reveals that there is no evidence of strong correlation. The only independent variable which seems to have a tendency toward strong correlation with the examinations and the total score is the grade in Applied Mathematics I (Math 50 grade). This would indicate that students who did well in the mathematics course also tended to do well in the slide rule course. This is not contrary to what one would expect.

Table 15. Experimental group correlation coefficients between the independent variables and the four examinations and also between the independent variables and the total score

Independent variable	One-hour examinations				
	First	Second	Third	Post-test	Total score
MSAT	0.0136	0.0803	-0.0549	0.0248	0.0400
Math Placement	-0.0257	0.1064	-0.0793	0.0672	0.0349
Percentile HSR	-0.0520	-0.0487	-0.1241	-0.0262	-0.0677
Math 50 grade	0.4752	0.6023	0.5119	0.5275	0.6206
Otis-Gamma	0.1891	0.1535	0.0083	0.1417	0.1469
Space Relations	-0.0825	0.0455	0.0715	0.0380	0.0300
Pre-test	0.1732	0.2243	0.2164	0.2092	0.2428

Table 16. Control group correlation coefficients between the independent variables and the four examinations and also between the independent variables and the total score

Independent variable	One-hour examinations				
	First	Second	Third	Post-test	Total score
MSAT	0.1595	0.0803	0.2717	0.2600	0.2467
Math Placement	0.2153	0.3592	0.4746	0.2698	0.3780
Percentile HSR	-0.2611	-0.3125	-0.4691	-0.4140	-0.4444
Math 50 grade	0.3825	0.4923	0.4926	0.4956	0.5608
Otis-Gamma	0.2882	0.2041	0.3088	0.5256	0.4401
Space Relations	-0.0553	0.1715	0.0988	0.0830	0.0884
Pre-test	0.0660	0.0380	0.1190	0.1706	0.1323

DISCUSSION

Throughout the quarter each student in the experimental group was required to "sign-in" when he came to the audio-tutorial laboratory to work on one of the lessons. To sign-in he simply had to write his name, the time of day, and the number of the lesson on a sheet of paper provided specifically for this purpose. When he had finished the lesson, he had to "sign-out" by recording the time of day. In this way, a fairly accurate record of the amount of time spent by each student on each lesson was maintained. At the end of the quarter the individual lesson times for each student were totaled to determine the amount of time spent by each student during the quarter to complete all of the lessons. This time was then compared to the total class time available for instruction to students in the control group. The results of these records indicated that, on the average, students in the experimental group took 2925 minutes to do all of the audio-tutorial slide rule lessons. This compares with 2900 minutes of class time available for slide rule instruction to students in the control group. It is rather difficult to glean anything very meaningful from this data since the 2900 minutes of instruction time available to students in the control group is not a precise indication of the amount of time they actually spent on the course. Some of the control group students would take their worksheets home and spend extra time, whereas other students would finish the assigned work and leave the classroom before the end of the period. Also, some students in the control group were occasionally absent from class. It was virtually impossible for the control group instructors to maintain any accurate records of the amount of time spent on the course by each student.

One might expect that students who exhibit a high profile in other areas (in the upper half of their high school graduating class for example) would spend less time in doing the audio-tutorial slide rule lessons and also earn higher scores on the examinations. It did seem to be true that in general these students spent less time doing the lessons, but their examination scores were not in general higher than the scores earned by the low profile students. The conclusion seems to be that the extra time spent by the low profile students brought a reward in terms of examination scores which were higher than would normally be expected if the extra supervised study time had not been available. No attempt was made to investigate the very real possibility that students who spent extra time doing the audio-tutorial slide rule work might be jeopardizing their progress in other courses.

Educators who have never used the audio-tutorial method of instruction often criticize it because of the apparent lack of personal contact between the instructor and the student.

This investigator and the three persons who were employed to serve as room attendants during the study found the opposite to be true. Each felt that he knew these students better at the end of the quarter than any students they had had in regular classes. Two of the assistants hold the rank of instructor and the third is a graduate teaching assistant in the engineering college at Iowa State University.

The personal contact between student and instructor in a course of this kind came at any time while the student was in the room. The student had to sign-in when he started a lesson, and in this way the instructor very quickly learned his name. If the student had a question during the lesson he asked the instructor for assistance and obtained personalized service to get the question answered. At the conclusion of the lesson the student submitted his work to the instructor for immediate evaluation. Most of the students would voluntarily rework the problems for which they had incorrect answers until they had all answers correct. In other words, the majority of students would require virtually 100% accuracy of themselves in spite of the fact that only 70% accuracy was formally required to be eligible to start the next lesson.

When the student submitted his work to the instructor for evaluation, he was free to watch as the instructor looked at each answer and marked it as either correct or incorrect. The sheet containing the correct answers was in full view of the student at all times, and one might suspect that the student would quickly commit to memory the correct answer for a problem that he had missed, and then return to his seat and enter the correct answer without using his slide rule to actually rework the problem. This investigator observed that this very rarely, if ever, was the case. Virtually all the students were very concerned about finding out where they had made an erroneous setting, performed the wrong operation, or made an incorrect reading, etc.

The audio-tutorial method of teaching the slide rule course offers the student at least two major advantages which are not available to the students in a conventional slide rule course. One of these is that the course is available to the student at his convenience rather than at the convenience of an administrator who prepares a formal schedule of class meeting times. Often times the student in a conventional slide rule class has another class immediately after slide rule, and he finds it difficult to concentrate on his slide rule work especially if an examination is scheduled in the following class. The student in the audio-tutorial slide rule class does not have this problem because he is free to do his slide rule work after the examination in the other class. Thus, he is free to study for the examination if he wishes to do so. The implication is that he should do better on the examination and also in his slide rule work.

The second major advantage that the audio-tutorial method provides the student is the opportunity to listen to the lecture or any part of the lecture as many times as he desires. The student, rather than the lecturer, is in command of the rate at which he gets the material. No effort was made to ask the students to maintain a record of the number of times they stopped the tape recorder to review lecture material during any of the lessons. However, at the end of the quarter the students in the experimental group were asked to complete a questionnaire. In one part of the questionnaire the students were asked to estimate the number of times they stopped the tape recorder to relisten to selected portions of any given lecture. Seventy-five percent estimated that they did this one or two times during each lesson. Other answers were 3, 4 or 5 times. A copy of this questionnaire and the tally of responses are included in Appendix H.

A second questionnaire was completed by students in the experimental group and also by students in the control group. This questionnaire dealt with student attitudes about structured vs. unstructured courses and about instructor-student relationships. Students in both groups apparently had about the same attitudes in these areas. A copy of this questionnaire and the tally of responses are included in Appendix I.

During this study each student in the experimental group did not have his own set of supplementary lecture notes. Rather, a complete set was available in each of the individual study booths in the audio-tutorial laboratory, and each student had access to them only during the time he was using a study booth. It would be desirable for each student to have his own set of notes in order that he could study them at home if he desired to do so. Since the notes are not complete, he would be unable to achieve 100% effectiveness without the accompanying tape recorded lectures. Several students remarked at one time or another during the quarter that they would like to have their own set of notes.

In conjunction with the above suggestion this investigator believes that a checkout system for the tape recorded lectures could be established whereby the students could check out a tape recorded lecture to use in their personal tape recorder at home to do the slide rule lessons. This system would eliminate the advantage of having an instructor available at all times to answer questions. However, the student would still receive personal attention when his worksheet was evaluated, and he could ask any questions he might have at that time. This would offer more flexibility for the convenience of the student, and it could result in reducing the cost of offering the course since the audio-tutorial laboratory would have to be open fewer hours per week.

It was observed that during the course of this study students would occasionally bring their own tape recorders to the laboratory. This was especially noticeable during periods of heavy use prior to the examinations.

Another suggestion which would benefit the student would be to provide him with a study guide of the course. The study guide would contain such information as the title and a basic outline of each lesson, an estimate of the time normally required to complete each lesson, a statement of the objective of each lesson in behavorial terms, a list of all materials needed for each lesson and a list of previous lessons which have subject matter that might be helpful in case they run into trouble with the current lesson.

The review of literature revealed that in several instances audio-tutorial courses are conducted in such a fashion that each student is told at the outset, that his final grade will not be less than C if he completes the course. He is also told just exactly what the minimum requirements are for the higher grades. This seems to have considerable merit and perhaps the system should be used in the slide rule course so long as each lesson has a minimum required level of achievement. Minimum levels of satisfactory performance on the one-hour examinations and the post-test could very easily be established and the information given to the student at the outset of the course. If this system were used, the student would know his exact status at any time during the quarter.

Some of the audio-tutorial materials for this study were prepared as the quarter progressed, and, therefore, each student in the experimental group could not proceed through the lessons as rapidly as he might have wished. When the course is taught again, it is suggested that all the materials be prepared at the outset of the course. This would allow those students who wish to do so the opportunity to proceed through the lessons at a rapid pace, and perhaps finish well before the end of the quarter. This would facilitate still more flexibility and convenience for the student.

It was not possible to eliminate all potential sources of bias from the study. For example, it is almost impossible to completely eliminate the Hawthorne effect from a study of this nature. However, a sincere effort was made to reduce its effect to a minimum by not mentioning the words experiment or research during conversations with the students in either group. If a student asked why the course was being taught in two distinctly different manners, the answer was that the audio-tutorial system being used was an attempt to teach slide rule in a modern fashion. If possible, the conversation would quickly change to another topic.

The independence of group data was maintained as much as possible by not allowing any students in the control group to listen to any of the tape recorded lectures used by students in the experimental group. In a similar fashion, no students in the experimental group were allowed to attend any of the control group sessions.

Another possible source of bias, differences between instructors, could have been eliminated if one person had taught all students in the control group as well as prepare all of the audio-tutorial material for students in the experimental group. However, this was not possible. The 42 students in the control group were subdivided into three sections, and these sections were taught by individuals who had taught the slide rule course in previous quarters and who were considered to be better than average instructors.

SUMMARY

The task of teaching engineering technology students at Iowa State University how to use the slide rule has traditionally been accomplished by the conventional method of "lecture and practice". However, this method exhibits several shortcomings when it is evaluated in terms of

(1) Individual differences among students with different levels of past achievement, in the rate at which they learn, and in manual dexterity and muscular control capabilities,

(2) Efficient use of the students' and instructors' time,

(3) Efficient use of classroom facilities, and

(4) The cost of offering the slide rule course in terms of the number of students per instructor.

This study was conducted to investigate and also evaluate the effectiveness of modern audio-tutorial methods of instruction in teaching the use o the slide rule. In order to conduct the study it was necessary to design an audio-tutorial slide rule course and then compare the performance of students in this course versus the performance of students in a conventional slide rule course.

Specifically, the objectives of the study were to answer the following broadly stated questions.

(1) Do students who receive slide rule instruction in the audio-tutorial format learn at least as much as

students who receive slide rule instruction in the conventional format?

(2) Does audio-tutorial slide rule instruction benefit some students more than others? If so, what are the characteristics of these students?

The study was conducted at Iowa State University during the fall quarter 1970. The two quarter credit engineering technology slide rule course entitled Technical Problems I was used as the vehicle for the conduct of the study. At the outset of the quarter each student enrolled in the course was randomly placed into one of two groups (experimental or control) which were approximately equal in size. The experimental group consisted of 40 students who were taught the use of the slide rule by the exclusive use of audio-tutorial methods of instruction. The control group consisted of 42 students who were taught the use of the slide rule in the conventional manner.

All students in both groups were exposed to the same slide rule material, and all students in both groups took the same examinations. The effectiveness of the audio-tutorial instruction was evaluated by comparing the performance of students in the experimental group versus the performance of students in the control group on examinations. Three one-hour examinations were administered during the quarter, and at the conclusion of the quarter a post-test, or final examination, was given.

In order to compare the performance of the two groups on the examinations, the following null hypotheses were formulated and tested.

(1) There is no difference between the mean scores of the experimental group and the control group on the first one-hour examination.

(2) There is no difference between the mean scores of the experimental group and the control group on the second one-hour examination.

(3) There is no difference between the mean scores of the experimental group and the control group on the third one-hour examination

(4) There is no difference between the mean scores of the experimental group and the control group on the post-test.

In addition to the four null hypotheses mentioned above, a fifth null hypothesis in regard to the examinations was formulated and tested. This one was formulated for the artificial variable called "total score" which was generated in the following manner. The raw scores on each of the three one-hour examinations and the post-test were converted to standard scores and then a "total score" datum point was calculated for each student by summing his standard scores on the three one-hour examinations plus twice his standard score on the post-test.

The null hypothesis for this "total score" variable was:

(5) There is no difference between the mean total score of the experimental group and the control group.

The t test was used to test each of these five hypotheses. Hypotheses (1), (2), (4) and (5) were rejected, and hypothesis (3) was not rejected. In all cases the experimental group mean was greater than the control group mean.

In order to investigate the possibility that the composition of two groups might be such that one group was composed of generally higher caliber students than the other group, and thereby affect the outcome of the study, seven independent variables were selected, and the data for each of these were collected for each student. The seven independent variables were:

(1) The Minnesota Scholastic Aptitude Test

(2) The College Level Mathematics Placement Examination

(3) The percentile rank in high school graduating class

(4) The final grade in Applied Mathematics I

(5) The Otis-Gamma IQ test

(6) The Spatial Relations test

(7) The pre-test

The analysis of these seven independent variables indicated that the groups were composed of students of virtually identical caliber. The group means of the independent variables were essentially equal in all seven cases.

A total of 35 two-factor analyses were performed for the three one-hour examinations, the post-test and the total score. The purpose of these two-factor analyses was to determine whether or not the audio-tutorial instruction tended to benefit some students more than others, and, if so, to determine the characteristics of these students. In each two-factor analysis, factor A was group and factor B was one of the independent variables. Factor A (group) consisted of two subdivisions (or levels) - experimental and control. Factor B also had two levels - high and low.

The two-factor analyses revealed that the audio-tutorial instruction tended to benefit all types of students, but those students exhibiting a low profile in variables (3) and (4) tended to receive the most benefit. That is, the audio-tutorial instruction seemed to boost the performance of the low achiever more than it did the performance of the high achiever.

SUGGESTIONS FOR FURTHER INVESTIGATION

Several seemingly interesting and productive areas for further investigation are summarized.

(1) A comprehensive follow-up of the students who participated in this study would provide informative data about the academic progress of the students in each group subsequent to the slide rule course. Since the caliber of student was essentially the same in both groups in this study, any differences between groups in academic achievement subsequent to the slide rule course may in some way be correlated to the method of slide rule instruction. It seems reasonable to expect that the students who were in the experimental group in this study might do better in future courses which require extensive use of the slide rule since they by and large performed at a higher level in the slide rule course.

(2) It would be well to prepare a comprehensive examination over the slide rule course material and administer it to these same two groups of students sometime after the conclusion of the course (perhaps a quarter or two later). If the experimental group mean is greater than the control group mean on this examination, it might be an indication that the

audio-tutorial method of teaching the use of the slide rule produces better retention of the material than does the conventional method.

(3) If the study was repeated on a larger scale (i.e., a larger number of students in the groups), more data would be available for evaluation and a more precise description of students who seem to receive the most benefit from audio-tutorial instruction could be obtained.

(4) The effect of student attitude about structured versus unstructured courses and about instructor-student relationships should be investigated more thoroughly. The attitude of the student is extremely important in any learning situation, and is probably of paramount importance in an audio-tutorial situation since the student is almost totally responsible for assuring that he gets the work done and that he does not procrastinate an inordinate amount.

BIBLIOGRAPHY

1. Avner, Sidney H. An audio-visual approach to self-instruction. Engineering Education 60: 748. 1970.

2. Bloom, B. S., ed. Taxonomy of educational objectives. New York, Longmans, Green and Co. 1956.

3. Ernst, Edward W. Self-instruction in the laboratory. Engineering Education 60: 879-880. 1969.

4. Good, Carter V., ed. Dictionary of education. New York, McGraw-Hill. 1945.

5. Hamelink, Jerry H. The name of the game is learning. Educational Research and Methods 3-1: 16-20. 1970.

6. Hurst, R. N., Husband, D. D., Hetherington, M. T. and Postlethwait, S. N. Minicourses as audio-tutorial units. Engineering Education 60: 737-738. 1970.

7. Kobelin, Joel. Computer scoring of slide rule tests. Engineering Education 60: 929-931. 1970.

8. Koen, Billy V. Self-paced instruction for engineering students. Engineering Education 60: 735-736. 1970.

9. Lee, James Leftwich, Jr. Audio-tutorial versus a traditional method of laboratory instruction in agronomy 114A. Unpublished M.S. thesis. Ames, Iowa, Library, Iowa State University of Science and Technology. 1968.

10. Lindenlaub, John C. Applying audio tutorial techniques to laboratory instruction. IEEE Transactions on Education E-12: 92-97. 1969.

11. Lindenlaub, John C. Audio-tutorial instruction - what, why, and how. Engineering Education 60: 759-761. 1970.

12. Lindenlaub, John C. Audio-tutorial techniques for laboratory instruction. Engineering Education 60: 896-898. 1970.

13. Mager, Robert F. Preparing instructional objectives. Palo Alto, California, Fearon Publishers. 1962.

14. Mitzel, Harold E. The impending instruction revolution. Engineering Education 60: 749-754. 1970.

15. Postlethwait, S. N. An audio-tutorial approach to teaching botany. Typewritten copy of a speech. West Lafayette Ind., Dept. of Botany, Purdue University. ca. 1966.

16. Pressey, S. L. A simple apparatus which gives tests and scores - and teaches. School and Society 23: 373-376. 1926.

17. Pullias, Earl V. The effective college teacher. Engineering Education 60: 716-717. 1970.

18. Rainey, Gilbert L. Learner controlled laboratory. Unpublished typewritten description of laboratory courses in electrical technology. Lafayette, Indiana, Dept. of Elec. Technology, Purdue University. ca. 1966.

19. Ratledge, Earl T. Individualized instruction. Engineering Education 60_ 739-740. 1970.

20. Stuck, Dean Leo. A comparison of audio-tutorial and lecture methods of teaching. Unpublished Ph.D. thesis. Ames, Iowa, Library, Iowa State University of Science and Technology. 1968.

21. Sumter, Paul Edward. Learning experiment: effectiveness of controlling environmental distractions. Unpublished Ph.D. thesis. Ames, Iowa, Library, Iowa State University of Science and Technology. c1970.

22. Wert, James E., Neidt, O. and Ahmann, J. Stanley. Statistical methods in educational and psychological research. New York, Appleton-Century-Crofts, Inc. 1954.

APPENDIX A

The Detailed List of Topics Covered and the Planned Schedule for Fall Quarter 1970 for Both Groups

Week of September 8, 1970
- Logical and Systematic approach to problem solution
- Workmanship standards
- Practice problem solution an engineering problems paper

Week of September 14, 1970
- Unit conversion
- Dimensional analysis
- Interpretation of markings on the C and D scale
- Reading values on the C and D scale
- Powers of 10; Scientific notation; Characteristic system
- Introduction to 2-factor multiplication and division

Week of September 21, 1970
- Practice solving 2-factor problems
- Solution of 3-factor problems using the C and D scales
- Introduction to the use of the CI scale in the solution of 3-factor problems
- Practice using the C, D and CI scales in the solution of 3-factor problems

Week of September 28, 1980
- Introduction to the folded scales (CF, DF, CIF)
- Practice using the C, D, CI, CF, DF and CIF scales in the solution of 3-factor problems
- Introduction to the techniques of solving multifactor (four or more) problems using the C, D, CI, CF, DF and CIF scales
- First one-hour examination

Week of October 5, 1970
- Introduction to the trigonometry scales (overview)
- Introduction to the solution of problems involving the sine function
- Introduction to the solution of problems involving the cosine function
- Introduction to the use of problems involving the tangent function
- Solution of 2-factor problems involving trig functions sin A, cos A, tan B $0° < A \leq 90°$, $0° < B \leq 45°$
- Solution of 2-factor problems involving tan B where $45° < B < 90°$
- Resolution of a vector (when magnitude and direction are known) into horizontal and vertical components
- Right triangle solution (when the hypotenuse and one acute interior angle are known)

Week of October 12, 1970
- Resolution of horizontal and vertical component vectors into a resultant vector with magnitude and direction
- Right triangle solution (when the length of the two sides of a right triangle are known)
- Special case of right triangle solution (one very small acute angle and one very large acute angle)
- Use of the sine law in triangle solution

Week of October 19, 1970
- Second one-hour examination
- Introduction to the L scale
- Introduction to the LL scales
- Introduction to "e"
- Finding e^x for $0.001 \leq x \leq 10.0$
- Finding e^{-x} for $0.001 \leq x \leq 10.0$

Week of October 26, 1970
- Special case of finding e^x and e^{-x} for very large and very small values of x
- Finding natural log x $\quad x > 1.0$
- Finding natural log x $\quad x < 1.0$
- Practice and review all LL scales
- Solution of 2-factor problems involving natural logs
- Finding B^x when $B > 0$ and $x > 0$
- Finding B^{-x} (treat as special case of B^x)
- Practice and review finding B^x and B^{-x}

Week of November 2, 1970
- Finding roots of numbers using the LL scales
- Practice and review all work involving the L and LL scales
- Third one-hour examination

Week of November 9, 1970
- Introduction to the square root scales (A and/or R_1R_2 scales)
- Introduction to the cube root scales (K scale)
- Practice and review the square and cube root scales
- Practice and review all slide rule scales

Week of November 16, 1970
- Post-test (two-hour examination)

APPENDIX B

The Typewritten Manuscript of the Tape Recorded Lecture for Lesson 11

This is lesson no. 11 and in this lesson we will introduce the methods of solution of 3 factor problems using the C and D scales. At the conclusion of the lesson and after you have finished the practice sheets you should be able to solve any type of 3 factor problem in 2 minutes or less using only the C and D scales of your SR. Open the manual now to page no. 31 and also remove your SR from its case and also get out a sheet of scratchpaper. Notice on page 31 of the manual that 3 types of 3 factor problems are possible. First x = FG/H. We solve this type of problem by finding the quantity F/H and then multiplying the result by G. The second type of 3 factor problem is x = F times G times H. This type of problem is solved by finding the quantity of F times G and then multiplying the result by H. The third type of 3 factor problem F/GH is solved by finding the quantity F/G and then dividing the result by H. Notice that in each case we are in effect solving a pair of 2 factor problems within each 3 factor problem. Now advance the manual to page no. 32 and we will examine several examples of 3 factor problems. The first type of 3 factor problem we will concern ourselves with is FG/H. Recall that the first thing we did in the solution of a 2 factor problem was to record the characteristics of the factors. The same thing is true for a 3 factor problem. In this first example notice that the characteristics are +1+3 and -1 and these characteristics have been recorded above the factors, except in the denominator where we record the characteristic below the factor simply for convenience. Now we are prepared to begin the SR manipulations. In this type of problem the first step is to divide 60.60 by 3180. Use your SR now and follow along as I talk through the solution. Set the HL over 60.60, or in other words set the HL over 6060 on the D scale. Now move the slide so that 3180 of the C scale is under the HL. Notice that the initial index of the C scale does not extend outside the D scale so the index extension rule does not apply. The answer is this division problem is under the index of the C scale and now we wish to multiply this result by 1004, so simply move the HL to 1004 on the C scale. Does the initial index of the C scale extend outside the D scale this time. No it does not, so once again the index extension rule does not apply. The digits of the answer of the problem are under the HL on the D scale and the digits are 1913. If you do not read these 4 digits or something very close to these 4 digits then stop the recorder and repeat the problem until you obtain the correct 4 digits. Now we are ready to find the characteristic of the answer. The characteristics of the factor must be added algebraically. Don't forget that we have to change the sign of the denominator characteristic when we bring it to the numerator to be added. In this case, then we have +1+3+1 = +5 so the answer to the problem must be 191,300. Always be sure to show the decimal point in the answer and also commas if they are necessary. The second type of 3 factor problem that we will deal with now is F times G times H. As before we must record the characteristics of the 3 factors before making the SR setting. The characteristics are 0+2 and -1. Notice that the characteristics have been recorded above the factors. Now we are ready to begin the SR manipulation. First, we will multiply 7340 by 1110. So set the initial index of the C scale over 7340 on the D scale. Now move the HL to 1110 on the C scale and the result of this part of the problem is under the HL on the D scale. Does the index extension rule apply? No, it does not since the initial index of the C scale is not outside the initial index of the D scale. To complete the solution of the 3 factor problem we must multiply the result of the first part of the solution by 4440. Please observe once again that the HL is marking the result to the first multiplication. Leave the HL where it is and move the slide so that the final index of the C scale is under the HL. Now move the HL to 4440 on the C scale. Observe that the initial index of the C scale extends outside the initial index of the D scale so we must add +1 to the characteristic of 0.4440. Notice that this has been done in the work shown on page 32 of the manual. The digits of the final answer are under the HL on the D scale and you should read on your SR 3618 or something very close to this. Now we are ready to add the characteristics of the factors to find the characteristic of the result. In this case we have 0+2-1+1 = +2 so the final answer to the problem must be 361.8. The third type of 3 factor problem is F/GH. The characteristics are recorded as -3-1 and +3 and the first step in the solution of this type of problem is to divide 1565 by 6110. Set the HL of your SR over 1565 on the D scale and then move the slide so that 6110 of the C scale is under the HL. Notice that the initial index of the C scale extends outside the initial index of the D scale so we must add +1 to the characteristic of 0.6110. The result of this division is on the D scale under the final index of the C scale, and now we wish to divide this result by 1716. Mark the answer to the previous division by setting the HL over the final index of the C scale. Now move the slide so that 1716 of the C scale is under the HL. The final answer to this problem is on the D scale under the initial index of the C scale and notice that the initial index of the C scale is over 1493 of the D scale. If you did not obtain these digits or something very close to these digits then stop the recorder and repeat the problem until you do. Adding the characteristics of the factors algebraically we have -3+1-1-3 = -6. So the final answer to this example problem is 0.000,001,493. In the lower part of page 32 of the manual are 3 other example problems. Notice that there is one example of each type of 3 factor problems. Copy these problems on your scratch paper now and then use your SR to obtain the answer for each one. In a moment I will give you the correct answers. Do not forget to observe whether or not the initial index of the C scale extends outside the initial index of the D scale after each operation. The answer to example 1 is 164.2. The answer to example 2 is 63.40, and the answer to example 3 is 0.3710. Work very carefully and very diligently on these three example problems until you get each one of them exactly or very nearly exactly correct. The answers I have given you are the best answers for each of these problems. Don't forget that there are acceptable answers on either side of these best answers. Stop the recorder while you work on these examples. Stop the recorder. Now turn your attention to practice sheets 11A and 11B. Solve each problem as directed on the sheet. Notice that in the appropriate space you are to record the 4 digits that you read and you are also to record in the designated area the characteristic of the answer. Finally, record the answer with the decimal point properly located. Please observe the following 3 rules of good practice. First, always show the decimal point in the answer. Second, include a 0 to the left of the decimal for answers which are less than 1. For example if you get an answer such as .1250 then put a 0 to the left of the decimal so that the answer reads 0.1250. The third rule of good practice is to always use commas to block the answer off to groups of 3 digits either way from the decimal point. For example if an answer is 9860000 then include commas so that the answer reads

9,860,000. The best answer for the first problem on practice sheet 11A is 0.9030. The best answer to the third problem on practice sheet 11B is 85,050. We cannot demand absolute accuracy in SR work so there are acceptable answers on either side of the best answer in each case. Work the problems on both sheets very carefully but at the same time work as rapidly as possible. Your goal should be to work each problem in less than 2 minutes. Before you submit your practice sheet to the room attendant I suggest that you rework each problem just to verify that the answer you obtained the first time is in fact correct. This is the end of lesson no. 11.

APPENDIX C

The Supplementary Lecture Notes for Lesson Number 11

3 - FACTOR PROBLEMS

THREE (3) TYPES:

$X = \frac{FG}{H}$ SOLVE $\frac{F}{H}$ AND MULTIPLY THE RESULT BY G

$X = FGH$ SOLVE (F)(G) AND MULTIPLY THE RESULT BY H

$X = \frac{F}{GH}$ SOLVE $\frac{F}{G}$ AND DIVIDE THE RESULT BY H

NOTICE THAT IN EACH CASE WE ARE IN EFFECT SOLVING A PAIR OF 2-FACTOR PROBLEMS WITHIN EACH 3-FACTOR PROBLEM.

EXAMPLES OF 3-FACTOR PROBLEM SOLUTION

USING C & D SCALES

TYPE $\frac{FG}{H}$

$$\frac{\overset{+1}{(60.60)}\,\overset{+3}{(1004.)}}{\underset{-1}{0.3180}} = \overset{+1+3+1\ =\ +5}{1913} = 191{,}300.$$

TYPE FGH

$$\overset{0}{(7.340)}\,\overset{+2}{(111.0)}\,\overset{-1+1}{(0.4440)} = \overset{0+2-1+1\ =\ +2}{3618} = 361.8$$

TYPE $\frac{F}{GH}$

$$\frac{\overset{-3}{0.001{,}565}}{\underset{-1+1}{(0.6110)}\,\underset{+3}{(1716.)}} = \overset{-3+1-1-3\ =\ -6}{1493} = 0.000{,}001{,}493$$

EXAMPLE 1: (0.0603)(7.090)(384.3)

EXAMPLE 2: $\frac{933.0}{(6.660)(2.210)}$

EXAMPLE 3: $\frac{(0{,}046{,}10)(46.75)}{5.810}$

APPENDIX D

The Practice Sheets for Lesson Number 11

Practice Sheet 11A

No.	Record the characteristics of the factors, and added characteristics, if any.	digits of answer	Char. of ans.	ANSWER Show decimal point and point off properly.
1	(1.415) (2.02) (0.316)			
2	(32.15) (0.003985) (6645.)			
3	$\frac{(75.25)(23700.)}{186.5}$			
4	$\frac{(3530.)(977.5)}{387.5}$			
5	$\frac{6725}{(3660.)(1.741)}$			
6	(4.095) (0.02458) (1732.5)			
7	$\frac{(0.3225)(87.75)}{2795.}$			
8	$\frac{19.33}{(74.0)(0.00317)}$			
9	(5105.) (1.713) (0.0003195)			
10	$\frac{(87.75)(502.5)}{171.25}$			

This space for instructor use:

Lettering: G A P

Score__________

Standards noted: 1 2 3 4 5 6 7 8

Instructor's initials

No.	Record the characteristics of the factors, and added characteristics, if any.	digits of answer	Char. of ans.	ANSWER Show decimal point and point off properly.
1	(1.315) (2.050) (0.3160)			
2	(31.25) (0.002935) (8645.)			
3	$\frac{(65.25)(21700.)}{16.65}$			
4	$\frac{(3150.)(966.5)}{388.5}$			
5	$\frac{6625.}{(3235.)(1.630)}$			
6	(4.085) (0.02597) (1837.5)			
7	$\frac{(0.3825)(97.75)}{2855.}$			
8	$\frac{18.43}{(7.60)(0.003190)}$			
9	(4.205) (1.523) (0.0003285)			
10	$\frac{(67.75)(412.5)}{107.25}$			

This space for instructor use:

Lettering: G A P Score________

Standards noted: 1 2 3 4 5 6 7 8 Instructor's initials________

APPENDIX E

The Pre-test Administered to all Students in Both Groups

Name ________________

G. Tech. 14

Preliminary Exam

Fall Quarter 1970

Purpose:	To determine proficiency in the use of the slide rule at the beginning of the course.
Instructions:	Do your best to answer the questions. Do not guess. If you cannot solve a problem by using the slide rule, then leave that answer space blank. DO NOT MAKE LONGHAND CALCULATIONS.
Note:	Your score on this examination will not count in any way toward your final grade in this course
Time Allowance:	One (1) hour is the maximum time limit. If you finish early, please just sit quietly until the instructor collects the papers when all students are obviously finished.

Part I. Slide Rule Fundamentals

Fill in the blanks or circle either True or False.

1. Name the three (3) major physical parts of the slide rule.

   1._______________ 2._______________ 3. _______________

2. When reading the C & D scales, we mentally divide each small interval into _________parts.

3. To find the cube root of a number, we would use either the C or D scale in conjunction with the ______ scale.

4. The left end of the C scale is usually called the _______ index, and the right end is usually called the _______ index.

5. If the hairline is positioned over a particular number on the C scale, then it is also positioned over the reciprocal of that number on the CI scale. True or False.

6. The "folded" scales (CF, DF, CIF) can be read with more accuracy than the regular scales (C, D, CI). True or False.

7. The Sine scale is effectively twice as long as the slide rule. True or False.

8. The Tangent scale is effectively four times as long as the slide rule.

9. The black LL1 scale is the reciprocal of the red LL1 scale. True or False.

10. The LL scales are used in conjunction with CIF scales to find logarithms in the base 10 number system. True or False.

Part II. Multiplication and Division

Write your answers in the spaces provided. Show decimal points distinctly.

1. (174.6)(23.66) = ______________

2. $\frac{4797.}{0.863}$ = ______________

3. $\frac{(0.675)(3.426)}{479.7}$ = ______________

4. (37.83)(1.467)(6.074,35) = ______________

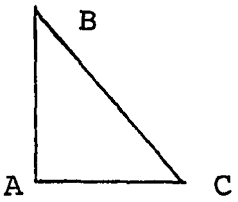
5. $\frac{(674.)(7.439)(0.000,549,7)}{(0.8754)(86.6)}$ = ______________

Part III. Trigonometry

Write your answers in the spaces provided. Show decimal points distinctly.

1. sin 37.5° = __________
2. tan 29° = __________
3. tan 52° = __________
4. arcsin 0.759 = _______
5. cos 37.5° = __________
6. arctan 4.7 = _________
7. sin 2.5° = __________

8. Given the triangle below, solve for the length of sides AB and AC.

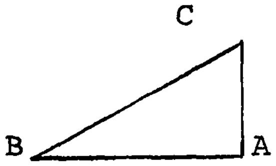


∡A = 90° AB = __________

∡C = 75.3° AC = __________

BC = 5.55 inches

9. Given the triangle shown below, solve for the length of BC and angles ABC and ACB.



∡BAC = 90° BC = __________

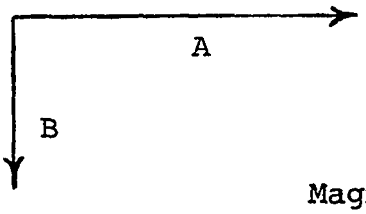
AB = 9.42 inches ∡ABC = __________

AC = 2.57 inches ∡ACB = __________

10. Given the horizontal and vertical vectors shown below, find the magnitude and direction of the resultant vector.

A = 25 lb.

B = 5 lb.



Magnitude of resultant vector ____________

Direction of resultant vector from the reference axis ________________________

Part IV. LL Scales

Write your answers in the spaces provided. Show decimal points distinctly.

1. $e^{1.7}$ = ____________

2. In 1.02 = ______________

3. In 0.76 = ______________

4. $e^{-0.6935}$ = _______________

5. If e^{x} = 0.7, then x = _______________

6. If ln x = 4.0, then x = _______________

7. $3^{2.5}$ = ________________

8. $7.0^{1/4}$ = _______________

9. $95.0^{0.5}$ = _____________

10. 0.26^{3} = ______________

11. $\sqrt[2]{0.2114}$ = _____________

12. $\sqrt[3]{2748.}$ = _____________

13. If 8.6^{x} = 100.0, then x = _________________

APPENDIX F

The Three One-hour Examinations Administered to all Students in Both Groups

G. TCH. 14
EXAM # 1 133

NO.	Record the characteristics of the factors and added characteristics, if any.	Digits of Answers	Char. of Ans.	ANSWER Show decimal point and point off properly.
1	(160.5)(30.25)			
2	$\frac{0.012,76}{0.17,267}$			
3	(32.48)(66.10)			
4	$\frac{0.6025}{2.335}$			
5	(0.2095)(13.77)			
6	$\frac{174,800.}{2.515}$			
7	(0.036,40)(0.5170)			
8	$\frac{606.0}{30.15}$			
9	(0.2075)(0.1407)			
10	$\frac{0.066,90}{0.6160}$			

NO.	Record the characteristics of the factors and added characteristics, if any.	Digits of Answers	Char. of Ans.	ANSWER Show decimal point and point off properly.
1	$\frac{(32.48)(73.95)}{1.983}$			
2	$\frac{(805.)(6450.)}{0.9730}$			
3	(60.45)(0.034,75)(1372.)			
4	$\frac{2.768}{(38.76)(0.051,70)}$			
5	(14.17)(38.64)(0.9275)			
6	$\frac{(2.986)(0.8175)}{11.64}$			
7	(74.95)(0.037,62)(7245.)			
8				
9				
10				

G. TCH. 14

EXAM # 1 135

NO.	Record the characteristics of the factors and added characteristics, if any.	Digits of Answers	Char. of Ans.	ANSWER Show decimal point and point off properly.
1	$\frac{(32.75)(6975.)(0.000,131,5)}{(27,660.)(0.799)}$			
2	$\frac{(3.982)(12,450.)(0.0987)(6.25)}{476.5}$			
3	(0.004,96)(32,740.)((1.718)(6.395)(100.4)			
4	$\frac{0.006,325}{(9625.)(1.132)(0.009,975)}$			
5	$\frac{867,500.}{(317.2)(0.000,106,5)(63.15)(1977.)}$			
6	$\frac{(32.48)(97,650.)(825.)(0.000,100,2)}{2975.}$			
7				
8				
9				
10				

NO.	PROBLEM	ANSWER (with commas, decimal, etc.)
1	$\sin 70^o$	
2	$\tan 4^o$	
3	$\cos 86.2^o$	
4	$\cos 83.25^o$	
5	$\sin 0.9^o$	
6	$\tan 72.67^o$	
7	$\tan 35^o$	
8	$\sin 4^o$	
9	$\cos 6.2^o$	
10	$\tan 88.56^o$	
11	$\tan 45.2^o$	
12	$\sin^{-1} 0.5120$	
13	$\tan^{-1} 0.7250$	
14	$\cos^{-1} 0.555$	
15	$\cos^{-1} 0.0555$	
16	$\sin^{-1} 0.0512$	
17	$\tan^{-1} 1.825$	
18	$\sin^{-1} 0.0951$	
19	$\tan^{-1} 12.20$	

G. TECH 14

trig. quiz 137

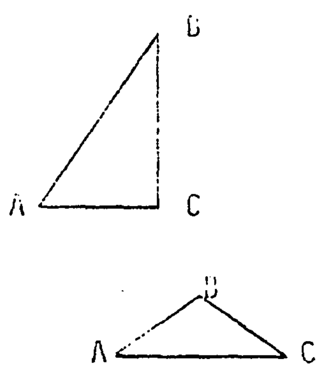
2/3

NO.	PROBLEM	CHAR.	DIGITS	ANSWER (with commas, decimal, etc.)
1	0.0137 sin 26.4			
2	0.04 cos 87.6			
3	$\frac{0.4775}{\tan 20.6^{o}}$			
4	$\frac{0.003,990}{\sin 73.35^{o}}$			
5	0.004,75 tan 46.6^{o}			
6	$\frac{80.5}{\cos 30.55^{o}}$			
7	$\frac{80.5}{\tan 40^{o}}$			
8	0.018 sin 5.70^{o}			

Solve for the missing parts in each triangle.

NO.	$\overline{AB}$	$\overline{AC}$	$\overline{BC}$	∡C	∡B	∡A
1	2550.			90^0		35^0
2		7.465	40.74	90^0		
3		9.674	146.8	90^0		
4	0.6744			90^0	15^0	
5		0.048,76	0.3002	90^0		
6	325.7			121.5^0	25^0	
7		27.75	67.44			85^0

General triangles:



1

2

3

4

5

6

7

NO.	PROBLEM	MODIFIED PROB. (if needed)	MANTISSA	CHAR.	DIGITS (if needed)	ANSWER
		(use these columns only if you so desire)				
1	log 6745.					
2	log 0.1271					
3	log 0.000,07					
4	antilog 4.875					
5	log 10.74					
6	antilog 0.0123					

NO	PROBLEM	COMPUTATION (if needed)	ANSWER
1	$e^{1.55}$		
2	ln 375.		
3	$e^{-0.064}$		
4	ln 0.4510		
5	$\frac{\ln 1.020,22}{0.020,22}$		
6	$e^{-0.000,05}$		
7	2.6(ln 3.44)		
8	$e^{0.029}$		
9	ln 0.986,051		
10	$\frac{\ln 0.0145}{4.6}$		
11	$e^{-5.76}$		

G. TCH. 14

EXAM #3 141

3/4

NO.	PROBLEM	SCALE CALCULATIONS	ANSWER
1	$(1.186)^{34.}$		
2	$(0.59)^{0.05}$		
3	$(0.75)^{-3.}$		
4	$(1.076)^{125.}$		
5	$(1.18)^{-2.5}$		
6	$\sqrt[-3.1]{0.7542}$		
7	$(0.713)^{-0.356}$		
8	$(360.)^{\frac{1}{17}}$		

NO	PROBLEM (Solve for x)	CALCULATIONS (if needed)	ANSWER
1	$\ln x = 0.7544$		
2	$e^{x} = 0.011,05$		
3	$0.8055^{x} = 0.000,560$		
4	$\sqrt[x]{255.} = 2.159$		
5	$1.041,10^{x} = 0.1156$		

APPENDIX G

The Post-test Administered to all Students in Both Groups

G. Tech. 14
Final Exam
144

No.	Problem	Char.	Digits	Answer
1	$\frac{(374.5)(0.027,44)}{4.924}$			
2	(204.4)(0.059,36)(6.511)			
3	$\frac{671,432.}{(9212.)(5,675,100.)}$			
4	$\frac{19.125}{(3.110)(7.6441)}$			
5	(761.2)(0.1272)(1.025)			
6	$\frac{(16,854.)(256.14)}{9846.}$			
7	$\frac{(5544.)(0.084,43)}{1115.}$			
8	(4.504)(23.96)(0.091)(8.15)			
9	$\frac{(743.4)(0.1255)}{(30,446.)(568.4)(0.006,501)}$			
10	$\frac{2721.4}{(671.4)(0.001,146)(21.1)(0.974)}$			

Instructor____________

Brand name of slide rule__________

No.	Problem	145 Modified Problem	Answer
1	$\sqrt[2]{4675.}$		
2	$(124.)^3$		
3	$(9.874 \times 10^2)^2$		
4	$(14.6 \times 10^4)^{0.3333}$		
5	$\sqrt[3]{947.4}$		
6	$(74.64 \times 10^{-1})^2$		
7	Sin 64.12°		
8	Tan 43.05°		
9	Sin^{-1} 0.1104		
10	Cos 7°		
11	Tan^{-1} 0.061,44		
12	Tan 67.44°		
13	Sin 1.436°		
14	Cos 83.56°		
15	Sin 9.11°		
16	Tan 89.156°		

Find the unknown sides and angles.

Space is provided for your sketches.

NO.	$\overline{AB}$	$\overline{BC}$	$\overline{AC}$	∢C	∢A	∢B
1	8.884		21.41		90°	
2		0.1146			90°	32°
3	8444.				46.2°	58.90°
4	31.44			25.92°	90°	
5		714.11	965.			44.61°
6	0.061,44		0.8744		90°	

1

2

3

4

5

6

No	Problem	Calculations	Answer
1	$(1.0311)^{19.82}$		
2	ln 1.5562		
3	$(0.6064)^{-4.051}$		
4	$e^{-1.8412}$		
5	$\sqrt[6.41]{141.1}$		
6	ln x = 1.2111 x = ?		
7	$e^{0.0114}$		
8	$(38.46)^{-\frac{1}{61.12}}$		
9	$x^{2.44} = 1.1854$ x = ?		
10	$0.985,12^{x} = 0.000,113$ x = ?		
11	$\sqrt[0.3166]{x} = 2.544$ x=?		

APPENDIX H

The Questionnaire Completed by Students in the Experimental Group at the End of the Quarter

G. Tech. 14 Questionnaire F'70

1. How do you feel about the slide rule course (G. Tech. 14) now that it's almost over? (Please check one or more and please be honest)

    (16) I enjoyed it.

    (5) I did the work, but only because the course is required.

    (26) I appreciated the freedom in choosing my own time to study slide rule.

    (3) I would have preferred having slide rule class on a regular schedule, (for example, M.W.F. 8-10).

    If you checked the 4th choice, please briefly state why.
    (No response)

2. Do you feel that in G. Tech. 14 you were provided with

    (3) insufficient individual help

    (36) sufficient individual help

    (0) too much individual help

3. Did you prefer one brand of tape recorder over the other?

    Yes (19)   No (20)

    If yes, which did you prefer?

    Large Wollensak (14) small Norelco (5)
    If yes, please briefly state the reason for your preference.

    (most popular reason: superior sound)

4. Did you ever stop the tape recorder, rewind the tape part way, and then relisten to selected portions of the lecture?

Yes (39) No (0)

If yes, how many times (on the average) during a given

1 2 3 4 5 6 7 8 9 10

(18 students circled 1)
(12 students circled 2)
(4 students circled 3)
(3 students circled 4)
(1 student circled 5)

5. In many of the lectures you were asked to use your slide rule while listening to the step-by-step solution of example problems. Did you actually use your slide rule as you listened to the solution of the example problem(s)?

Yes (39) No (0)

If yes, about what percentage of the time did you do so?

100%	80%	60%	40%	20%	10%
(8)	(22)	(8)	(1)		

6. Do you feel that the number of example problems given in the lectures was about right?

Yes (33) No (6)

If no, please check one of the following

too many	too few
(4)	(2)

7. Several of the lectures were 18 or 19 minutes in length, but most were shorter than this. Do you feel that, in general, the lectures were:

too long	about right	too short
(7)	(32)	

8. Did you find that the tape recorded lectures held your interest or did you often find yourself thinking of other things while listening to the lectures?

always held my interest (13) usually held my interest (25)

occasionally held my interest (1)

9. Do you feel that the pictures of the slide rule shown in the manual to illustrate proper settings for the example problems were helpful?

Please check one or more of the following.

(28) The pictures were very helpful.
(0) The pictures usually caused confusion.
(3) The pictures were difficult to use.
(8) The pictures were generally ignored.
(0) Too many pictures were included in the manual.

10. Early in the quarter, the policy was that all work in this course had to be done in the classroom. Do you think this policy was unfair and created undue hardship?

Yes (8) No (31)

Later in the quarter, the policy was that when you had correctly finished 50% of the work on a set of practice sheets, you could finish them at home. Do you feel that this policy was also unfair and created undue hardship?

Yes (3) No (36)

11. The lectures and manual were, in general, designed around the Post slide rule. If you use another brand of slide rule (Pickett, for example) do you feel that you were at a disadvantage? (If you have a Post slide rule, skip this question)

Yes (3) No (3)

12. Do you feel that the voice speed on the tape recorded lectures was:

too fast	about right	too slow
(0)	(33)	(6)

13. Do you feel that the example problems were presented:

too fast	about right	too slow
(4)	(31)	(4)

14. Did you find that poor word pronunciation in the tape recorded lectures caused confusion and exasperation?

often	occasionally	hardly ever	never
(0)	(2)	(20)	(17)

APPENDIX I

The Attitude Questionnaire Completed by Students in the Experimental Group and also by Students in the Control Group at the End of the Quarter

G. Tech. 14 Questionnaire F'70

[ ] experimental group response ( ) control group response

I. Some students prefer much STRUCTURE in their courses (definite meeting times, definite assignments and due dates, precise grading system, etc.).

In general (not G. Tech. 14) do you think you would prefer:

a. Very little structure [9] (2)
b. Moderate structure [29] (26)
c. Very high structure [1] (10)

Would you classify G. Tech. 14 as:

a. Very little structure [10] (3)
b. Moderate structure [28] (19)
c. Very high structure [1] (16)

II. Some students' performance in a course is very dependent upon their relationship with the instructor. They work hard, perform well, and feel good about the course if the relationship with the instructor is good.

In general, (not G. Tech. 14 specifically) how do you feel about your relationship to the instructor?

a. Not too important [2] (6)
b. Moderately important [28] (20)
c. Very important [9] (12)

Do you feel that you were able to develop a satisfactory relationship with your G. Tech. 14 instructor?

Yes [36] (35) No [3] (3)

III. Some students prefer to learn on their own (without a structured class situation and without much interaction with an instructor).

Are you this type of student?

a. Not at all [6] (15)
b. Somewhat [31] (22)
c. Very definitely [2] (1)

How do you feel about G. Tech. 14?
(Please check one of the following)

[4] (5) I was on my own too much
[34] (31) I was on my own just about the right amount
[1] (3) I was not on my own enough.