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THE ROLE OF MATHEMATICS IN ELECTRICAL-ELECTRONIC TECHNOLOGY.

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DESCRIPTORS- *ELECTRONICS TECHNICIANS, *EDUCATIONAL NEEDS, *MATHEMATICS, JUNIOR COLLEGES, TECHNICAL EDUCATION, TECHNICAL MATHEMATICS, FIELD INTERVIEWS, Q SORT, TEACHER ATTITUDES, EMPLOYEE ATTITUDES, SURVEYS,

THIS STUDY WAS CONCERNED WITH DETERMINING THE KIND OF MATHEMATICS THE ELECTRONICS TECHNICAL WORKER ACTUALLY USED, OR NEEDED TO HAVE KNOWLEDGE OF ON THE JOB SO THAT JUNIOR COLLEGES COULD DETERMINE THE WAYS AND MEANS OF INTEGRATING OR SCHEDULING IT INTO THE TECHNICAL CURRICULUM. DATA WERE GATHERED FROM 90 TECHNICAL WORKERS, SELECTED AT RANDOM FROM 44 RANDOMLY SELECTED CALIFORNIA ELECTRONICS COMPANIES, AND FROM 29 INSTRUCTORS SELECTED AT RANDOM FROM 45 JUNIOR COLLEGES WITH ELECTRONICS PROGRAMS. THE TWO METHODS OF COLLECTING DATA WERE INDIVIDUAL INTERVIEWS IN WHICH PERSONAL DATA AND JOB HISTORY DATA WERE COLLECTED, AND Q-SORTS WHICH DETERMINED MATHEMATICAL CONCEPTS OR SKILLS NEEDED TO PERFORM ON THE JOB. THE Q-SORT WAS A MEANS OF GETTING THE TECHNICAL WORKERS TO DISTRIBUTE INTO 9 DIFFERENT PILES 66 MATHEMATICAL PROBLEMS ACCORDING TO THE EXTENT TO WHICH THESE PROBLEMS WERE CHARACTERISTIC OF THEIR DAY-TO-DAY WORK. MATHEMATICAL CONCEPTS OR SKILLS DEFINED AS ESSENTIAL TO ELECTRONICS TECHNICAL WORKERS IN RESEARCH AND DEVELOPMENT WERE CONVERSION OF FRACTIONS TO DECIMALS, PERCENT CALCULATIONS OF TOLERANCE, CHANGING PERCENTAGE TO DECIMALS, CONVERSION OF METRIC TO AMERICAN MEASURING SYSTEM, SQUARE ROOT LONG-HAND METHOD, DIVISION OF SIGNED NUMBERS, SCIENTIFIC NOTATION, ESTIMATION OF ARITHMETIC PROBLEMS, MULTIPLICATION WITH EXPONENTS, DIVISION WITH EXPONENTS, RAISING TO A POWER WITH EXPONENTS, USE OF NEGATIVE EXPONENTS, RATIOS, AND PYTHAGOREAN THEOREM. INSTRUCTORS RECRUITED TO TEACH THIS CURRICULUM SHOULD HAVE HAD EXPERIENCE IN RESEARCH AND DEVELOPMENT IN INDUSTRY, AND HAVE COMPLETED MATHEMATICS THROUGH CALCULUS. (HC)

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The Role of Mathematics in Electrical-Electronic Technology

DIVISION OF VOCATIONAL EDUCATION

UNIVERSITY OF CALIFORNIA, LOS ANGELES

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Foreword

The California State Department of Education through the Bureau of Industrial Education has been sensitive to the needs of the junior colleges in California for research concerning critical elements of the Technical Education curriculum.

The project concerning the role of mathematics in Electrical-Electronic Technology was made possible through funds allocated to the State of California by Title VIII of the National Defense Education Act. The project was planned and conducted in cooperation with the Division of Vocational Education, University of California, Los Angeles.

The Bureau of Industrial Education feels that service in the area of curriculum development is most important at this time of rapid change in the manpower profile of California. The opportunity to co-sponsor curriculum projects along with the Division of Vocational Education of the University of California at Los Angeles provides a significant manner in which the instructional content of trade and technical programs can be updated. We are indebted to the Division of Vocational Education and especially to its director, Dr. Melvin L. Barlow, for the continued interest in building an ever better program of trade and technical education in California.

Ernest G. Kramer
Chief, Bureau of Industrial Education
California State Department of Education

Preface

The Division of Vocational Education has for many years worked in cooperation with the vocational services of the California State Department of Education to prepare studies of state-wide significance and value in vocational-technical education. Such studies have been largely concerned with elements of the instructional program of the public schools of California and were prepared as an aid to the schools in improving their instructional programs. The study of the role of mathematics in Electrical-Electronic Technology was begun in the fall of 1960 and completed in the fall of 1961.

The study involved cooperative arrangements with many industrial concerns in California for the purpose of interviewing technical workers and for the purpose of identifying mathematical competencies of such workers. Industry cooperated wholeheartedly in this undertaking. Similar cooperative arrangements were made with the junior colleges having curriculums in Electrical-Electronic Technology. Both the administration and the instructors of these junior college programs gave generously of their time and spent many hours with representatives of the research staff in meetings related to the study.

Identification of all persons who have made contributions to the research is not possible. However, it is appropriate to identify the members of the advisory committee. Invitations to assist with the project in an advisory capacity were issued jointly by the Chief of the Bureau of Industrial Education, California State Department of Education, and the Director of the Division of Vocational Education, University of California.

Advisors From Junior Colleges

Norman Harris, Dean, Vocational-Technical Education, Bakersfield College, Bakersfield, California.

Frank T. Jacobs, Dean, Technical and Vocational Center, Stockton College, Stockton, California.

Franklin Johnson, Dean, Los Angeles Trade-Technical College, Los Angeles, California.

P. W. Knowles, Vice-President, Sacramento City College, Sacramento, California.

Ivan Lauritzen, Electronics Instructor, San Diego City College, San Diego, California.

Robert Moses, Chairman, Engineering and Technical Department, Pasadena City College, Pasadena, California.

Phil H. Putnam, President, Compton College, Compton, California.

Walter L. Thatcher, Director, San Diego City College, San Diego, California.

F. Parker Wilber, President, Los Angeles Trade-Technical College, Los Angeles, California.

Advisors From Industry

Henry Gunderson, Coordinator, Santa Clara–San Benito Counties Electrical Construction Industry, San Jose, California.

Max Selby, Manager of Personnel, Hughes Aircraft Co., Newport Beach, California.

Advisors From The State Department of Education

Samuel L. Fick, Ernest G. Kramer, David Allen, Sidney McGaw, Mack Stoker, Van Lawrence.

Advisors From The University of California

Bonham Campbell, William Brownell, CDR John Meyer, Lawrence H. Stewart, Fred Kintzer, B. Lamar Johnson, Howard Wilson, Evan Keislar, Leta Adler, C. Wayne Gordon.

Workshop Assistance

Mention should be made also of the special workshops in which problems related to the study were probed deeply. The keen insight of the instructors who participated in the workshops and the understanding and enthusiasm of junior college administrators were valuable aids to the research staff. Instructors from the following junior colleges participated in the workshops:

American River Junior College, Sacramento, California
Antelope Valley College, Lancaster, California
Bakersfield College, Bakersfield, California
Cerritos College, Norwalk, California
Chaffey College, Alta Loma, California
Coalinga College, Coalinga, California
College of Marin, Kentfield, California

College of San Mateo, San Mateo, California
Compton College, Compton, California
Diablo Valley College, Concord, California
El Camino College, Los Angeles, California
Foothill College, Los Altos Hills, California
Los Angeles Pierce College, Los Angeles, California
Los Angeles Trade-Technical College, Los Angeles, California
Long Beach City College, Long Beach, California
Modesto Junior College, Modesto, California
Monterey Peninsula College, Monterey, California
Oakland City College, Oakland, California
Pasadena City College, Pasadena, California
Reedley College, Reedley, California
Sacramento City College, Sacramento, California
San Diego City College, San Diego, California
San Francisco City College, San Francisco, California
San Jose City College, San Jose, California
Santa Monica City College, Santa Monica, California
Shasta College, Redding, California
Ventura College, Ventura, California

Lee W. Ralston, Director of Practical Arts, Los Angeles County Schools, assisted with the organization of instructor conferences and acted as a discussion leader for the conferences. Three meetings of the advisory committee were held: two on the Los Angeles Campus of the University of California and one on the Berkeley Campus.

RICHARD S. NELSON
Supervisor of Technical Education
Bureau of Industrial Education
California State Department of Education

Contents

Introduction

The programs of vocational and technical education in the public schools of California have been sensitive to industrial and technological changes and consequently to the curriculum adjustments which such changes require. Advisory committees representative of the vocational or technical area concerned and also representative of the needs of labor and management assist the public schools in keeping abreast of technological change. The school, armed with the advice and suggestions of a group representative of industry, makes appropriate educational adjustments to the end that the salable knowledge and skills of graduates are in tune with current industrial needs.

The rate of technological change varies greatly among the various technical areas. In the case of the electrical-electronic industry the rate of change has been most rapid. Since 1950, the electronic industry has grown at a rate of about three times that of the national economy as a whole.

The electronic industry in California is centered in the Los Angeles area and in the San Francisco Bay area and radiates outward to other locations. Service agencies such as the Federal Aviation Agency, the IBM customer service installations, and local radio and television repair shops are distributed throughout the state. Employment in the industry has been good, particularly for the person who can qualify for employment in a classification roughly identified as a "technician." The term "technician" has not been used in the report and has been replaced by the term "technical worker" or "technical employee." (The problem of identification of technical workers is discussed in Chapter 2.)

The majority of the students being trained in the California public junior colleges for entry occupations in electronics is located in the Los Angeles and San Francisco Bay areas. Outlying junior colleges also have electronics programs due to the geographical mobility pattern of the

Figure 1

Centers of the Electronics Industry in California

working force in California and to the location of service agencies throughout the State.

Forty-five public junior colleges in California had programs of instruction in electrical-electronic technology during the period of this study, 1960–61. These programs differed in many respects, particularly in the amount of mathematics required of a student to enter the program and in the amount and nature of mathematics to be included in the curriculum. This study of the role of mathematics in the electrical-electronic technology

provides data for junior colleges to use as they attempted to resolve the knotty problems of the technical curriculum.

The Nature of the Study

The study was concerned largely with the kind of mathematics the technical worker actually used, or needed to have knowledge of, on the job. From such data the junior colleges could then determine the ways and means of integrating or scheduling the needed mathematics into the technical curriculum.

In order to accomplish the primary purpose of the study it was important to consider a number of related elements. Data which would be supplementary to the primary purpose and which would expand the general area of understanding of the total problem were obtained through the following activities:

—Group discussions with electrical-electronic instructors.
—Interviews with a selected sample of the technical workers.
—An experimental study involving the use of self-instructional devices.
—An analysis of instructional materials used in electrical-electronic programs.
—A review of the literature related to the basic study.

These activities provided a vast amount of data concerning technical workers in California, their instructors, their jobs, and their need for mathematics. These data are reported in the study where appropriate in developing the main problem of needed mathematics.

For the most part the data were gathered by conferences with small groups of persons, by reviews of printed documents, and by questionnaires. The data concerning mathematical concepts needed by technical workers on the job were acquired by the use of a special adaptation of a technique known as the Q-sort. The Q-sort, which is described in more detail in a following chapter, was simply a means of getting the technical workers to distribute into nine different piles 66 mathematical problems according to the extent to which these problems were characteristic of their day-to-day work.

All data acquired were subjected to exhaustive statistical treatment using appropriate statistical methods to determine significance, validity, reliability, and relationships. The facilities of the Western Data Processing Center on the U.C.L.A. campus were used generously in the treatment of data.

The Plan of the Report

Part I consists of a brief abstract of the entire report. Since this part deals with the report only in summary fashion it is necessary to refer to other parts, and to the appendix, for the supporting rationale, assumptions,

hypotheses, procedures, and other data. In addition, the recommendations for the entire report are shown in Part I.

Part II consists of four chapters related to mathematical competencies needed by the technical worker. The interview schedule and the Q-sort are described in Chapter 1. Data concerning the technical worker and the environment in which he works are shown in Chapter 2. Description and analysis of workshops conducted with electrical-electronic instructors are found in Chapter 3. Chapter 4 reports upon the mathematical competencies needed by technical workers as revealed by an analysis of the Q-sort.

Part III of the report is related to the general topic of instructional materials and includes, as Chapter 5, a report of an experimental study concerning self-tutoring devices. A general treatment of instructional materials in electrical-electronic technology is included in Chapter 6.

Part IV consists of an appendix of three parts. Appendix A is an annotated bibliography of selected research related to the topic of the study. Appendix B includes a reproduction of the various forms, scales, letters and other materials used in the study. Appendix C consists of the data upon which the report was based.

How to Use the Report

The only purpose for which this study was made was to provide data of state-wide significance which could be used by junior colleges to improve and expand their programs of technical education which were related to the electrical-electronic industry.

The report provides an adequate realistic treatment of the characteristics of instructors involved in the junior college program in the area of electronics in general. Such data could be useful when considering selection and professional growth of instructors.

The data concerning the technical workers employed in the electrical-electronic industry provide insight into the characteristics of persons employed in the industry and have implications for screening and selection of students for programs in electrical-electronics technology.

The data concerning the mathematical competencies needed by technical workers were derived from the technical workers themselves. These data indicate the exent to which employed technical workers have need for mathematics in their work.

Junior colleges can therefore use the report as an aid in selecting instructors and students and as a means of determining how their electrical-electronic programs will provide experiences leading to mathematical competencies upon which technical workers place value. No attempt has been made to suggest specific patterns to be used because such decisions must be made with full knowledge of situational factors which are peculiar to

a particular institution. Each institution must determine how it will provide for the needed mathematical competencies. Usual, customary, and traditional courses in mathematics have many advantages but also have severe limitations. This would be true also of a thoroughly integrated program of mathematics as a part of the electrical-electronic curriculum. It is probable that neither extreme is thoroughly appropriate. It is also probable that some combination of newly designed mathematics courses and an integrated mathematics structure will offer enticing advantages.

Part I

Abstract and Recommendations

Abstract

The persons most qualified to assess the mathematical competencies needed by technical workers in the California electronics industry are the workers themselves. The instructors of electronics in the California public junior colleges are well qualified to assess the applicability of mathematical competencies to their programs.

Job Classification

Data were gathered from 90 technical workers, selected at random from 44 randomly selected California electronics companies, and from 29 instructors selected at random from 45 junior colleges with electronics programs. Figure 1 shows the distribution of the technical workers among the nine job classifications in which they are employed and the distribution of the instructors among job classifications in which they obtained their industrial experience.

Educational Attainment

The two methods of collecting data from the technical workers and electronics instructors were: (1) individual interviews in which personal data and job history data were collected, and (2) Q-sorts which determined mathematical concepts or skills needed to perform on the job.

The interview data were used to divide the respondents into groups with similar educational attainment and mathematical background. The distribution of technical workers and electronics instructors for educational attainment is shown in Figure 2.

Mathematics Achievement

The highest level of mathematics achieved correlated highly with educational attainment, but the relationship was not 1 to 1. This indicates that

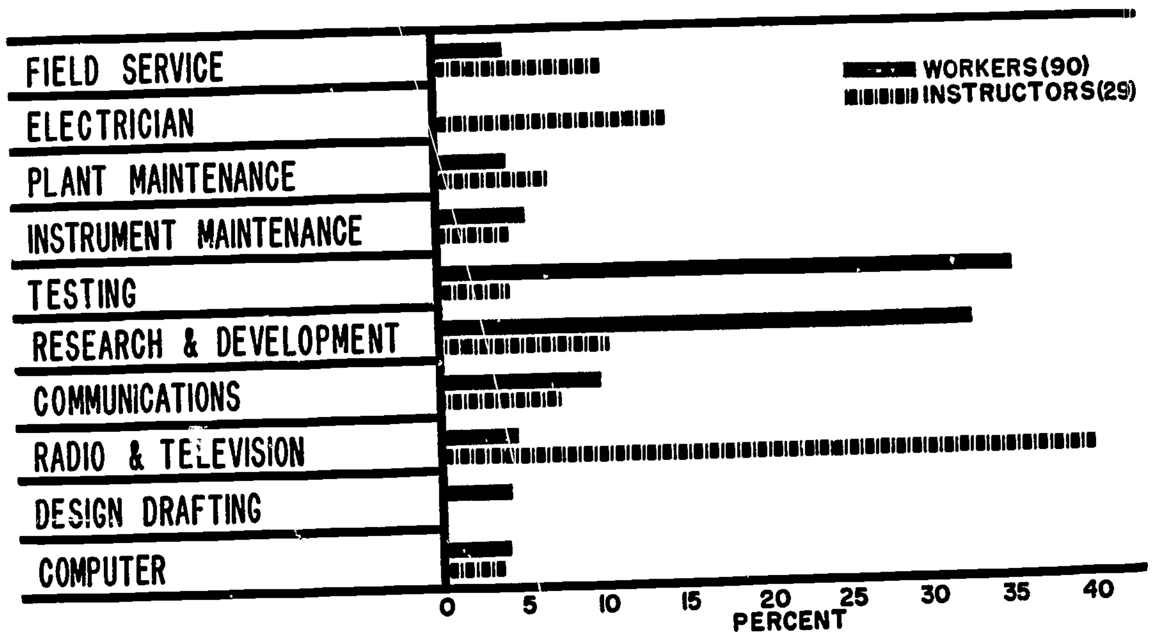

Figure 1

Distribution of Technical Workers and Electronics Instructors Among the Job Classifications

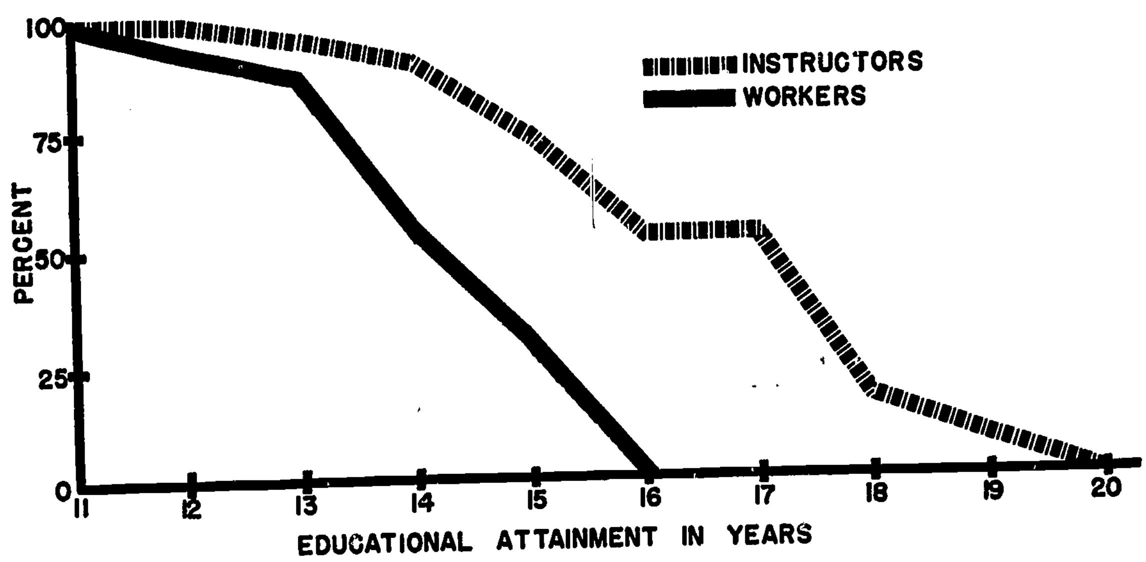

Figure 2

Distribution of Technical Workers and Electronic Instructors on Educational Attainment

the respondent with the highest educational attainment is not necessarily the one with the most mathematics in his background. Therefore, the level of mathematics achieved is shown for the technical workers and the instructors in Figure 3.

Needed Mathematical Skills or Concepts

In the body of the report the analysis of the Q-sort data is accomplished by partialing on the basis of job classification; however, for this abstract the mathematics needed on the job is reported for the technical workers

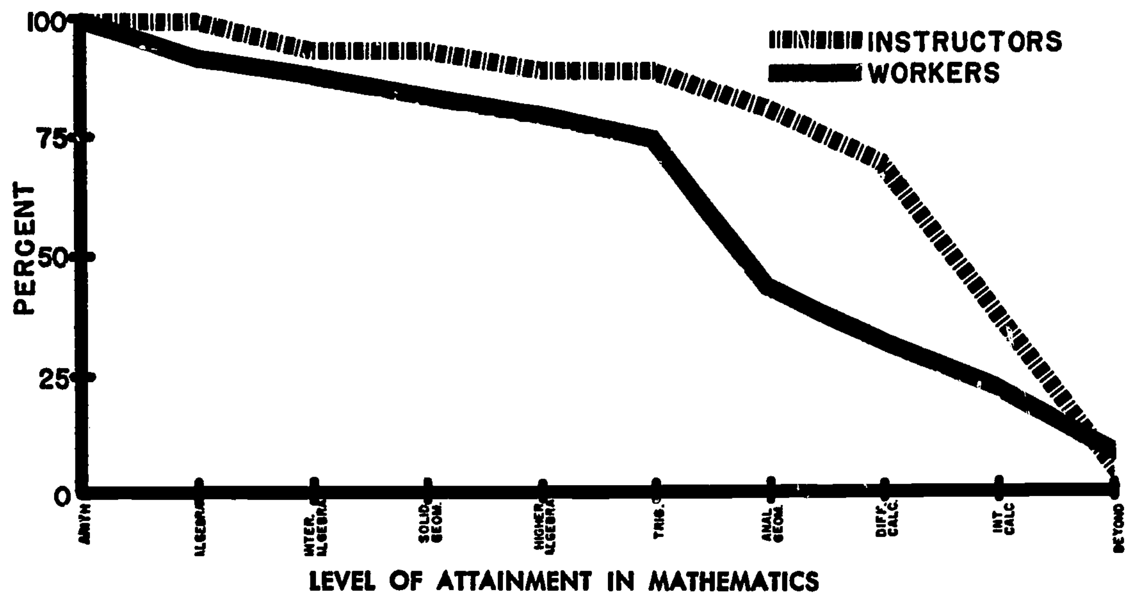

Figure 3

Distribution of Technical Workers and Electronics Instructors on Mathematics

as a whole. The ratings of the mathematical concepts or skills used in the Q-sort was from 9 (most essential) to 1 (least essential). Figure 4 shows the mean rating given each item along with the customary groupings in areas of mathematics and the cut-off points used to define "essential," "useful," and "of questionable value" items.

Before discussing the conclusions and recommendations drawn from the data, it is essential that the reader be acquainted with the assumptions upon which the research was based. It has already been stated that the technical workers were assumed to be qualified to assess the mathematical skills or concepts needed on their job. In addition, there were the following assumptions:

1. Addition, subtraction, multiplication, and division were assumed to be essential to all productive members of our industrial society.

2. The concept of ratio or proportion as included in algebra was representative enough without including the same arithmetic concept.

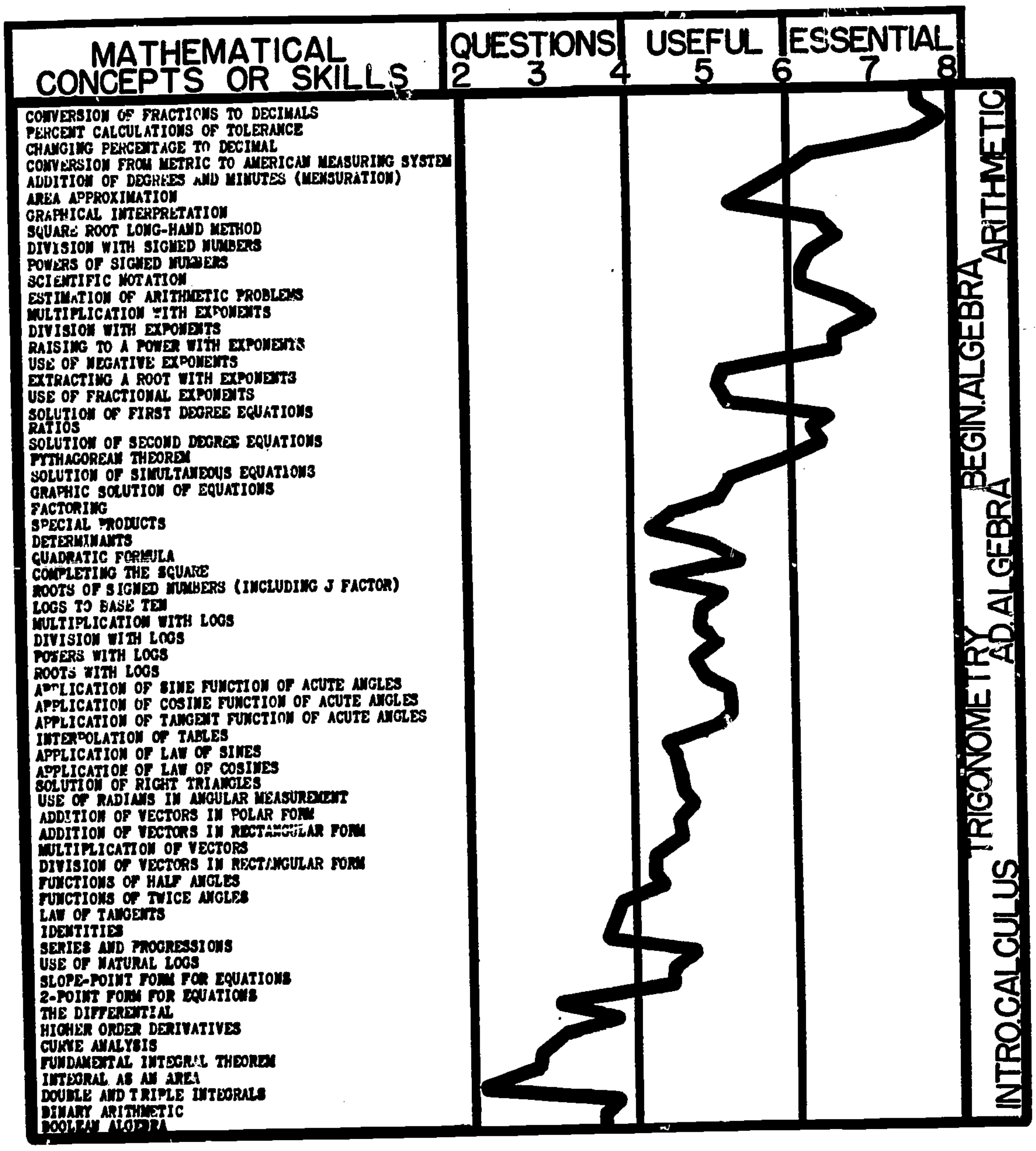

Figure 4

Mean Ratings of 63 Math. Concepts or Skills on a 9 to 1 Scale by 90 of the Technical Workers in 44 California E-E Companies

3. Linear, angular, arc and volume measurements with the addition, subtraction, multiplication, and division of units involved are covered in geometry and trigonometry, and need not be investigated separately.

4. The conversion from fractions to decimals and vice versa is covered by the use of tables.

5. The use of logarithmic and trigonometric tables, interpolation, extrapolation, and the like can be derived from the extent to which logarithms and functions are used.

6. Vectors in rectangular form and complex numbers involve the same mathematical concepts.
7. The slide rule is a tool and not a mathematical concept in itself.

The assignment of items in the Q-sort into "essential," "useful," and "of questionable value" was determined by analysis of the Q-sort data. The three categories fit nicely into another frame of reference. The "essential" category contains basic arithmetic skills which are considered to be needed by all technical workers in the electrical-electronics industry. These can be considered prerequisite mathematical skills or concepts, and they are

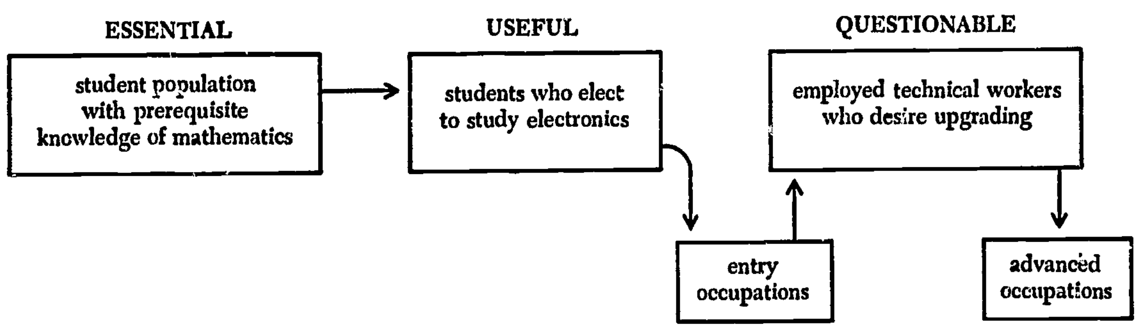

Figure 5

Theoretical Relationships Between Mathematical Categories, Training and Advancement in the Electronics Industry

of a sufficiently low order to allow the majority of high school graduates to qualify.

Those students who elect to study electronics should be required to master the items in the "useful" category in the process of completing their training. Mastery of these skills or concepts would assure sufficient knowledge of mathematics to gain entry into the industry.

The items listed in the "of questionable value" category are of questionable value to the training of students for entry occupations only and are not of questionable value in themselves. It is proposed that these items be considered as part of the offering in part-time programs designed to upgrade employed technical workers.

A graphical representation of the discussion above is shown in Figure 5.

Experimental Study

Instructional materials are considered to be highly correlated with student achievement and, therefore, two attempts were made to assess the effectiveness of instructional materials related to the teaching of mathematics for electronics.

An experiment was conducted at Bakersfield College in the use of automated instruction. Experimental and control groups were used to

assess the relative effect of automated instruction upon student achievement in mathematics. The results are shown in Figure 6.

Instructional Material

A questionnaire survey was employed to collect data on five self-instructional textbooks and eight commercially prepared teaching aids. Electronics instructors were asked to answer the following questions about each of the books and aids:

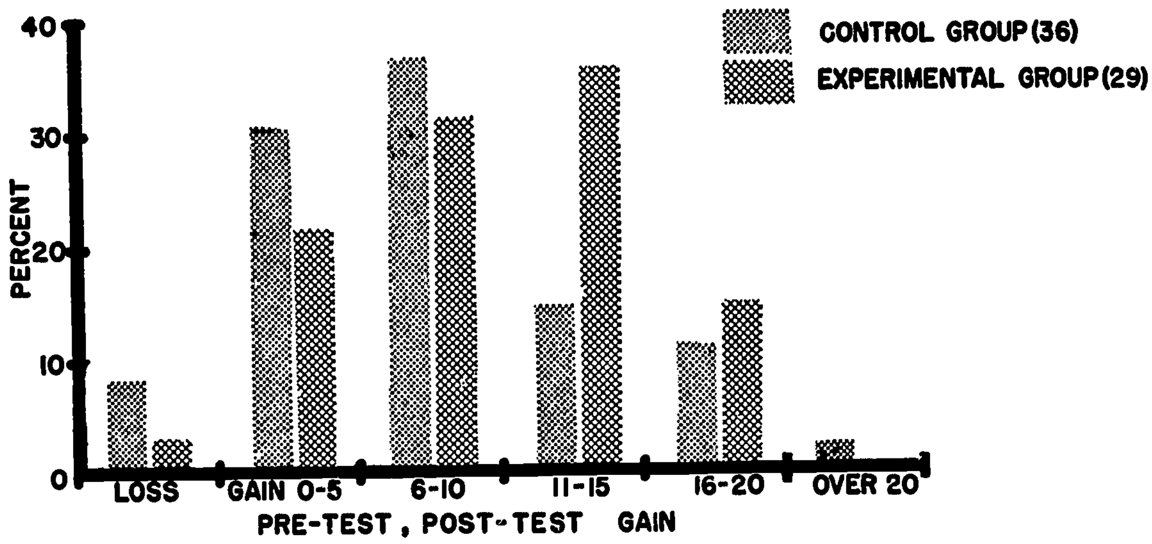

Figure 6

Distribution of Students on Gain in Mathematics by Control and Experimental Groups

1. Are you acquainted with the book or aid?
2. Do you see an application to instruction in electronics or mathematics related to electronics?
3. Have you used the book or aid in your program?
4. Do you think this book or aid was an asset?

The questions were so worded that if an instructor gave a negative response to any one of them, the subsequent questions were not applicable. This means that each of the four questions has a different number of responses.

Eighty-nine percent of the instructors responded. There was no differentiation among the teaching aids nor among the books. Consequently, the responses are for the two groups as a whole. The affirmative responses to the four questions listed above are shown in Figure 7.

Recommendations

(1) In order to define the mathematical skills or concepts to be included in a curriculum designed to train technical workers for occupations in

electronics, the first consideration should be to decide the entry level for which the students are being trained.

(2) Students planning to enroll in electronics curricula should be asked to demonstrate that they have mastered the fundamental algebraic processes. This would insure that all of the mathematical skills or competencies listed as "essential" had been mastered. Satisfactory completion of algebra or a satisfactory score on a standardized mathematics test should, therefore, be prerequisite to enrolling in classes designed to prepare students for entry occupations in electronics.

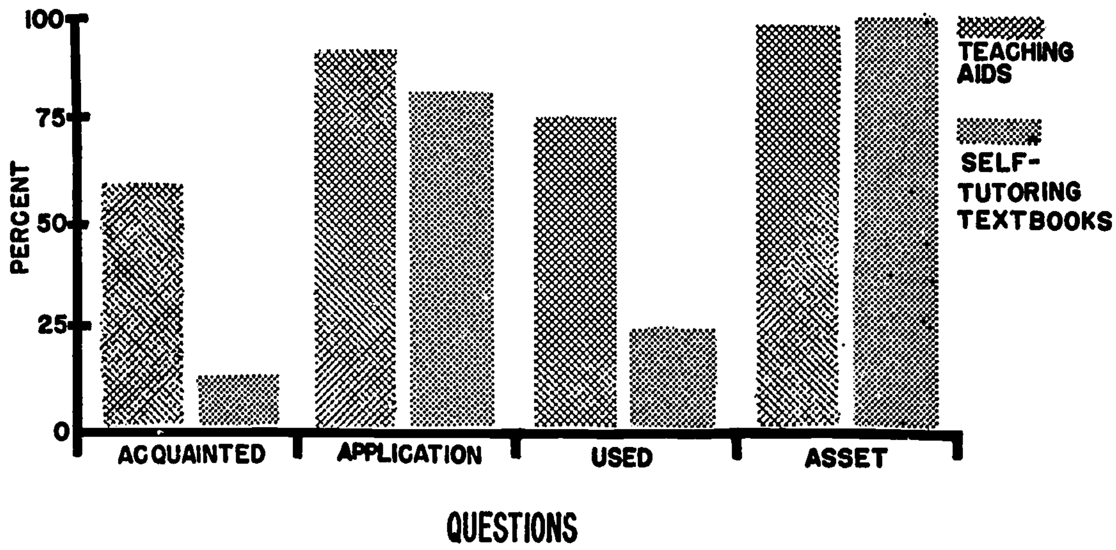

Figure 7

Affirmative Responses to Instructional Materials Questionnaires

(3) All curricula in electronics should incorporate mathematics through the basic trigonometric functions as a minimum requirement for completion.

(4) Courses in electronics and mathematics designed to provide the necessary training to upgrade employed technical workers in electronics should include calculus, number theory, Boolean algebra, and the like.

(5) Public school programs in electronics should be designed to incorporate the theoretical concepts applicable to all branches of the electronics industry in any given occupational classification.

(6) Teachers recruited for electronics programs should have had industrial experience in the job classifications for which the program is designed and should have completed mathematics beyond the level to which the students will be expected to achieve.

(7) Extension courses and/or state-sponsored workshops should be developed to provide instructors of electronics with the opportunity to gain advanced mathematical skills.

(8) The teacher training agencies in California that offer programs leading to a baccalaureate degree should strive to include advanced mathematics courses in the programs of their students who aspire to teach electronics.

It is recommended that commercially prepared teaching aids be considered an asset to instruction in electronics and be given preference over instructor-prepared devices.

Example

In order to define the mathematical skills or concepts to be included in a curriculum designed to train technical workers for occupations in electronics, the first consideration should be to decide the entry level for which the students are being trained. On the basis of the preceding data and discussion, it is evident that testing and research and development should receive prime consideration as entry occupations. To point up the use to which this report can be put, the recommendations to the junior colleges that follow will be in the form of an example. This example is based upon the assumption that the junior college involved has a student body sufficiently large from which to recruit students into electronics and the necessary facilities to conduct the program.

On the basis of the report and knowledge of the electronics companies in the junior college area, it was concluded that a program designed to prepare students to enter the electronics industry in the area of research and development is necessary.

The following concepts or skills have been defined as being essential to technical workers in research and development:

1. Conversion of fractions to decimals
2. Percent calculations of tolerance
3. Changing percentage to decimal
4. Conversion from metric to American measuring system
5. Square root long-hand method
6. Division with signed numbers
7. Scientific notation
8. Estimation of arithmetic problems
9. Multiplication with exponents
10. Division with exponents
11. Raising to a power with exponents
12. Use of negative exponents
13. Ratios
14. Pythagorean Theorem

To facilitate the teaching of the required electronics theory, knowledge of the foregoing list of "essential" mathematical skills or concepts would be required for entry into the electronics program. The entry requirements

in mathematics could be satisfied by having satisfactorily completed high school algebra (which would guarantee the completion of all 14 of the concepts listed above). In the absence of the prerequisite mathematics courses the student could gain entry into the electronics program by demonstrating on an entrance test that he was able to use the "essential" mathematical concepts.

The mathematical competencies or skills listed below have been defined as being useful to research and development technical workers and will, therefore, be built into the curriculum.

1. Addition of degrees and minutes (mensuration)
2. Area approximation
3. Graphical interpretation
4. Powers of signed numbers
5. Extracting a root with exponents
6. Use of fractional exponents
7. Solution of first degree equations
8. Solution of second degree equations
9. Solution of simultaneous equations
10. Graphic solution of equations
11. Factoring
12. Special products
13. Quadratic formula
14. Completing the square
15. Roots of signed numbers (including j factor)
16. Logs to base ten
17. Multiplication with logs
18. Division with logs
19. Powers with logs
20. Roots with logs
21. Application of sine function of acute angles
22. Application of cosine function of acute angles
23. Application of tangent function of acute angles
24. Interpolation of tables
25. Application of Law of Sines
26. Application of Law of Cosines
27. Solution of right triangles
28. Use of radians in angular measurement
29. Addition of vectors in polar form
30. Addition of vectors in rectangular form
31. Multiplication of vectors
32. Division of vectors in rectangular form
33. Functions of half angles
34. Functions of twice angles
35. Use of natural logs
36. Slope-point form for equations
37. 2-point form for equations

To insure the ability of the instructor to teach the required mathematics, the person recruited to teach this proposed curriculum in research and development technology for electronics would have had experience in research and development in industry and would have completed mathematics through the calculus, even though the calculus itself is not included in the concepts to be taught in the curriculum.

To provide the opportunity for the research and development workers in local industries to upgrade themselves, extended-day classes would be offered in advanced mathematics including the calculus number theory and Boolean algebra.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Research is needed in the area of physics, chemistry, and property of materials applicable to electronics to help define the extent to which they should be included in electronics curricula.

2. A long-term follow-up of the graduates of programs in electronics technology should be made to determine the occupational success of these graduates in comparison with industry-trained, service-trained and untrained technical workers in industry.

Part II

Chapter 1

THE INTERVIEW SCHEDULE AND THE Q-SORT

Developing the Interview Schedule

The determination of the data to be obtained by interviewing technical workers was dictated to a large degree by two obvious variables: the amount of formal education completed and the amount of mathematics studied.

It was apparent that the amount of formal education and of mathematics studied would have a bearing upon the amount of mathematics a technical employee used on his job, or at least would have bearing upon his opinion concerning mathematics needed on his job. Therefore, in the process of interviewing technical employees, data concerning the amount of formal education and the level of mathematics achieved were collected. Formal education was broadly interpreted to include public schools, private schools, military service schools, correspondence courses, and classes held in industry. Because formal education was broadly defined, it was necessary to devise a scale of equivalency to indicate achievement of each of the technical workers. The customary units of high school or college courses completed were not satisfactory because military service schools and classes conducted in industry are not measured in this fashion. The assessment of formal education achieved and formal mathematics completed took place during the interview with the technical employee and his placement on the following scales was determined:

Formal Education

1—less than high school
2—high school or equivalent
3—high school +
4—Associate of Arts or equivalent
5—Associate of Arts +
6—Bachelor of Arts or equivalent
7—Master of Arts or equivalent
8—Master of Arts +

Baccalaureate and higher degrees were included in the classification of formal education in order to permit classification of the electronics instructors on the same scale with the technical workers.

The respondents were asked to recall the courses in mathematics they had studied in high school, college, and/or other formal educational programs. These were then classified according to the following categories:

Formal Mathematics

1—none	7—higher algebra
2—arithmetic	8—trigonometry
3—plane geometry	9—analytical geometry
4—algebra	10—differential calculus
5—intermediate algebra	11—integral calculus
6—solid geometry	12—beyond

The assumption was made that a person who completed the mathematics courses identified by any point on the scale would not necessarily have completed all of the courses listed below that point; but he would have had to master the aspects of the preceding courses that are prerequisite to the course at that particular point on the scale.

As a part of the interview process, the technical employees were asked to identify the factors that influenced their choice of occupation. It was anticipated that there would be considerable personal influence involved in occupational choice. During the interview, the technical employees were asked to identify (by name, if possible) any individual who had had an effect upon their occupational choice. If they could not remember anyone having influenced them, or if they credited someone with having influenced them, but could not recall the individual's name, it was recorded as "no personal influence." It was anticipated that military service or other employment circumstances influenced occupational choice. This, too, was investigated in the process of interviewing.

The question concerning the development of an interest in electronics by technical workers (whether there was any personal influence involved and where they received their training) was an attempt, in addition to investigating the mathematical skills necessary, to identify the extent to which public education had contributed to occupational-vocational guidance of the technical workers currently employed in the industry.

Occupational Mobility

The occupational experience pattern of the respondents was considered to be an important variable that might have an effect upon the Q-sort. For this reason a job history was solicited from each respondent. The job history was pursued far enough to enable the investigator to determine

whether the individual involved was stable within the occupational area, horizontally mobile within the occupational area, or vertically mobile.

Job stability needs no definition; however, horizontal and vertical mobility do. For the purposes of this study, horizontal mobility means that the technical employee has made two or more job changes within the past three years without substantially improving his status. Vertical mobility means that the technical employee has made two or more moves, each of which improved his occupational status.

It seemed imperative to check the validity of the job histories reported by the technical employee. Nine of the interviewees (10 percent of the total) were selected and their job histories and formal education, as reported, checked against the job histories and formal education on file with the personnel office of their employers. Of the nine investigated, two had actual job histories slightly different from those reported. In each instance, however, the difference was not great enough to change their classification by mobility. This investigation satisfied the validity requirements of this phase of the research report.

Developing the Q-Sort

To identify the mathematics continuum, a variety of published studies was consulted. A study by David Allen listed approximately 100 mathematical skills or competencies needed in the electrical-electronics industry in California.[1] In addition, standard texts, final examinations administered at the junior colleges in the State, and interviews with 25 teachers of electronics who were attending the 1960 summer session at U.C.L.A. were used. Each of the teachers interviewed was asked to submit five problems representative of concepts or skills that they would expect their graduates to master. All of the skills and concepts accumulated from the aforementioned sources were grouped according to similarity and arranged in a logical sequence. It was assumed that knowledge and understanding of the fundamental arithmetic skills (addition, subtraction, multiplication, and division of whole numbers) could be deleted from the list since such concepts were representative of the needs of society as a whole.

Sixty-six mathematical concepts evolved, ranging from the more complex arithmetic processes to integral and differential calculus. Typical problems were then developed that represented these specific mathematical concepts or skills. The problems were constructed to represent each skill or concept involved and were screened to be sure that the jargon of the electrical-electronics industry had been omitted, and that as often as possible only one mathematical skill or concept was represented by the problem.

[1] *A Guide for Developing Electronics Courses*, Electronic Committee of the Local Administration of Vocational and Practical Arts, and the Bureau of Industrial Education, Second Edition, California State Department of Education (Sacramento: 1960).

In the process of the Q-sort the interviewees were asked to make a forced normal distribution of the mathematical skills or concepts (which were printed on 66 cards) into nine piles with the distribution of the cards ranging from those representative of problems most similar to the problems encountered on the job to problems which were least similar to the problems encountered on the job. (The directions, reporting forms, and sample problems used in the Q-sort are shown in Appendix B.)

By definition, the technical workers included in the sample (see Chapter 2) had to make use of basic electrical-electronics theory on the job. This eliminated the workers whose jobs were repetitive. If the technical worker used the entire range of mathematics, it was assumed that the resulting sort would follow the recommended order of instruction in mathematics.

The Q-sort, as it was used in this study, seemed the best possible way to determine whether specific skills or concepts in algebra, trigonometry, and other branches of mathematics were widely used while others in the same broad categories of mathematics were seldom used.

Pilot Study

A pilot study was conducted for the purpose of checking: (1) whether the questions to be asked were meaningful and capable of being answered by technical workers in industry; (2) the time required to complete the Q-sort (this proved to be between 45 and 70 minutes); (3) the validity of the problems (determining whether the problems truly represented the mathematical skill or concept that they were intended to represent).

The pilot study consisted of 18 interviews with technical workers in the electrical-electronics industry in Southern California. These workers were selected because they had been identified by their employers as having mathematical skills and as being able to recognize the skill or concept involved in each problem. After the interview and the sort an extensive discussion was held with each interviewee to determine whether he could in fact identify the specific mathematical skills or concepts represented on each of the 66 problems. As the result of these interviews, a number of problems were changed. There were items that unwittingly included electrical or electronic terminology in the symbols used in the mathematical problems. A good example was the use of "db" as a literal number, whereas in electronics it represented decibels. Another example was the use of "S" as a literal number, whereas in electronics it represented the complex "j" factor. After each interview, the Q-sort problems were re-evaluated and changed so that by the time the 18 interviews had been completed, the last three interviewees were able to identify the mathematical skills or concepts represented by each of the 66 problems.

Falsifiers

During the process of constructing the Q-sort, three items were injected that were false or mathematically impossible. One was for the calculus, one for binary arithmetic, and one for Boolean algebra. The purpose of the falsifiers was to identify the respondents who recognized the mathematical skills or competencies involved and included them in the "essential" category but could not have made use of the skill or competency in that they were unable to differentiate these falsifiers from the other examples. During the process of recording the Q-sort, notice was taken of the placement of the falsifiers in the sort. If a respondent placed the false items in the "essential" or "useful" category, a discussion with the respondent was held to provide an opportunity for him to mention the items that were impossible. On three occasions the falsifiers were placed in the "essential" or "useful" section of the sort. In each case during the discussion the respondent remarked that there were items that were mathematically impossible but he had interpreted them as mistakes and had included them along with the true items which represented the skill or concept involved. This satisfied the validity of the sort, and the falsifiers have been ignored in reporting the items in the Q-sort.

Necessary Assumptions

As has already been mentioned, the mastery of addition, subtraction, multiplication, and division was assumed essential to productive members of our industrial society. In addition, other assumptions were made and validated during the interviews with 18 technical workers and 33 instructors. These were as follows:

1. The concept of ratio or proportion as included in algebra was sufficiently representative to make it unnecessary to include the same arithmetic concept.
2. Linear, angular, arc, and volume measurements, including addition, subtraction, multiplication, and division of units are covered in geometry and trigonometry, and need not be investigated separately.
3. The conversion from fractions to decimals and vice versa is covered by the use of tables.
4. Knowledge of logarithmic and trigonometric tables, interpolation, extrapolation, and the like can be derived from the extent to which logarithms and functions are used.
5. Vectors in rectangular form and complex numbers involve the same mathematical concepts.
6. The slide rule is a tool and not a mathematical concept in itself.

Summary

Gathering information concerning the role of mathematics in electrical-electronics technology required that certain technical workers be inter-

viewed and be asked to participate in supplying data concerning themselves and their use of mathematics.

Personal data were to be obtained. The interview schedule included provisions to identify the extent of formal education completed and the nature of formal mathematics studied. In addition, it was important to the study to inquire into the nature and circumstances of the occupational choice of the technical workers, and to record information concerning the job history of the technical workers. From these data the occupational mobility of technical workers could be studied.

A technique known as the Q-sort was used to determine the amount of mathematics actually used on the job. This made it possible for the technical worker to make a distribution (from a previously prepared list of problems representative of mathematical skills or concepts) of the problems which were most like those he actually encountered in his work to those which were least like those encountered in his work. The Q-sort was used as the basis for determining the role of mathematics in electrical-electronics technology.

Chapter 2

THE TECHNICAL WORKER

The Industrial Universe for the Study

It was intended that the sample of technical workers to be included in the study be representative of all technical workers in the State employed in the electrical-electronics industry. To insure representation, it was necessary to have randomly selected technical workers from randomly selected electrical-electronics companies.

The list of companies involved in the manufacture, installation, repair, and service of electrical-electronics components, sub-systems, and systems was derived from the following sources: (1) directory of the Western Electronics Manufacturers' Association; (2) *Electronic Sources,* published by Directories of Industry, Inc.; (3) rosters of advisory committees serving junior college electronics courses; (4) *California Manufacturers Annual Register,* 1960; (5) Federal Communications Commission List of Radio and TV stations; (6) directories prepared by Chambers of Commerce and County Boards of Trade for the major cities in the State; and (7) the yellow pages of telephone directories.

The name and location of each company were punched on IBM cards (the list included the various branches of the large corporations). When all of the sources had been listed, the cards were alphabetized and printed and duplications were removed. A total of 2,643 specific installations comprised the list of the State's electrical-electronics industry. With the aid of a table of random numbers, a sample of companies was selected. The original sample was 50, with two matched alternates for each.

The total number of companies contacted was 86, of which 44 were included in the study. Thirty-nine companies were rejected because they did not employ technical workers of the classification desired, or because they employed only one or two such workers. Three companies which met the requirements of the study refused to participate. The breakdown by sample, first alternates, and second alternates is shown in Table I.

TABLE I

DISTRIBUTION OF COMPANIES CONTACTED BY SAMPLE AND ALTERNATES

	1st sample	1st alternate	2nd alternate	Totals
Companies contacted	50	22	14	86
Companies participating in study	28	8	8	44
Rejected	19	14	6	39
Companies refused to participate	3	0	0	3

Selecting the Sample of Technical Workers

Inquiries were made of each of the companies to determine whether they employed technical personnel that fell within the scope of the study. The next step consisted of a visit with the chief personnel officer, factory superintendent, or general manager, to solicit cooperation in the research. At this point, the person authorized to give approval to participate was given a prospectus of the study and copies of the interview schedule and Q-sort information. Once permission had been obtained to interview the technical workers and to give the Q-sort, a number of technical workers were selected at random from the total technical working force. This number had been previously set in relation to the total number of employees who fell within the general classification of technical worker. This was accomplished in a variety of ways dependent upon the size of the group involved. If the total number of such workers was 30 or fewer, they were given consecutive numbers, and those to be interviewed were drawn from a hat. If the number was above 30, they were also given consecutive numbers, and the starting point for selection was drawn from a hat, and every *n*th man was picked.

Definition

There have been numerous efforts to define the technical employee and his place in industry. The following definition is similar to many, but a little more precise than most:

The technician is a person who works at a job which requires applied technical knowledge and applied technical skill. His work in this respect is somewhat akin to that of the engineer, but usually narrower in scope. His job also requires some manipulative skills, those necessary to handle properly the tools and instruments to perform the technical tasks. In his special field he has considerable technical knowledge of industrial processes, and in the field he knows how to apply the necessary principles of the physical sciences and mathematics. In general, he uses

instruments in contrast with tools. His contribution is mainly through mental effort in contrast with muscular exertion.[1]

For the purpose of this study, technical employees in the electrical-electronics industry were defined as "skilled workers who are required on their jobs to apply basic electrical-electronic theory." This definition was limited by an additional requirement that the "skilled workers" have not as yet received a baccalaureate degree. This was intended to, and did, eliminate the engineers who were performing technicians' jobs.

From the 44 companies that participated in the study, 90 technical workers, selected at random, were interviewed and were given the Q-sort. These 90 were representative of the 963 technical workers employed in the 44 companies.

Development of Job Classifications for Technical Workers

The specific classifications within the broad classification of technical worker were determined by defining operationally the jobs of the employees included in the study. The job functions of those employees who performed similar functions were grouped into one classification, and the description of this classification became a synthesis of the operational definitions of the jobs of the men who fell within this classification. By this method, nine classifications were established, and the technical workers who fell into each classification did approximately the same type of work. These classifications are as follows:

Testing

Performs product tests (test after production) from specifications. Tests and troubleshoots components, sub-systems, and systems to locate causes of failure. Checks components, sub-systems, and systems for capability of doing the job for which they are designed (reports findings to engineer or supervisor). Conducts operational checks on instruments such as oscilloscope, VTVM, multimeter, signal generator (AF-RF), and E-put meters.

Field Service

Installs, maintains, and/or repairs complex electrical or electronic equipment (work is generally performed on customer's premises). Troubleshoots and makes necessary adjustments and repairs (adjustments and repairs are commonly made with the aid of the manufacturer's detailed specifications and maintenance manuals).

Plant Maintenance

Constructs, installs, maintains, and/or repairs electrical and occasionally electronics in-plant equipment. Troubleshoots and makes adjustments

[1] *Vocational-Technical Education for American Industry*, U. S. Department of Health, Education, and Welfare, circular No. 530 (Washington: 1958), p. 1.

and/or repairs to obtain satisfactory operation, i.e., rewires or rewinds electrical motors. Understands and applies knowledge of simple circuitry (generally works without prints and diagrams).

Instrument Maintenance

Tests, adjusts, maintains, calibrates, repairs, and modifies electronic and electrical test equipment. Performs periodic functional tests on all types of electrical and electronic instruments to determine if equipment meets specifications. Generally works from equipment manufacturer's manual to insure measurement within the specifications.

Research and Development

Works from schematics and/or verbal instructions to build "breadboards" of design circuits and prototypes (the initial model of production item). Sets up testing procedures and designs test programs to check out production items. Designs or participates in the design of electro-mechanical packaging and sets up environmental test procedures. Checks and calibrates prototypes of production items; makes modifications and redesigns circuits when and where necessary; uses complete line of electronic test equipment.

Design Drafting

Prepares detailed drawings and circuit diagrams (from rough sketches, block diagrams, or verbal instructions, furnished by engineers or designers) to be used in the installation and manufacture of various types of electrical or electronic equipment; makes modification in drawings as required by engineering changes.

Communications

Installs, maintains, and repairs radar, telemetry, sonar, NAV-AID radio transmitters, and similar equipment; insures operation of the equipment within specifications, makes on-the-spot adjustments, replacements, or modifications required; performs periodic functional checks to guarantee continuous operation; uses multimeter, VTVM, milliammeter, tube checker, oscilloscope, pulse generator, RF generator, audio oscillator, sound analyser, spectrum analyser, echo box, and other similar instruments.

Computer

Lays out experimental computer circuits from engineering sketches, using knowledge of computer logic, transistors, semi-conductors, circuit analysis, and other electronic computer technical skills; prepares test data and charts indicating operating characteristics under each of the test conditions to which the component or system was subjected; applies

Boolean algebra, binary and octal number systems to the design of computer logic circuits.

Radio and Television

Troubleshoots and brings to satisfactory operation radio, television, and sound reproduction sets (work is performed in the shop, or on the premises of the owner; generally, this work is done with the aid of the manufacturer's specifications and repair manual). Uses VTVM, multimeter, tube tester, oscilloscope, and the basic test instruments.

Distribution of Technical Workers Within the Classifications

The nine classifications listed can be divided into three categories: one concerned with manufacture, one concerned with engineering, and one concerned with service. The research supports this as a representative distribution with *one* exception, that of radio and television repairman.[a]

An inspection of the yellow pages of the telephone directories of metropolitan areas of California showed thousands of radio and television repair shops in the State. The universe established for this study included only a few radio and television repair shops. As a consequence, the percentage of technical workers in radio and television in the sample is smaller than a representative sample should have been.

Table II shows the distribution of technical workers in each category.

TABLE II

TECHNICAL WORKERS INCLUDED IN THE STUDY BY JOB CLASSIFICATIONS, IN GROUPS

	N
1. Manufacture (43)	
Plant maintenance	3
Instrument maintenance	5
Design drafting	3
Testing	32
2. Engineering (32)	
Computers	3
Research and development	29
3. Service (15)	
Field service	3
Communications	8
Radio and television	4

[a] A 1952 study of eight metropolitan areas in the United States, conducted by the Bureau of Labor Statistics, concluded that there were 70,000 technical workers in radio and television in these eight areas. (See *Mobility of Electronic Technicians 1940–52*, U. S. Bureau of Labor Statistics, Bull. No. 1150 [Washington: 1954], p. 46.)

Analysis of Interview Data

A correlation analysis of the interview data was made to demonstrate the extent to which the variables investigated in the interviews varied with one another. In addition, Kruskal-Wallis (H) one-way analysis of variance[3] was computed to determine whether the technical workers varied significantly in the amount of formal education and mathematics when grouped by job classification.

Fourfold correlations and multiple correlations were computed to investigate the relationship between mobility, age, and educational background for the technical workers in total and by job classification.

Formal Education of the Technical Worker

TABLE III
FORMAL EDUCATION OF TECHNICAL WORKERS IN THE SAMPLE BY JOB CLASSIFICATION

Job classification	Less than high school	High school	High school plus	A.A. or equivalent	A.A. plus	N	Mean formal education
Radio and television	0	1	0	1	2	4	A.A. or equivalent
Plant maintenance	1	1	0	1	0	3	High school
Field service	0	0	2	0	1	3	A.A. or equivalent
Design drafting	0	1	0	1	1	3	A.A. or equivalent
Testing	2	4	14	7	5	32	High school plus
Instrument maintenance	0	1	1	2	1	5	A.A. or equivalent
Research and development	0	0	8	8	13	29	A.A. or equivalent
Communications	1	1	1	3	2	8	High school plus
Computer	0	0	0	2	1	3	A.A. or equivalent
N	4	9	26	25	26	90	A.A. minus

The distribution of formal education by job classifications is shown in Table III. The mean formal education background of the technical worker proved to be 3.72 on the scale of educational equivalency. This is equiva-

[3] The Kruskal-Wallis (H) one-way analysis of variance does not require normal distribution, but it does require that the data being analyzed be continuous. Explanation

lent to slightly less than two years of junior college. The technical workers in this study have a slightly higher mean formal education background than did those in Stewart's[4] study who had a mean formal education of slightly more than one year of junior college.

To carry forward the description of the technical worker, a Kruskal-Wallis (H) one-way analysis of variance for formal education by job classification was computed (see Table IV). From this analysis it was concluded

TABLE IV
KRUSKAL-WALLIS (H) ONE-WAY ANALYSIS OF VARIANCE

Categories	H	Degrees of freedom
Formal education by job classification	16.40†	8
Formal education by job classification with horizontally mobile technical workers omitted	17.23†	8
Formal education by service, manufacturing, and engineering categories	13.75*	2
Formal education by service and manufacturing categories	3.58	1
Formal education by service and engineering categories	1.50	1
Formal education by manufacturing and engineering categories	11.90*	1
Level of mathematics achievement by job classification	34.89*	8
Level of mathematics achievement by job classification with horizontally mobile technical workers omitted	37.77*	8
Level of mathematics achievement by source credited with having contributed most to the ability to perform on the job	4.23	8

* Significant at 1%.
† Significant at 5%.
H varies as Chi square (theoretically from zero to infinity) and the significance of the differences in rank order is based upon the number of sub-groups (job classifications) minus one.
If H is significant at five per cent, this is interpreted to mean that the difference in rank order could have occurred by chance five times out of a hundred.

that there is a difference in the amount of formal education from classification to classification for the technical worker. However, it *seemed possible* that the technical worker on the lower end of the educational ladder may be undesirable in terms of performance on the job. The only attempt made to measure the job efficiency of the respondents was in terms of

of the scales used and the basis for assuming continuous data are given in Chapter 1.

The reason for using this statistic is to determine if the differences that exist among the job classifications in this study could have occurred by chance. The Kruskal-Wallis (H) statistic compares the placement of the sub-groups within the rank order of the total group and assesses the distribution of the sub-group ranks in terms of the probability of the distribution occurring by chance.

[4] *Mathematics and Science Competencies for Technicians*, by Lawrence H. Stewart and Arthur D. Workman, Bulletin of the California State Department of Education, Vol. XXIX, No. 12 (Sacramento: Dec. 1960), p. 14.

their job history. From the history solicited each man was assigned to a category dependent upon his job history. These categories are "stable," "horizontally mobile," and "vertically mobile" (see Chapter 1). It is assumed here that if the technical worker is stable or upwardly mobile, he has demonstrated his efficiency to the satisfaction of the employer. If he is horizontally mobile, it is *possible* that he may not be able to validate as an efficient technical worker.

With these assumptions in mind, another (H) was computed in which the horizontally mobile technical workers were left out (see Table IV). This increased the (H), and it remained significant.

The nine classifications of technical workers had previously been combined to form three categories of technical workers: service, manufacturing, and engineering. These categories were then subjected to the Kruskal-Wallis (H) one-way analysis, which yielded a significant (H). (See Table IV.) Since the initial analysis omitting the horizontally mobile worker demonstrated that the significance was not artificial, this analysis was not repeated with these categories. The analysis led to the conclusion that not only is there a difference in the formal education of technical workers, based on job classifications, but that the classifications can be ranked according to the formal education scale in Chapter 1 as follows:

Rank Order

1—plant maintenance
2—testing
3—instrument maintenance
4—design drafting
5—communications
6—radio and television
7—field service
8—research and development
9—computers

Formal Mathematics Background of the Technical Worker

It is to be expected that the amount of mathematics an individual has studied will correlate highly with the amount of formal education in his background. The correlation of mathematics with education is .622 (see Appendix C). The mean level of formal mathematics of the technical workers as a whole is through trigonometry. Formal mathematics, when considered by job classifications, is shown in Table V. (Notice that research and development and computer technical workers exceed the other classifications in the level of formal mathematics completed.)

To follow the same procedure as in the analysis of formal education, Kruskal-Wallis (H) was computed for level of mathematics by job classification (see Table IV). An additional (H) was computed, leaving out those technical workers who were horizontally mobile. The resulting (H) was significant at one percent (see Table IV).

This leads to the conclusion that the mathematical attainment of the

TABLE V

FORMAL MATHEMATICS OF TECHNICAL WORKERS BY JOB CLASSIFICATION

Job classification	Less than algebra	Algebra	Inter-mediate algebra	Solid geometry	Higher algebra	Trigo-nometry	Analyt-ical geometry	Differ-ential calculus	Integral calculus	Beyond	N	Mean level of mathematics
Radio and television	0	1	0	0	0	2	1	0	0	0	4	Higher algebra
Plant maintenance	1	1	0	1	0	0	0	0	0	0	3	Algebra
Field service	1	0	0	0	0	0	0	0	2	0	3	Trigonometry
Design drafting	0	0	0	0	0	2	0	0	1	0	3	Analytical geometry
Testing	2	3	2	2	3	14	2	2	2	0	32	Higher algebra
Instrument maintenance	0	0	0	0	1	3	1	0	0	0	5	Trigonometry
Research and development	0	1	1	0	0	3	7	4	7	6	29	Differential calculus
Communications	0	1	2	0	0	2	2	0	1	0	8	Higher algebra
Computer	0	0	0	0	0	0	0	0	2	1	3	Integral calculus
N	4	7	5	3	4	26	13	6	15	7	90	Trigonometry

technical workers varies with the classification and, again, the classifications can be ranked in terms of mathematical attainment. This ranking is the same as the ranking on formal education.

There were five sources credited by the technical workers as having contributed to the ability to perform on the job. These were Armed Forces

TABLE VI

SOURCES CREDITED BY RESPONDENTS AS CONTRIBUTING MOST TO THEIR ABILITY TO PERFORM ON THE JOB, BY JOB CLASSIFICATION

Job classification	Sources					
	On own	Service	Public schools	Private schools	Industry	N
Radio and television	0	0	1	1	2	4
Plant maintenance	0	0	1	0	2	3
Field service	0	1	2	0	0	3
Design drafting	0	1	1	0	1	3
Testing	4	9	2	3	14	32
Instrument maintenance	0	0	0	2	3	5
Research and development	7	3	6	0	13	29
Communications	0	4	0	0	4	8
Computer	0	0	1	1	1	3
N	11	18	14	7	40	90

training, public school training, private school training, classes held in industry, and studying on their own (see Table VI). Anyone acquainted with these five methods of acquiring the technical skills would expect a differing amount of mathematics dependent upon the method under which the technical worker had been trained. The Kruskal-Wallis (H) one-way analysis of variance was computed to determine whether this was the case (see Table IV). The analysis demonstrated that there was no significant difference in the amount of mathematics dependent upon the source of training.

Of the 90 technical workers in the sample, 18 were upwardly mobile.

It is impossible to demonstrate whether the achievement in mathematics contributed to mobility, but it is possible to demonstrate whether there is a correlation between achievement in mathematics and mobility. The correlation between achievement in mathematics and mobility for the total sample is –.146.

This is to some extent misleading because mathematics achievement was ranked on a continuum, whereas mobility was grouped as one of three classifications. To investigate the possibility that a correlation existed between mathematics achievement and mobility and that the negative correlation previously mentioned was misleading, multiple correlations were computed in which job classifications and then age were held constant, while mathematics achievement was correlated with mobility.[5] These correlations were .285 and .322 respectively (see Table VII). In addition, a fourfold correlation was computed for testing and for research and development workers (see Table VII). These two classifications were used because the number of workers was large enough to permit the calculation, whereas the number in the other seven classifications was too small.

The correlations between mathematics achievement and vertical mobility demonstrates that the two do not vary together for the technical workers in the testing area, but they do vary together for the workers in research and development. This would seem to indicate that the research and development technical workers, who are on the upper end of the rank order, are vertically mobile when they possess more mathematics background than their co-workers.

The fourfold correlations coupled with the multiple correlations demonstrated that the more mathematics the technical worker has, the more likely it is that he will progress upward within the industry.

Age of the Technical Worker

From sociological studies about occupations it is generally concluded that "the first job is a good predictor of the subsequent career" and that "mobility decreases with age."[6] The correlation between mobility and age

[5] The correlations used in this study are product-moment, multiple, and fourfold correlations. In each case, normal distribution and a linear relationship are assumed. The function of a correlation is to measure the extent to which variables are related to one another.

Correlations can vary from minus one to plus one. The significance of the correlation is dependent upon the number of observations being correlated. If a correlation is significant at five percent, this indicates that the variables being measured vary with one another to the extent that this relationship could happen by chance five percent of the time.

The product-moment correlation is based upon raw scores and the multiple correlations are in turn based upon the product-moment correlations. The fourfold (tetrachoric) correlation is based upon dichotomized variables.

[6] Seymour Martin Lipset and Reinhard Bendix, *Social Mobility in Industrial Society* (Berkeley and Los Angeles: University of California Press, 1959), pp. 173–74.

for the total sample was –.292 (see Appendix C), which would seem to suggest that the technical workers in this study follow the pattern of most of the industrial workers, and that the statements quoted above are applicable to the technical workers in this study.

Electronics education in the California public schools has been receiving more and more attention during the last decade. Considering the variety of sources from which the technical workers could receive training and

TABLE VII

CORRELATION OF SELECTED INTERVIEW DATA FOR TECHNICAL WORKERS

Multiple Correlations

C = Classification   M = Mathematics   Mo = Mobility   A = Age

$R_{C.M.Mo} = .285$† with N = 90

$R_{A.M.Mo} = .322$* with N = 90

Fourfold Correlations

Fourfold correlations	N	
Between technical worker's age (split at the median) and source of training (public schools and other training agencies).........	90	.184
Between mathematics (above or below the median) and mobility (vertical or not vertical) for test.............................	32	.028
Between mathematics (above or below the median) and mobility (vertical or not vertical) for research and development......	29	.596
Between mobility (stable and unstable) and age (above and below the median)...	90	–.334
Between mobility (horizontal and vertical) and age (above and below the median)...	41	.032

* Significant at 1%.
† Significant at 5%.

the age range of the technical worker, it was not surprising that only 16 percent of the workers in the sample credited the public schools with having contributed most significantly to their ability to perform on the job (see Table VI). For this reason, a fourfold correlation was computed to determine whether there was any correlation between the age and the source of training, which proved to be –.184 (see Table VII). This fourfold correlation of –.184 differs with the correlation between age and the area of training as reported in Appendix C, which is –.057, because the fourfold correlation is a dichotomous correlation comparing the technical workers who received their training in public schools with the technical workers who received their training elsewhere, whereas the correlation reported in Appendix C is between age and all five areas as they were listed in the interview reporting form. Hence, it is concluded that the public schools are increasing in importance in terms of their contribution to the training of technical workers.

Factors Influencing Occupational Choice of the Technical Worker

There were two considerations in determining how the technical workers became interested in electronics to the point where they sought employment in the industry. The first was circumstantial influence, and the second was personal influence. The distribution of sources of interest by

TABLE VIII
SOURCES OF INTEREST IN ELECTRONICS

Job classification	None	Service	Hobby	School	Job	N
Radio and television	4	0	0	0	0	4
Plant maintenance	1	2	0	0	0	3
Field service	2	1	0	0	0	3
Design drafting	0	3	0	0	0	3
Testing	7	11	9	2	3	32
Instrument maintenance	1	0	2	1	1	5
Research and development	4	7	13	3	2	29
Communications	0	2	6	0	0	8
Computer	1	2	0	0	0	3
N	20	28	30	6	6	90

classification is shown in Table VIII, by personal influence in Table IX. Hobbies have played a significant role in the development of the interest in electronics and in some cases have contributed to the ability of the technical worker to perform the job. There were only seven instances where technical workers named teachers or classes as having contributed to the interest in electronics.

Interest and influences which led prospective technical workers to seek employment in the electrical-electronics industry turned out to be as complicated and varied as they are for workers in other avenues of employment.

One-third of the interviewees credited hobbies as the source of interest. Nearly one-third of the technical workers indicated their source of inter-

est as arising from military services. More than 20 percent of the technical workers reported that their interest was self-developed and could not attribute the development of this interest to any person or institution. Six of the technical workers indicated that their previous school experience had stimulated their interest in electronics.

The responses of technical workers concerning the source of personal influence which led to their choosing the electrical-electronics industry as

TABLE IX

THE ROLE OF PERSONAL INFLUENCE IN CHOOSING A CAREER IN ELECTRONICS

Job classification	Source of influence				
	None	Family	Teacher	Friend	N
Radio and television	2	1	0	1	4
Plant maintenance	2	1	0	0	3
Field service	3	0	0	0	3
Design drafting	3	0	0	0	3
Testing	19	8	4	1	32
Instrument maintenance	2	2	1	0	5
Research and development	23	2	1	3	29
Communications	4	0	1	3	8
Computer	3	0	0	0	3
N	61	14	7	8	90

an occupational area is equally interesting. These data are shown in Table IX. More than two-thirds of the workers interviewed indicated that the source of influence was their own personal effort and could not be credited to others.

SUMMARY

The technical workers in the study fall into nine classifications. In terms of mathematics and formal education, these classifications differ from one another. The nine classifications were grouped into three categories which describe the major job functions. These categories are the manufacturing, service, and engineering. These three categories also vary significantly in terms of mathematics and formal education of the technical worker in each category.

The classifications can be ranked in terms of the amount of formal education the technical workers possess and the amount of mathematics they have studied. Both formal education and mathematics are related to the age of the technical worker, as is mobility. Technical workers become interested in electronics in four ways: through military service experience, through job experience, through hobbies, and through school experience. There seems to be evidence of some contribution on the part of educational institutions in developing the interest in electronics. This, however, did not come about through any conscious effort toward vocational guidance on the part of the institutions. The technical workers do not differ in the amount of mathematics dependent upon where they received this training.

Chapter 3

THE INSTRUCTOR

Instructor Workshops

It is obvious that the electronics instructor holds a commanding position in relation to the mathematical competencies which students can ultimately bring to their industrial employment. The instructor's close relationship to the industry he serves and to the student preparing to enter that industry are valuable components to be considered in research concerning the role of mathematics in the electrical-electronics industry.

Forty-five of California's junior colleges offered electronics programs at the time of the study. In order to consult with as many junior college electronics instructors as possible, three regional workshops were conducted during the fall of 1960. Thirty-three full-time electronics instructors, representing 27 junior colleges, participated in these meetings.

The major purposes of the workshops were: (1) to discuss the nature and progress of the research with instructors and administrators; (2) to solicit the advice and suggestions of each group; (3) to test the Q-sort technique and to interview instructors; and (4) to obtain information and recommendations about teaching aids used in developing mathematical concepts in electronics classes.

The 33 instructors who participated in the workshops were asked to sort the cards in terms of the extent to which they would expect graduates of their programs to encounter and master the mathematical skills and concepts of the problems involved. As in the interviews with the technical workers there was a discussion of the problems in the sort after each of these workshops. A further refinement of the Q-sort developed from the experience of these workshops. At this point, the Q-sort deck was sufficiently refined and reflected the mathematics continuum well enough to be used empirically in an investigation of the needed mathematical competencies in the electrical-electronics industry in California.

Following the regional workshops, a statewide workshop was held at U.C.L.A. to consider the advisability of developing a standardized test for predicting student success in junior college electronics programs and the desirability of self-instructional devices for remedial areas of mathematics.

The workshops provided an opportunity for the instructors to exchange ideas on instructional materials and practices. The instructors also discussed at length their individual mathematics prerequisites for entering electronics students. From this discussion agreement was reached that junior colleges with advanced algebra as prerequisite for students entering electronics were able to cover more theory in the electronics courses than those that did not have such prerequisites. The lack of prerequisites in mathematics, it was agreed, handicapped the electronics program by requiring remedial work in mathematics.

From this agreement came the recommendations to the research project to investigate the efficacy of self-instructional techniques in the area of mathematics considered to be of a remedial nature for electronics students. This led to the establishment of an experimental study at Bakersfield College which is described in detail in Chapter 5.

The feasibility of developing a standardized test for predicting students' success in junior college electronics programs was discussed. It was recommended that the test include the following areas of mathematics:

1. *Simple Arithmetic*
   - —lowest common denominator
   - —addition of common fractions
   - —addition of mixed numbers
   - —converting fractions to decimals
   - —converting decimals to fractions
   - —percentage
   - —negative numbers
   - —ratio and proportion
2. *Visual Mathematical Skills and Reasoning*
   - —simple syllogism
   - —interpretation of graphs
   - —use of tables
   - —Markov-chain
3. *Units and Mensuration*
   - —area
   - —volume
   - —time rate
   - —angular
4. *Related Concepts*
   - —powers of ten
   - —exponents
   - —logarithms
   - —manipulation of radicals
   - —adding literal numbers
   - —subtracting literal numbers
   - —multiplying literal numbers
   - —dividing literal numbers

The test which was developed from the recommendations had 75 multiple choice items (see Appendix B) and was used as the pre- and post-test in the experimental study (see Chapter 6).

Another outcome of the workshops was the testing of the Q-sort for validity.

Analysis of Interview Data

Data were collected from 29 junior college instructors of electronics in a manner similar to that for technical workers. The instructors reported on their work experience in industry, their formal education, and their mathematics background. The study of their mobility was based upon their industrial experience rather than upon their teaching experience.

A correlation analysis of the interview data was made to demonstrate the extent to which the variables investigated in the interview varied with one another. In addition, Kruskal-Wallis (H) one-way analysis of variance was computed to determine whether the instructors varied significantly in the amount of formal education and mathematics when grouped by job classification.

Fourfold correlations and multiple correlations were computed to investigate the relationship between mobility, age, and educational background for the instructors in total and by job classifications.

The t-test was used to measure the significance of the difference in the mean amount of formal education and formal mathematics background comparing the total sample of instructors with the total sample of technical workers.[1]

Electronics Experience of Instructors

The distribution by job classification of the industrial experience of the instructors is shown in Column N of Table I. Compared with the distribution of the technical workers by classification, it is apparent that the research and development area is underrepresented in the teaching ranks as is the testing area. The fact that 41 percent of the instructors gained their electronics experience in radio and television repair may be disconcerting for the electronic industry but *may* be justified in terms of the number of radio and television repairmen employed in the State.

The reason for the large number of instructors with radio and television repair backgrounds has not been explored in this study, but it is very likely due to the historical development of electronics. Just as radio and then television were the forerunners of the more complex electronic systems in use today, radio and television repair classes preceded the more ambitious technical program in the junior colleges of California.

[1] The t-test is used to determine the probability of the means for two groups differing by chance. Normal distribution is assumed. The significance of the t-ratio is dependent upon the size of the sample being tested, and the degrees of freedom are equal to the total sample minus the number of groups being compared.

If a t-ratio is significant at the five-percent level, this indicates that the difference that exists between two groups being tested could have occurred by chance five times out of a hundred.

TABLE I

FORMAL EDUCATION OF INSTRUCTORS IN THE SAMPLE BY JOB CLASSIFICATION

Job classification	High school	High school plus	A.A. or equivalent	A.A. plus	B.A. or equivalent	M.A. or equivalent	M.A. plus	N	Mean years of formal education
Radio and television	1	0	2	3	4	2	0	12	15.25
Plant maintenance	0	1	1	0	0	0	0	2	13.50
Field service	0	0	1	0	2	0	0	3	15.33
Testing	0	0	0	0	1	0	0	1	16.00
Instrument maintenance	0	0	0	0	0	0	1	1	18.00
Research and development	0	0	0	1	2	0	0	3	15.67
Communications	0	1	0	1	0	0	0	2	14.00
Computer	0	0	0	0	0	1	0	1	17.00
Electrician	0	0	0	1	1	1	1	4	16.50
N	1	2	4	6	10	4	2	29	15.40
%	3.4	6.9	13.8	20.7	34.4	13.8	6.9	100	

Formal Education of the Instructors

The mean amount of formal education of the instructors in total and by job classification exceeds that of the technical workers, as would be expected. However, it still seemed necessary to test the significance of the difference of the mean amount of formal education (instructors compared

TABLE II

TESTS OF SIGNIFICANCE FOR SELECTED INTERVIEW DATA ON ELECTRONICS INSTRUCTORS

t-test

	t	Degrees of freedom
t = test for significance of the difference in the mean amount of formal education comparing the total sample of technical workers with the total sample of instructors	5.97*	117
t = test for significance of the difference in mean formal mathematics backgrounds comparing total sample of technical workers with total sample of instructors	2.91*	117
t = test for significance of the difference in mean formal mathematics backgrounds of total sample of instructors with technical workers in research and development	.62	56

Kruskal-Wallis (H)

	H	Degrees of freedom
Formal education by classification of industrial experience of instructors	10.44	8
Formal education by mobility	1.43	2
Formal education (above and below the mean) comparing upwardly mobile instructors with all others	1.43	1

* Significant at 1%.

The significance of the t-ratio is dependent upon the size of the sample being tested, and the degrees of freedom are equal to the total sample minus the number of groups being compared.

with technical workers). It was demonstrated that this difference was significant (see Table II). Based upon the random method by which the instructors and technical workers were selected, it can be concluded that electronics instructors in the California public junior colleges possess significantly more formal education than technical workers currently employed in the industry. The presence of electricians in the instructor group, the absence of design draftsmen, and the small N in all classifications, except radio and television, makes further comparison of the formal education of the instructors with technical workers undesirable.

A Kruskal-Wallis (H) one-way analysis of variance was computed for

TABLE III

DISTRIBUTION OF MATHEMATICS BACKGROUND OF INSTRUCTORS BY INDUSTRIAL EXPERIENCE

Job classification	Algebra	Solid geometry	Trigo-nometry	Analytical geometry	Differ-ential calculus	Integral calculus	Beyond	N	Mean math background
Radio and television	1	0	1	2	3	5	0	12	Analytical geometry +
Plant maintenance	0	0	1	0	1	0	0	2	Analytical geometry
Field service	0	0	0	0	2	1	0	3	Differential calculus +
Electrician	0	0	0	0	1	3	0	4	Integral calculus
Testing	0	0	0	0	1	0	0	1	Differential calculus
Instrument maintenance	0	0	0	0	0	1	0	1	Integral calculus
Research and development	0	1	0	0	1	0	1	3	Differential calculus
Communications	0	0	2	0	0	0	0	2	Trigonometry
Computer	0	0	0	1	0	0	0	1	Analytical geometry
N	1	1	4	3	9	10	1	29	Differential calculus

formal education by classification of industrial experience of the instructors, and by mobility and education (see Table II). Even though the formal education of the instructors ranged from high school to beyond the Master of Arts degree, it was concluded that there was no difference when they were treated as groups within each job classification. There was demonstrated relationship between education and mobility for the electronics instructors.

Formal Mathematics Background of the Instructors

The amount of formal mathematics background of the electronic instructor is shown in Table III. As with the technical worker, a high correlation existed between mathematics and formal education (see Appendix C). A comparison of the mean amount of formal mathematics background of the instructor with the mean of the technical worker by a t-test demonstrated a significant difference (see Table II). This indicates that for the 29 instructors in the study and the 90 technical workers the mean amount of formal mathematics in the background of the instructors is greater than the mean amount of formal mathematics in the background of the technical workers, and this difference would not be expected to exist by chance.

There were 29 instructors in all and 29 technical workers in the research and development classification. The mean amount of formal mathematics for the instructor was between analytic geometry and differential calculus. The mean amount of formal mathematics for the technical worker in research and development was slightly above differential calculus. A t-test of the significance of this difference was computed (see Table II) which proved to be less than significant.

SUMMARY

The only reliable conclusion that can be reached from the interview data concerning instructors is that there is no significant difference in the amount of formal education and the amount of formal mathematics background of the instructors when considered in groups by source of industrial experience.

Comparing instructors with technical workers leads to the conclusion that the instructors have significantly more formal education and more formal mathematics than technical workers. However, when comparing the instructors in total with the technical workers in research and development, it is found that the technical workers have more formal mathematics in their backgrounds than do the instructors, even though this difference is not significant. Assuming that the instructor should know significantly more than his students are required to learn, it would appear that only those instructors with mathematics background through the calculus should be involved in curricula intended to train technical workers in research and development or for computer occupations.

Chapter 4

MATHEMATICAL COMPETENCIES NEEDED BY TECHNICAL WORKERS

Administering the Q-sort and Interviewing the Technical Workers

The instrument for investigating the mathematical competencies needed by technical workers employed in the electronics industry in California was the Q-sort. The methods by which the instrument was built and validated are described in detail in Chapter 1.

The general pattern of the interview and Q-sort administration was as follows:

The men involved were assembled in a conference room on the industry's premises and introduced to the investigator by someone from the management. In the presence of the management's representative, the individuals to be interviewed were given a brief explanation of the purpose of the research and were assured that all responses were confidential and would remain anonymous. None of the materials collected were coded by name (ID numbers were assigned on the spot to keep the interview and Q-sort material together). The respondents were also assured that management would not at any time see nor receive a report of any of the information from the interview or Q-sort, but that management would receive a copy of the final report in which it would be impossible to identify individuals. Immediately before the interview began, the respondents were told that participation was entirely voluntary and should they elect to do so, they were free to leave at any time, and no mention would be made of their desire not to participate. Once the respondents had started on the Q-sort, every possible measure was taken to avoid interruption and communication among them. The investigator also made it a point to assure sufficient table or desk space for each respondent to distribute the cards. All of the interviews were conducted by the same person and the information

gathered from the interview written on the interview schedule in the presence of the respondents (see Interview Schedule, Appendix B).

The Recommended Order of Instruction

In addition to the sort made by the technical workers in industry, which was determined by the extent to which they encountered the mathematical skills or concepts involved in the problems on the cards, a sort to define the recommended order of instruction was made by instructors in the area of mathematics. They sorted the mathematical skills and concepts into the order in which they would present them if they were to teach the entire range of mathematics involved. This allowed for a comparison between the sorts made by the technical workers and the logical sequence of mathematics as seen through the eye of the mathematics instructor.

Technical Workers Assessing the Mathematical Competencies Needed

Even though there was significant agreement among technical workers as a whole concerning the mathematical concepts or skills needed, the possibility existed that this may have been distorted by the presence of technical workers with very little mathematics background who, in the process of sorting, relegated those problems that were beyond their understanding to the least needed end of the sort. If this were the case, it would bring about an apparent agreement with the recommended order of instruction, because the more complex mathematical processes are taught after the simpler ones have been mastered. This does not mean that the technical worker is unsuited for the chore of determining the mathematics needed on his job, but rather that the sorts need to be analyzed further to demonstrate whether the consensus holds up. The mean correlation for the Q-sort by job classification exceeded the mean correlation for the total group of technical workers in each case (see Appendix C). A similar result was obtained when technical workers were grouped by level of mathematics. Grouping the 28 technical workers with mathematics backgrounds in the calculus or beyond resulted in a range of correlations from .968 to –.512 with a mean of .409. At the other end of the continuum, the four technical workers with less than high school algebra in their mathematics backgrounds had a mean Q-sort correlation of .454.

The increase in mean correlations, when technical workers were grouped according to their mathematics background, seemed sufficient to conclude that the mathematics used on the job varied with job classification and with the amount of mathematics in the background of the technical workers. The more mathematics mastered, the more mathematics would be used on the job.

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Analysis of the Q-sort

By combining the information from the interview and the Q-sort, it was possible not only to identify the essential mathematics, the useful mathematics, and the mathematics of questionable value in the industry, but also to investigate: (1) the extent to which mathematics contributed to occupational mobility; (2) the extent to which formal mathematics, formal education and background of the respondent contributed to the mathematics used on the job; (3) the difference in the mathematical skills needed in the various classifications in the industry.

A program was written for the 709 computer at Western Data Processing Center to perform the Q-sort correlations.[1] The program provided 6430 correlations, with a range from –.750 to +.968, with a mean correlation of .331. As was hypothesized at the beginning of the study, most of the disagreement on the mathematics needed was between technical workers in different job classifications. When the Q-sort correlations were grouped according to job classifications, the negative range decreased and the mean correlation increased. A good example of this is the matrix of correlations on technical workers in research and development. Here the range was from –.649 to +.742 with a mean correlation of .359. There were 32 negative correlations in this matrix, 29 of which were with technical worker No. 23, i.e., he contributed greatly to the diminishment of the mean correlation. To measure the significance of the agreement between sorts, the mean correlations for each job classification and for the instructors were converted into the coefficient of concordance (W)[2] and tested for significance[3] (see Table I). Interpreting the matrix of Q-sort correlations

[1] The correlation of Q-sort data is basically a rank order correlation. The value given to each of the items in the sort is taken to be its rank, and the correlation is then computed and corrected for ties (the correction for ties is constant in a set of Q-sort data).

The Q-sort correlation compares the ranks assigned to all items by one respondent with the ranks assigned by another respondent. These correlations are computed for all possible combinations among the respondents. The significance of a Q-sort correlation is dependent upon the number of items in the sort and is constant for a given set of Q-sort data.

If the Q-sort correlation is significant at the five-percent level, this indicates that the ranks assigned by the two respondents for whom the correlation is being reported are related to each other to the extent that this relationship would occur by chance five times in a hundred. Therefore, if the correlation is positive and significant at the five-percent level, it can be concluded that the agreement demonstrated between the sorts of the two respondents could have occurred by chance only five times in one hundred.

[2] Allen L. Edwards, *Statistical Methods for the Behavorial Sciences* (New York: Reinhart & Company, Inc., 1954), p. 412.

[3] The coefficient of concordance has been demonstrated to have a linear relationship to the mean of all the possible correlations between rank order data. The value of this statistic is that it allows a composite statement to be made about the overall agreement or disagreement demonstrated by the individual correlations.

The coefficient of concordance can vary from zero to one and the significance of the

for the total group of technical workers and for the job classification group is quite difficult, unless there are some statistical means used to draw all of the sorts into a composite. For this reason each job classification was consolidated into a resultant sort.[4] The correlations between the resultants ranged from .993 to –.502 with a mean of .355. Technical workers in research and development and in testing correlated at .993 and .870 respectively with the resultant of the total group. This was to be expected since they were the largest groups and contributed the most to the total resultant Q-sort.

TABLE I

COEFFICIENT OF CONCORDANCE FOR Q-SORTS BY JOB CLASSIFICATION

Testing	W = .365	F = 17.27‡
Field service	W = .694	F = 4.54‡
Plant maintenance	W = .702	F = 4.71‡
Instrument maintenance	W = .631	F = 6.84‡
Research and development	W = .398	F = 18.27‡
Radio and television	W = .729	F = 8.07‡
Design drafting	W = .733	F = 5.49‡
Communications	W = .491	F = 6.76‡
Computer	W = .402	F = 1.34*
Total	W = .338	F = 45.44‡

* = significant at 10%.
‡ = significant at 1%.

The reason for soliciting a number of responses to the Q-sort was to insure a more accurate statement concerning skills or concepts needed on the job by technical workers. To measure the reliability of the average rank assigned each item by the groups within each job classification, Horst's[5] reliability coefficient was computed.[6] These are reported in Table II.

coefficient can be tested by converting it to an F-ratio and, therefore, the number of items and the number of respondents influence the significance of the coefficient.

If there is a positive coefficient of concordance which is significant at the five-percent level, the total agreement demonstrated could have occurred by chance in five cases out of a hundred.

For further discussion of the use of the coefficient of concordance with Q-sort data see:

William J. Schill, "The Use of the Q-Technique in Determining Curriculum Content," *California Journal of Educational Research*, XII, No. 4 (Sept. 1961), 178–184.

[4] Joseph E. Morsh, "The Q-Sort Technique as a Group Measure," *Educational and Psychological Measurements*, Vol. XV, No. 4 (Winter, 1955), pp. 390–95.

[5] Sidney Siegel, *Nonparametric Statistics for the Behavorial Sciences*, (New York: McGraw-Hill Book Company, Inc., 1936), pp. 184–92.

[6] It is generally conceded that the average of two or more estimates of an unknown parameter is more likely to approximate the true value than a single estimate. The

TABLE II

RELIABILITY COEFFICIENT OF RESULTANT SORTS

Communications	.853
Plant maintenance	.848
Radio and television	.875
Design drafting	.784
Computers	.451
Field service	.810
Instrument maintenance	.812
Testing	.944
Research and development	.942
Instructors	.971

Results of the Q-sort

The purpose of the statistics used in this chapter was to demonstrate the agreement among technical workers by job classification concerning the placement of mathematical skills or concepts contained in the Q-sort and to measure the reliability of the resultant sorts for each group. The agreement was significant and the reliability coefficient was high enough to insure meaningful resultant distributions.

Table III contains the 63 mathematical skills or concepts included in the Q-sort arranged in the recommended order of instruction. Following each item is the placement (essential, useful, questionable) given that item by technical workers in the nine job classifications and by the instructors of electronics who participated in the study.

The forced normal distribution of the mathematical concepts or skills was divided into "essential," "useful," and "of questionable value," by making the cut-off points approximately one standard deviation on either side of the mean. This placed the 14 concepts or skills on the *most similar* end of the distribution in the "essential" category and 14 concepts or skills on the *least similar* end of the distribution in the "of questionable value" category. The remainder in the center of the distribution comprised the "useful" category.

SUMMARY

There was unanimous agreement among the technical workers on the placement of four mathematical concepts or skills. All agreed that percent

statistic used to assess the reliability of the average ranks assigned to the items in the Q-sort was Horst's reliability coefficient.

The number of items in the sort and the number of respondents are included in the computation; however, there is no statement of probability connected with the coefficient of reliability.

TABLE III

PLACEMENT OF MATHEMATICAL CONCEPTS OR SKILLS BY JOB CLASSIFICATION

	Instructors	R. and D.	Testing	Radio and T.V	Communications	Plant maint.	Inst. maint.	Field service	Drafting	Computer
Conversion of fractions to decimals	E	E	E	E	E	E	E	E	E	U
Percent calculations of tolerance	E	E	E	E	E	E	E	E	E	E
Changing percentage to decimal	E	E	E	E	E	E	E	E	E	U
Conversion from metric to American measuring system	E	E	E	U	U	U	E	E	E	E
Addition of degrees and minutes (mensuration)	U	U	U	U	E	E	U	E	U	U
Area approximation	U	U	U	U	U	U	U	U	U	U
Graphical interpretation	U	U	E	U	U	U	U	U	U	..
Square root long-hand method	E	E	E	E	E	E	U	U	E	U
Division with signed numbers	E	E	E	E	U	E	U	E	E	U
Powers of signed numbers	E	U	U	E	E	E	E	E	E	U
Scientific notation	U	E	U	U	U	U	E	E	U	U
Estimation of arithmetic problems	U	E	U	E	E	E	U	U	U	E
Multiplication with exponents	E	E	E	E	E	E	E	E	E	E
Division with exponents	E	E	E	E	E	E	E	E	U	U
Raising to a power with exponents	E	E	E	E	U	E	E	E	E	U
Use of negative exponents	E	E	E	E	E	U	E	U	E	E
Extracting a root with exponents	U	U	U	..	U	U	U	U	U	..
Use of fractional exponents	U	U	U	U	U	U	E	U	..	U
Solution of first degree equations	U	U	U	U	U	U	U	U	E	U
Ratios	E	E	E	E	U	U	E	E	E	E
Solution of second degree equations	E	U	E	E	E	E	E	E	U	E
Pythagorean Theorem	E	E	E	E	E	E	E	U	U	U
Solution of simultaneous equations	U	U	U	U	..	U	U	U	U	E
Graphic solution of equations	U	U	U	U	U	U	U	U	U	U
Factoring	U	U	U	U	U	U	U	U	U	U
Special products	U	U	U	U	U	U	U	U	U	..
Determinants	..	..	U	U	U	..	U	U	..	..
Quadratic formula	U	U	U	U	U	..	U	U	U	..
Completing the square	U	U	U	U	U	U	U	U	E	U
Roots of signed numbers (including i factor)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Logs to base ten	U	U	U	..	E	U	U	U	U	U
Multiplication with logs	U	U	U	U	U	U	U	U	U	U
Division with logs	U	U	U	U	U	U	U	..	U	U
Powers with logs	U	U	U	U	U	U	U	U	U	U
Roots with logs	U	U	U	U	U	U	U	U	U	U
Application of sine function of acute angles	U	U	U	..	U	U	U	U	U	U
Application of cosine function of acute angles	U	U	U	U	E	U	U	U	U	U
Application of tangent function of acute angles	U	U	U	U	U	U	U	U	U	U
Interpolation of tables	U	U	U	U	U	U	U	U	U	U
Application of Law of Sines	U	U	U	U	U	U	U	U	U	U
Application of Law of Cosines	U	U	U	U	U	U	U	U	E	U
Solution of right triangles	U	U	U	U	U	U	..	..	U	U
Use of radians in angular measurement	U	U	U	U	U	U	E	..	U	U
Addition of vectors in polar form	U	U	U	U	U	U	U	..	U	..
Addition of vectors in rectangular form	U	U	U	U	U	U	..	..	U	..
Multiplication of vectors	U	U	U	U	U	U	U	U	U	..
Division of vectors in rectangular form	U	U	..	..	U	U	U	U	U	..
Functions of half angles	U	U	U	U	..	U	..	U	U	U
Functions of twice angles	U	U	..	U	U	U	U	U	U	U
Law of Tangents	..	..	..	U	U	..	..	..	U	U
Identities	..	..	..	..	..	U	..	..	U	U
Series and progressions	..	..	..	U	..	U	..	U	..	..
Use of natural logs	U	U	U	..	U	U	U	..	U	U
Slope-point form for equations	U	U	U	..	U	U	U	..	U	U
2-point form for equations	U	U	U	..	U	U	U	..	U	U
The differential	..	..	U	..	..	U	..	U	U	E
Higher order derivatives	U	U	U	U	U	..	U	U	..	U
Curve analysis	..	..	..	U	..	..	..	..	..	..
Fundamental Integral Theorem	..	..	..	..	..	..	..	..	..	U
Integral as an area	..	..	..	..	..	..	..	U	..	..
Double and triple integrals	..	..	..	..	..	..	..	..	..	..
Binary arithmetic	..	..	..	U	..	..	U	U	..	E
Boolean algebra	..	..	..	U	..	..	..	U	..	E

KEY: E = essential: U = useful: Blank = questionable.

calculations of tolerance, multiplication with exponents, and changing percentage figures to decimal figures were essential, and double and triple integrals were of questionable value. The disagreement on the needed mathematical competencies or skills took the form of shifting the concepts or skills from "essential" to "useful" and from "useful" to "questionable" and vice versa. The technical worker in computer occupations was the only one who listed mathematical skills considered to be of questionable value by technical workers in the other job classifications as being essential. In the case of this worker, binary arithmetic and Boolean algebra were considered "essential" to perform on the job, whereas these competencies were considered "useful" by only a few of the other workers, and of questionable value by most. Binary arithmetic and Boolean algebra for computer occupations are exceptions to the rule that the needed mathematical competencies follow the logical order of the mathematics continuum, and even here, such workers need, in addition to binary arithmetic and Boolean algebra, the higher mathematical skills built upon the fundamental arithmetic and algebraic processes.

It may seem that the range in correlations between the Q-sort for the technical workers individually and the resultants by job classifications is an indication of lack of agreement concerning what mathematics is needed for the technical worker as a whole or for a particular job classification. This is not the case. The statistical tool used to assess the extent to which technical workers agreed on needed mathematics was Kendall's coefficient of concordance (W). The agreements by job classification and for all technical workers were significant at one percent in every case, except for the workers engaged in computer occupations, in which case it was significant only at the 10-percent level (see Table II). Not only do the technical workers agree on the mathematics needed to perform on the job, but they also agree with the recommended order of mathematics. The range of correlations between technical workers and the recommended order is from .827 to −.081 with a mean correlation of .523.

The most significant aspect of the analysis of the Q-sort data was the finding that as a whole technical workers ranked the mathematical skills or concepts from "essential" to "questionable" in the same order in which the instructors of mathematics ranked the mathematical concepts or skills into their recommended sequence of teaching.

It was significant also that the rank order of the mathematical skills or concepts designated by technical workers with similar mathematics backgrounds correlated highly and led to the conclusion that the amount of mathematics used by the technical worker on a given job was dependent upon the job classification and also upon the amount of mathematics the particular worker had studied.

Not only do the technical workers agree that the order of need of mathematical competencies is much the same as the recommended order of teaching mathematics, but the electronics instructors also agree. Electronics instructors were asked to sort the Q-sort cards into a forced normal distribution in the order in which the problems were similar to those their graduates were expected to master. The correlations between instructor sorts and the recommended order of instruction ranged from .774 to .351 with a mean correlation of .619.

Part III

Chapter 5

THE EXPERIMENTAL STUDY

Statement of the Problem

The 45 public junior colleges in California having programs in electronic technology differ greatly in the amount of mathematics required for entry and the amount of mathematics included in the curriculum.

One of the outcomes of the instructor workshops (discussed in Chapter 3) was the recommendation that an experimental program be conducted to measure the efficacy of self-tutoring materials in mathematics which could be used for review or remedial purposes.

Without exception, the instructors in the workshops saw the need for a more uniform mathematical background of the electronics students. In some cases junior colleges accomplish a more homogeneous grouping by having mathematics prerequisites for entry into the electronics programs. In other cases junior colleges are faced with the problem of providing the electronics student with the necessary mathematical background concurrently with the study of electronic theory.

If self-instructional materials could remedy mathematical deficiencies, it would enhance the instructional process in electronics. A method of self-instruction that has been widely used is one which requires each student to review the necessary mathematics on his own time and turn the required work in to the instructor.

The experimental study compared student achievement under the traditional review method with student achievement under the newer self-instructional materials method as a means of review or remediation.

This study was limited to two classes taught by the same instructor at Bakersfield College.

Method of Student Assignment

Both the experimental and control classes consisted of second semester technical mathematics students enrolled in Bakersfield College.

They were assigned to the classes at random within the limits of the college program. Programming proved to be a rather severe limitation. The initial distribution is shown in Table I, and the final distribution, after drop-outs and program changes, is shown in Table II.

TABLE I
INITIAL DISTRIBUTION OF STUDENTS IN EXPERIMENTAL AND CONTROL CLASSES

	Experimental class	Control class	N
Electronics majors	24	20	44
Other majors	24	20	44
N	48	40	88

TABLE II
FINAL DISTRIBUTION OF STUDENTS IN EXPERIMENTAL AND CONTROL CLASSES

	Experimental class	Control class	N
Electronics majors	13	27	40
Other majors	15	9	24
N	28	36	64

Conduct of the Classes

An experimentally oriented and competent instructor conducted two sections of technical mathematics dealing with identical subject matter. A self-tutoring machine was provided for the experimental group and the students in that group were instructed in the use of the device and were required to spend a minimum of 12 hours on assigned materials throughout the semester.

The assignments consisted of a review of mathematical concepts already covered in the lecture section of the class. The students used the self-tutoring machine on the basis of a schedule set up by the instructor. The time that they were exposed to the self-tutoring materials was recorded.

The control group did not have access to the self-tutoring device but reviewed the same mathematics in the customary homework assignment method. Homework review assignments corresponded with the assign-

ments made on the self-tutoring machine. The experimental group was required to view the materials on the machine, and the control group was required to turn in homework assignments from day to day.

Material Covered

Listed below on the right is the instructor's outline of the material covered in the first and second semester of technical mathematics. Listed on the left is the material covered under self-tutoring materials.

SELF-TUTORING MATERIALS

1. *Introduction to Algebra*
   a. Positive rational numbers
   b. Negative numbers
   c. Definition of equation
   d. Fundamental assumptions
   e. Commutative Law of Addition
   f. Associative Law of Addition
   g. Commutative Law of Multiplication
   h. Distributive Law of Multiplication
   i. Laws of signs
2. *Algebra*
   a. Factors
   b. Exponents
   c. Decimals
3. *Algebra*
   a. Algebraic expressions
   b. Evaluating an expression
   c. Division of fractions with exponents
4. *Algebra*
   Factoring
5. *Algebra*
   a. Roots of numbers
   b. Square root briefly
   c. Fractional exponents
6. *Extracting Square Roots*
   a. Review of roots of numbers
   b. Square roots
7. *Equations*
   a. Identical and conditional equalities
   b. Satisfaction or solution
   c. Rules of equations
   d. Transposition
   e. Equations containing fractions
   f. Using equations with formulas
8. *Simultaneous Linear Equations*
   a. First degree of linear equations
   b. Variables and constants
   c. Using equations to plot graphs
   d. Simultaneous equations
   e. Use of quadratic equations
   f. Circle graphs

TECHNICAL MATHEMATICS—1ST SEMESTER

1. *Algebra*
   a. Literal numbers
   b. Addition and subtraction
   c. Multiplication and division
   d. Simple linear equations
   e. Simple simultaneous equations
   f. Fractional equations (simple)
   g. Special products and factoring
   h. Exponents and powers of ten
   i. Graphing of simple linear equations
   j. Graphing of simultaneous equations
2. *Slide Rule*
   a. Multiplication and division on C and D scales
   b. Multiplication and division on CI and CF scales
   c. Multiplication and division on S, T and ST scales
3. *Trigonometry*
   a. Angles and angular measurements
   b. Trigonometric functions and tables
   c. Fundamental identities
   d. Solution of right triangles
   e. Periodic functions
      Equations
      Graphs
4. *Elementary Plane Vectors*
5. *Vectors and Complex Numbers*
   a. Imaginary numbers
   b. The "J" operator
   c. Rectangular and polar forms
   d. Conversion techniques (slide rule)

6. *Fundamentals of Number Systems Other Than Base Ten*
   a. Counting symbols
   b. Place value of symbols
   c. Conversion from one base to another
   d. Addition and multiplication tables

TECHNICAL MATHEMATICS—2ND SEMESTER

1. *Algebra*
   a. Fractions
   b. Fractional equations
   c. Exponents and radicals
   d. Quadratic equations
   e. Simultaneous quadratic equations
   f. Exponential equations and logarithms
2. *Slide Rule*
   a. L scale
   b. L L scale
   c. A and B scales
   d. K scale
3. *Vector Algebra (continued)*
4. *Boolean Algebra (introduction)*
5. *Trigonometry*
   a. Law of Sines
   b. Law of Cosines
   c. Diagonal Parallelogram
6. *Introductory Lectures on Calculus*
   a. Four-step delta process
   b. Slope
   c. Idea of infinitesimals and infinity
   d. Functional notation

The self-instructional materials used in this study consisted of about 1,000 microfilm images of texts on algebra, originally developed for the U.S. Air Force. The purpose of the materials was to provide prerequisite instruction in algebra for students beginning a course in basic electronics.

The content of the material was determined in two ways. First, the basic electronic course was analyzed in detail to isolate the mathematical skills required and second, the specific mathematics needed for electronics training was expanded to cover related topics also required in first-year physics and chemistry. The result was a short course in algebra suitable for students at the junior college level who had studied algebra in high school, but were deficient nonetheless.

Comparison of Experimental and Control Classes

The following data were abstracted from student personnel records of Bakersfield College for each of the students participating in the study: (1) age; (2) years of high school mathematics; (3) average grade in high school mathematics; (4) SCAT[1] verbal scores; (5) SCAT quantitative scores; (6) SCAT total scores (SCAT was given in September, 1960).

Measurements

The mathematics achievement test (included in Appendix B) prepared by the research project was administered on the first day of the semester and again upon completion of the self-instructional materials. The student scores on this test were used to assess the mean growth in mathematical achievement for the experimental and control classes.

[1] School and College Ability Test is made up of two sub-tests: one to measure verbal ability and the other to measure quantitative ability. The total test score is the combination of the two sub-tests (prepared and distributed by the Cooperative Test Division of the Educational Testing Service, Princeton, N.J.).

The test prepared by the research team had content validity in that the areas of mathematics covered by the test were decided upon in cooperation with ten selected electronics instructors from California junior colleges. Further, it had construct validity in that the problems were fashioned after final exams had been used with success in a variety of junior college programs throughout the State.

TABLE III

CORRELATION OF DATA ON STUDENTS FOR BAKERSFIELD STUDY

	Post-test	Pre-test	Average grade	Years of H.S. mathematics	Age	Total	Quantitative	Verbal
Post-test	1.0							
Pre-test	.830*	1.0						
Average grade	.020	.018	1.0					
Years H.S. math	.542*	.502*	−.140	1.0				
Age	−.146	−.180	.222	−.199	1.0			
Total	.375*	.393*	.190	.218†	−.021	1.0		
Quantitative	.430*	.416*	−.030	.219	−.049	.546*	1.0	
Verbal	.304†	.205	.089	.194	−.209	.450*	.136	1.0

N = 64.
* = significant at 1%.
† = significant at 5%.

To assess the reliability of the test, Pearson's[3] product-moment correlation coefficient was calculated for the split halves of the items on the test. This yielded a correlation coefficient of .842 which is significant at the one-percent level (see Appendix C).

[3] The split-halves reliability coefficient is the application of the product-moment correlation coefficient to objectives test items to assess the reliability of the test in instances where retesting is either impossible or undesirable. It consists of splitting the test into two groups of items and correlating the individual student's score on each group of items.

In this study the test used was split by assigning the odd problems to one group and the even problems to another.

Pearson's product-moment correlation was calculated to measure the correlation between the raw scores in the research-designed achievement test and the data collected on the students (see Table III). This was done to determine the extent to which standardized tests already in use at Bakersfield College predicted success in technical mathematics.

Characteristics of the Students in the Study

The students, control and experimental combined, are normally distributed on their SCAT scores (see Figure 1). The distribution on the pre-test

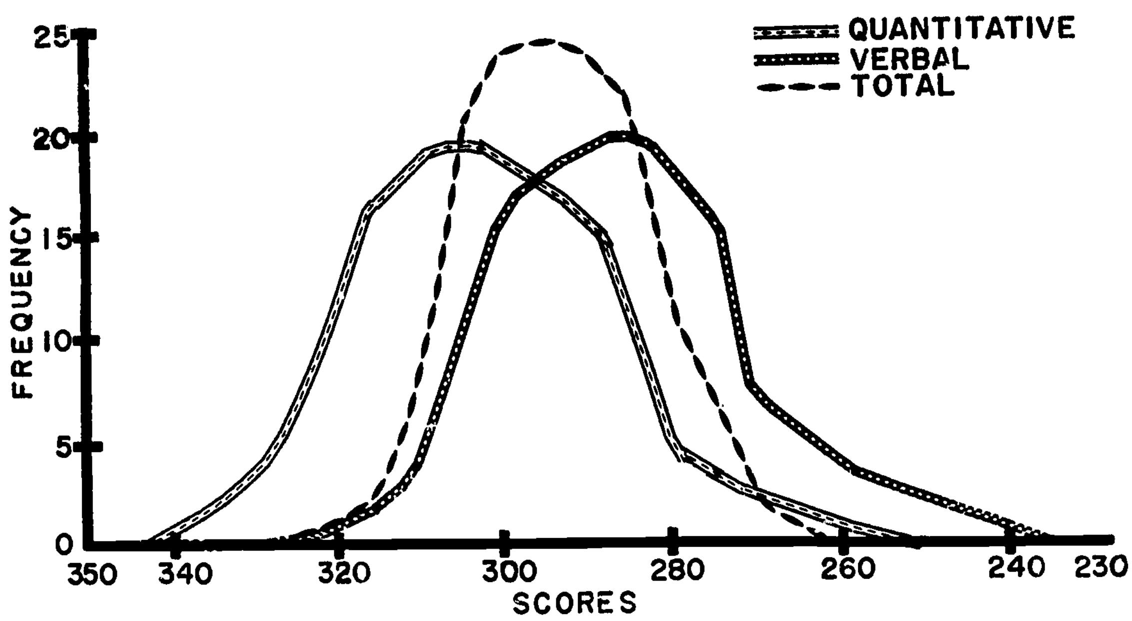


Figure 1

Distribution of Students' SCAT Scores

approximates normality (see Figure 2). There was little variance in the age of the students, and there were no significant correlations with any of the other measures. Consequently, age was not considered in any of the following analyses. The number of years in high school mathematics and the average grade in themselves had little variance and bimodal distribution, but when considered together, they became more meaningful and approximated a normal distribution. The multiplication of years of high school mathematics by the average grade in mathematics is equal to the total number of grade points earned in mathematics and this becomes the combined measure (see Figure 3).

Characteristics of the Students by Group

The control group was normally distributed on test score, but the experimental group had a bimodal distribution which was skewed strongly toward the lower end of the measures involved. Inspection of the data

also showed that the control group had a higher mean on each of the measures, except grade points earned in high school mathematics (see Appendix C). Because the two groups were not normally distributed, non-parametric statistics were used to determine whether the two groups

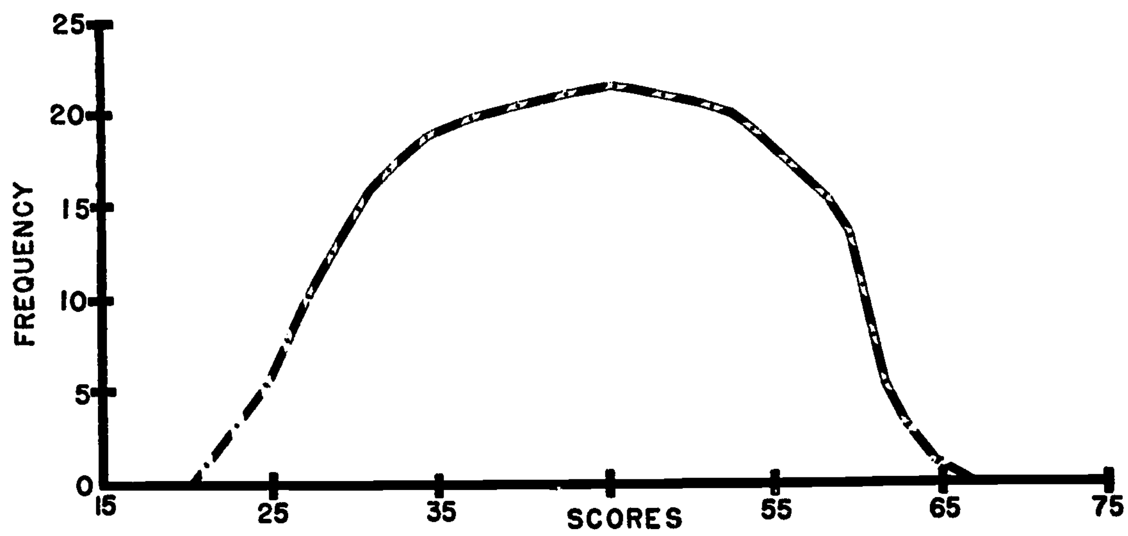


Figure 2

Distribution of the Pre-Test Scores

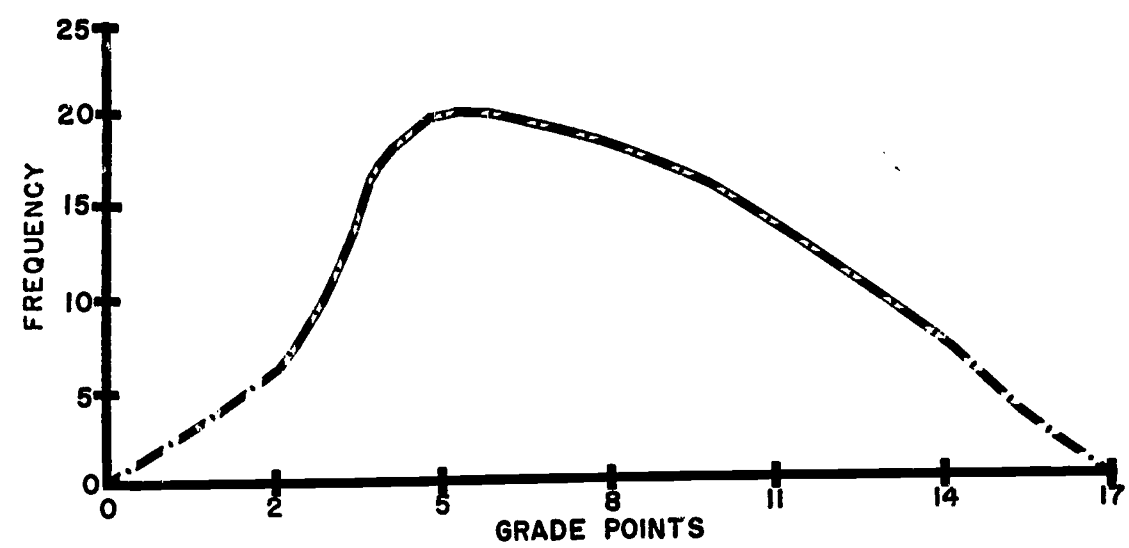


Figure 3

Distribution of Grade Points Earned in High School Mathematics

differed *significantly* on the five variables involved. The Kruskal-Wallis (H) one-way analysis of variance was computed for SCAT verbal, SCAT quantitative, SCAT total, grade points earned in high school mathematics and the pre-test (see Appendix C), none of which were significant.

Thus it was established that the experimental and control groups were not significantly different before the experiment.

Comparisons of Student Gain

Comparison of Control and Experimental Groups on Gain in Mathematics Achievement

The mean gain as measured by the pre- and post-tests, for all the students, was 7.625 points. Since the total group was normally distributed, a t-test was made to determine whether the mean gain was significant (see Appendix C). Once it had been established that the gain for the total group was a significant one, the next step was to determine whether there was any significance in the difference in gain between the experimental and control groups. The mean gain for the experimental group was 8.14 which exceeded the 7.31 mean gain of the control group.

The Kruskal-Wallis (H) one-way analysis of variance was used to assess the difference in gain (because of the nonparametric distribution). This proved to be .83 which is not significant and indicates that the difference may well have occurred by chance (see Appendix C). *Hence, it was concluded that there was no significant difference in gain of the experimental group compared with the control group.*

Fourfold Comparison of Gain in Mathematics Achievement

The control and experimental groups consisted of electronics majors and non-electronics majors. The mean gain for each of the four groups is

TABLE IV

DISTRIBUTION OF MEAN GAIN AMONG CONTROL AND EXPERIMENTAL, MAJOR AND NON-MAJOR GROUPS

	Electronics majors	Non-electronics majors	Total
Control	7.14	7.44	7.22
Experimental	7.69	8.53	8.14
Total	7.32	8.12	7.62

shown in Table IV. If the four sub-groups were listed in the order of their mean gain, they ranked as follows: (1) experimental group non-electronics majors; (2) experimental group electronics majors; (3) control group non-electronics majors; (4) control group electronics majors.

A statistical comparison was made between the four groups (see Appendix C). This showed that even though a difference existed, it was not significant.

Comparison Between Electronics Majors and Non-electronics Majors on Gain in Mathematics Achievement

Aside from the experimental group being exposed to the self-tutoring device, another difference in instruction existed. The electronics majors had a laboratory section during which the electronics theory and mathematical skills presented to them in lecture were put into practice, whereas the non-electronics majors did not have this experience.

The majors and non-majors were compared on the antecedent data (see Appendix C). After it had been demonstrated that they did not differ before the experiment, they were compared on their gain in the achievement in mathematics. The difference in mean gain of 8.12 for the non-majors against 7.32 for the majors seemed to indicate that the practical application of mathematical skills did not contribute to achievement in mathematics. When the statistical comparison was made, the difference proved to be less than significant (see Appendix C).

The Instructor's Comments on the Use of the AutoTutor

"The mechanics of scheduling for the AutoTutor were quite simple. A sheet was handed to the class which listed the available hours, and students were asked to sign for the most convenient hour. From this list, a daily schedule was printed, and each student signed in and out (for the Tutor) on this sheet. The weekly assignment was written on the blackboard. When handled in this manner, there was practically no additional teacher load, except to review the material each week for suitability of topic.

"One question that needed to be answered was: "Is this simply a 'new gadget' which the student will not use after it is no longer new?" Remembering that the (self-instructional) material was very well written, the students seemed to be genuinely sorry when all of the material had been covered. Some students asked for permission to go back over the material. Very few students wanted to give up the Tutor.

"As has been stated, the control class was given weekly review written assignments, from the textbook, in addition to the regular homework. The surprising result was that, after several weeks, many students volunteered that the weekly review work was a very effective learning aid. After the study ended, some of the better students asked for a continuation of the review assignments (these students did not use the AutoTutor).

"In conclusion, my opinion is that the machine *can be* a valuable teaching aid, provided the machine is regularly scheduled and the (self-instructional) material is well prepared. The AutoTutor is a device which calls for a minimum amount of teacher time after the schedule has been prepared. On the other hand, haphazard use of the machine, or too great a reliance upon the machine, would surely lead to disinterest and poor participation by the student.

"In my own case, I would use the machine to introduce and build background,

so that the classroom session could be spent in developing deeper concepts. I feel that about one class hour out of three could be saved in this manner."[3]

Student Reaction to the AutoTutor

Dr. Richard Hatch of Western Design prepared a questionnaire which was given to the students after the post-test. The following responses to the questions were the only students' reactions solicited:

1. If I had to study more of this kind of material, I would prefer to use:
   the AutoTutor (teaching machines) ....(18)
   class lecture ....(8)
   a typical textbook ....(0)
2. It would help if tests were placed in the middle of sections:
   strongly disagree (0) disagree (2) agree (18) strongly agree (6)
3. There should be more summaries:
   strongly disagree (0) disagree (9) agree (12) strongly agree (5)
4. The AutoTutor presentation of the material encourages me to learn:
   strongly disagree (0) disagree (11) agree (10) strongly agree (5)
5. How much humor should there be in this course?
   more (6) about the same (19) less (1)
6. I feel the course was:
   too difficult (0) about right (26) too easy (0)
7. The questions at the bottom of the page really tested my understanding of the points covered:
   strongly disagree (1) disagree (4) agree (13) strongly agree (8)
8. I think I would like to study on the AutoTutor about............hour(s) each day: (the mean of the responses was 1.74 hours).

SUMMARY

The experiment did not demonstrate any significant difference in gain between the experimental group and the control group although the mean gain of the experimental group was slightly higher than that of the control group. This is in agreement with research by Coulson[4] and Crowder.[5] The findings were totally inconclusive, possibly because of the limited exposure of the students to self-instructional materials. There was, however, a positive reaction from the students and the instructors toward the use of the self-tutoring devices.

[3] Lanning, L. Flint, A letter to William John Schill, dated at Bakersfield, Calif., May 20, 1961.

[4] John E. Coulson and Harry F. Silberman, "Automated Teaching and Individual Differences," *Audiovisual Communications Review*, Vol. 9, No. 1 (Jan.–Feb. 1961).

[5] Norman Crowder and Virginia Zachert, *Use of AutoTutors at Keesler AFB to Train in Fundamentals of Electronics: A Pilot Study* (Goleta, Calif.: Training Systems, Western Design, Division of U. S. Industries, 1960).

Chapter 6

INSTRUCTIONAL MATERIALS

The Initial Conception

At the beginning of the research project, the investigation of instructional materials was conceived to include the construction of teaching aids that would be applicable to mathematics for electronics. It was proposed that 10 or 12 such devices be constructed and a lesser number be tested in the public school setting to determine whether they aided the instructional process.

Materials Presented at the Workshops

In the four workshops held throughout the State, a variety of teaching aids was presented and discussed (see Chapter 3). Among the materials were commercially prepared teaching aids, teaching machines, self-instructional textbooks[1], closed-circuit overhead television, and instructor-prepared demonstrators. In general, teaching machines and self-instructional textbooks were enthusiastically received and the instructors saw the need for investigation into the efficacy of these newer media. The instructors also saw the need for evaluation of commercially prepared teaching aids. However, the general opinion was that instructor-prepared demonstrators were of questionable value. These opinions are supported by Johnson and Nickerson who advocate continuing review of instructional devices, lest "the development of future materials follow its expensive trial and error course."[2]

The recommendations of the workshops (Chapter 3) brought about the revision of the research project's concerns for instructional materials and

[1] Norman A. Crowder, *The Concept of Automatic Tutoring*, Organizational Paper, Air Force Personnel and Training Research Center, ARDC (Texas: Lackland Air Force Base, 1959).

[2] D. A. Johnson and J. F. Nickerson, "The Future of Visual Aids in Mathematics," *Mathematics Teacher*, Vol. 40 (1947), pp. 180–81.

led to the experimental study at Bakersfield (Chapter 5) and to the development of questionnaires, discussed in greater detail in the following paragraphs.

Questionnaires on Instructional Material

The questionnaires were developed and distributed to a representative sample of the electronics instructors in California. These questionnaires were mailed to 65 instructors, and the overall return was 89 percent. The ten questionnaires covered five self-instructional textbooks

TABLE I

Total Returns From the Questionnaire Survey of 65 Instructors of Electronics

Questionnaire	Response	Percent
1	62	95
2	62	95
3	62	95
4	58	89
5	58	89
6	58	89
7	61	94
8	61	94
9	61	94
10	39	60
Total	582	89

in the area of mathematics or electronics and eight commercially prepared teaching aids for electronics. The self-instructional books were those most readily available. The eight commercially prepared teaching aids were selected as representative of the types of teaching aids available and were widely known. Each questionnaire was concerned with only one aid or textbook, except three questionnaires which requested information on pairs of teaching aids. The questionnaires were accompanied by the manufacturer's descriptive brochure to insure that the responses were related to the material being investigated.

Table I shows the number of returns to each set of questionnaires. The questionnaires were so constructed that if a response was negative, all subsequent items on the questionnaire were not relevant. For example, the instructors were asked whether they had read a particular self-instructional textbook, and if the response was "no" the remainder of the questions concerning the applicability of the books to instruction in electronics was beyond the realm of the instructor's ability to answer (see Appendix B).

Self-Instructional Textbooks

The responses to the five questions on self-instructional textbooks were handled as a group. Of the 325 questionnaires sent out on self-instructional textbooks, 285 were returned and of this total only 22 responses indicated that the textbooks in question had been read. From this it can be concluded that the junior college instructors of electronics in California are not acquainted with the recent attempts to prepare self-instructional textbooks applicable to mathematics and electronics, notwithstanding the unanimous agreement in the workshops that methods which will provide remedial instruction for entering electronics students need to be investigated. There was no tabulation as to whether those instructors who had read the self-instructional textbooks were the same who attended the workshops, but considering the acceptance of these books at the U.C.L.A. workshop, it could be hypothesized that all 22 positive responses were the result of exposure to these materials at the workshops.

Twenty-two responses indicated that self-instructional textbooks had been read; 17 indicated an application to the electronics program. Of the 17 responses indicating that the books had some instructional value, four stated further that the self-instructional textbooks had been tried in an instructional program and were considered to be of value.

Unrelated to the questionnaire survey, but definitely related to the use of self-instructional textbooks for mathematics or electronics is the statement which follows, quoted from a letter of James Chapman, Head of the Mathematics and Engineering Department at Antelope Valley College:

"We have introduced the Algebra Tutor Text to a number of students currently enrolled in beginning algebra. These students have expressed a high degree of enthusiasm for the unique approach. We feel that these students have gained confidence and that their work has improved.

"As you know, I have been conducting an in-plant training program for technicians at Jet Propulsion Lab, Edwards. I made use of 15–20 Tutor Texts in algebra and electronics and 20 volume I and 20 volume II *Arithmetic for Computers.*

"These high-level technicians used the books more as a refresher course, but they too expressed the feeling that the books fill a need.

"There has been some talk here at AVC about the possibility of conducting one section of Elementary Algebra from the Tutor Text next fall. The only thing that is holding us back is the lack of a suitable testing program. . . ."[3]

Commercially Prepared Teaching Aids

A total of 520 responses was solicited concerning eight commercially prepared teaching aids. Of this number, 473 were returned; 311 (60 per-

[3] James Chapman, a letter to William John Schill, dated at Lancaster, California, May 12, 1961.

cent) indicated that the respondent was acquainted with the aid in question, or a similar one. The breakdown of the responses by teaching aid was as shown in Table II. The number of positive responses to the question, "are you acquainted with the . . . teaching aid?" was sufficiently large to lead to the conclusion that the electronics instructors are aware of aids available for teaching electronics.

TABLE II

RESPONSES INDICATING ACQUAINTANCE WITH COMMERCIALLY PREPARED TEACHING AIDS

Aid	Returns	Acquainted	Acquainted with similar
Rotating electrical machinery—Crow Advanced—Model 700	61	38	9
Philco classroom demonstrator	58	33	9
Packard-Bell 5 RI (tube) radio demonstrator	58	33	9
Packard-Bell 6 RTI (transistor) radio demonstrator	58	25	8
Philco matching lab chassis	58	23	5
Erectronic basic electronics kit BE-4	61	16	24
Erectronic basic electricity electronics and radio kit BE-5	61	16	24
Electronic kit multiproject board	58	7	32
Totals	473	191	120

Application of the Teaching Aids

Three hundred eleven responses indicated an acquaintance with the teaching aid in question, or a similar one; of this number, 292 (94 percent) considered them applicable to instruction in electronics. From this, it is concluded that the teaching aids surveyed have value in the eyes of the electronics instructors who are acquainted with them.

Use of the Teaching Aids

As would be expected, not all of the instructors who thought the teaching aids applicable had had an opportunity to use them in their classrooms. Of the 292 responses that indicated teaching aids were applicable, 178 (61 percent) responded that the teaching aid (or similar one) had been used in the instructional program. The distribution of the use by teaching aids was as shown in Table III.

The Instructors' Appraisal of the Teaching Aids in Use

The instructors in the workshops hoped that questionnaires on commercially prepared teaching aids would give guidance in selecting teaching aids. The instructors who had used these aids seemed best qualified to

assess them. Of the eight teaching aids included in the survey, it was anticipated that some might be of definite value, some of questionable value, and some of no value at all. The 178 responses indicating that the teaching aid had been used in the classroom contained only two negative responses to the question concerning the value of the teaching aids. Hence, it is concluded that the eight teaching aids covered by the questionnaires are generally acceptable.

TABLE III

RESPONSES INDICATING USE OF TEACHING AIDS COVERED IN SURVEY

Aid	Used teaching aid	Used similar teaching aid
Rotating electrical machinery—Crow Advanced—Model 700	16	7
Philco classroom demonstrator	14	6
Packard-Bell 5 RI (tube) radio demonstrator	22	8
Packard-Bell 6 RTI (transistor) radio demonstrator	12	7
Philco matching lab chassis	9	5
Erectronic basic electronics kit BE-4	7	22
Erectronic basic electricity electronics and radio kit BE-5	6	20
Electronic kit multiproject board	0	17
Totals	86	92

SUMMARY

Eight commercially prepared teaching aids were described by questionnaires and brochures which were mailed to 65 instructors of electronics in California public junior colleges. The instructors were asked to indicate whether they were acquainted with the device or a similar one, whether they thought it applicable to the teaching of electronics, whether they had used it, and whether they found it to be an asset. A satisfactory number of responses was received (89 percent). The only conclusion that can be drawn from the responses is that the teaching aids in question are applicable to instruction in electronics and if the instructors have the opportunity to use them, they find them to be of value.

Five self-instructional textbooks were submitted to the same instructors for their reaction. The instructors were asked to indicate whether they had read the book, whether they thought it applicable to instruction in electronics, or mathematics related to electronics, whether they had used it in their program, and whether they found it an asset. A satisfactory number of responses (87 percent) was received.

Only 22 of the responses indicated that the book in question had been

read. Four responses indicated that the book in question had been tried in the school setting and was thought to be of value. There were no data indicating the extent to which self-instructional textbooks had been used, with the exception of the comments from James Chapman.

Rather widespread acquaintance with commercially prepared teaching aids (other than self-instructional textbooks) seems to indicate that commercial distributors can be relied upon to acquaint instructors with their products.

Part IV

Appendices

Appendix A

ANNOTATED BIBLIOGRAPHY

Introduction

Trends

The early studies were devoted to defining the term technician, in order to develop criteria for classifying him. "What is a technician?" became a difficult question because the term was used to describe a tremendously wide range of individuals in diverse work situations. It soon became evident that two criteria were used extensively: first, that of training and education; second, and most generally, that of function and skill level. The governing factor seems to be the type of job performed. Consensus of opinion developed that in order to qualify as a technician, an individual must necessarily be performing one of the variety of specific types of jobs in a number of different fields.

Definitions of the Technician

On the basis of function and skill level, the U.S. Department of Health, Education, and Welfare, Office of Education, defines the word technician as "a general term applied to an individual who assists with technical details in a trade or profession; uses tools, instruments. and/or special devices to design, illustrate, fabricate, maintain, operate and test objects, materials or equipment; performs mathematical and scientific operations, reporting and/or carrying out a prescribed action in relation to them; examines and evaluates plans, designs, and data; determines action to be taken on the basis of analysis; assists in determining or interpreting work procedures and maintaining harmonious relations among groups of workers."[1]

Two essential factors characterizing most technicians are proficiency in craft, and manipulative skill and ability to employ scientific and engineering knowledge. To classify a job then, one must first examine the *scope* of

[1] *A Report of a National Conference*, U. S. Department of Health, Education, and Welfare, Office of Education (Washington: 1957), p. 16.

the job (the number of different skills and kinds of knowledge necessary) and the *level* of the job (extent of knowledge and intellectual ability required). Generally acceptable is the classification of technicians as two major categories (that of industrial technician and that of engineering technician). However, the classification of the Federal Government shows six main categories: engineering aids, surveying and cartography, engineering drafting, physical science aids, electronic technicians.

Fields of Work

Clearly identified also are the fields in which technicians are found, with research, design and development receiving greatest attention. In these fields, the technicians generally act as direct support personnel for engineers and/or scientists. Other fields include production, operations, control, installation, maintenance or sales.

The Employment Outlook

There appears to be some support for the notion that employment of technicians is stabilizing. Nearly 550,000 technicians, an average of 72 for every 100 scientists and engineers, was employed in industry in January 1959.[2] The number of technicians primarily engaged in research and development was estimated at 156,000, or 28 percent of the total number in all activities.

Training

There seems to be a trend in the formal technical education toward the need for an increasing preparation in mathematics and physical science. The primary sources of training at the present are

1. Company on-the-job training
2. Armed Forces technical schools
3. Formal education by technical institutes, junior colleges and other schools of higher education.

On-the-job training includes training at the working place, formal classroom instruction given by company personnel, and the support of part-time off-the-job education. This program has contributed and continues to contribute substantially to the current supply of technicians.

It has been reported that companies almost universally encourage their technician personnel to further their education by taking classes in local schools. Over 40 percent of the students enrolled in post high school technician training are part-time students, men generally concurrently employed in technician work. Large corporations combine on-the-job training with formal company classroom duties.

[2] *Employment Outlook for Technicians*, U. S. Department of Labor, Bureau of Labor Statistics, Bulletin No. 1131 (Washington: 1953), p. 6.

Supply from the Armed Forces

In the Armed Forces the trend appears to be toward an increase in the number of technicians trained. As of 1954, 35,000 enlisted personnel were engaged in supporting work of a technical nature in the Defense Department Research and Development Division. The high turnover of men in this classification provides 5,000–10,000 additional well-trained engineering technicians to industry each year. Many of the skills learned are utilized by ex-servicemen in civilian industrial technical positions. For example, 34 percent of 1,926 electronics technicians working in eight metropolitan areas surveyed in 1953 were found to have attended Armed Forces technical schools.[3]

Supply from Schools and Colleges

From technical institutes and schools of higher education approximately 12,000 technicians students graduate each year. Many of these institutes and colleges offer post high school, one to three-year curricula usually leading to an Associate Degree and preparing students for industrial and engineering technician work.

In the decade ahead it is anticipated that training of technical personnel at all levels—high school, technical institute, college—will become more intensive and contain more basic sciences. Changes are predicted on procuring men qualified to cope with increasing complexity of technology and new developments of automation and atomic energy.

1. Bearden, H. D., *Survey of Technical Occupations* (Texas A & M College, Division of Engineering Extension, 1959).

This publication is primarily a statistical report of technician requirements in principal industrial areas of Texas, prompted by the need to get information on reactivation and relocation of courses and classes. In addition, the inquiry included an examination of educational requirements for individuals who perform in the job of technician.

Data were taken from survey, narrative files of interviewers, minutes and notes of review bodies, and excerpts from interviewee comments. A proportional area-wide sample was taken of industries in Texas and from this sample a representative group of 300 industries was selected to aid in determining the needs of the industry. Industries were identified by standard industrial classification. Seventeen classifications were used. The State was divided into six general areas so as to provide for a simultaneous effort of six teams of analysts.

Six categories of technicians—engineering, mechanical, maintenance, production, laboratory and electronic technicians—were investigated.

Conclusions relating to employment practices of these industries were presented.

[3] James T. Brady et al., *Managing Technician Manpower* (Cambridge: Technician Manpower Associates, 1959), p. 13.

Minimum age requirements for technicians range from 18 to 21 years and maximum of 51 years in most firms. Most specified high school graduation as basic educational requirement. Preference was shown for male technicians.

"Most firms apparently were unwilling to accept the product of technical institutes and trade schools as qualified technicians. Many prefer these young men to begin their employment as apprentices or helpers, advancing by means of in-plant or company sponsored training programs. Several companies feel that the individual must develop on the job since a thorough knowledge of company background and specialized training is indispensable."

The firms felt that the answer to the qualified technician procurement program rests with the training of their skilled craftsmen, since they already possessed the required and related product knowledge.

The curriculum, it was proposed, should be strong in functional laboratory experiences, both in theory and skill area. All related theory should be of the applied variety. Certain basic work activities and educational requirements should be common to all technicians. Notably strong emphasis was placed on the *areas of communication and human relations in the educational* requirements. English and Mathematics were frequently mentioned. High school graduates were delinquent in both areas: manifestly unable to report intelligently or read instructions correctly due to limited understanding of mathematics and inadequacies in the use of the English language. The report presents approximately 50 tables summarizing the research data. Little attempt was made to analyze the data and interpret the findings.

2. Bodine, Merle W., *Training Needs of Highly Skilled Technicians in Twenty-three Selected Manufacturing and Processing Firms* (Kansas State Department of Vocational Education, 1959).

This study was designed to obtain estimates of the need for technicians in the State of Kansas for the next five years and to identify areas of technical skill and the knowledge required for highly skilled technicians in selected Kansas manufacturing and processing establishments.

Forty-two technical occupations were analysed and the frequency with which specific activities were performed, was noted. Also areas of related technical information and understandings required in the performance of the work activities were determined.

Interviews were held with 36 industrial representatives of 23 Kansas manufacturing and processing firms. The data were based on interviews which provided an analysis of 42 technical occupations, representing 830 highly skilled technicians.

Within the number of highly skilled technicians, 42 different titles were found, six of which were in electronics. Common characteristics of the work activities of the total group of technicians studied were described as those connected with experimenting, repairing, designing, and setting up equipment for production (30 percent performed in this area). Fifty percent of the technicians remodel or adapt equipment to new needs, while one-third engage in maintenance of equipment. More than 50 percent used instruments for the most common activities,

namely, inspecting, measuring and making computations. Nearly the same rate of technicians used instruments for trouble-shooting.

The study gives a most complete detailing of the specific activities for the six classifications of the technician. With reference to functional mathematical understandings needed by the total group of technicians, there were some notable conclusions. Based on data from personal interviews of industrial representatives of the 23 firms participating, it was concluded that beginning algebra was of considerable importance. An especially strong need was expressed for the functional understandings of computing ratios, solving equations, substituting in formulas, solving formulas, and interpreting reports. The engineering technician group required the strongest functional understanding of beginning algebra. Related science needed was found to be mechanics, electricity and magnetism. The establishment of training programs for technicians in local public schools on an area basis was supported strongly by industrial representatives.

3. Brady, James T., et al., *Teamwork in Technology: Managing Technician Manpower* (Scarsdale, New York: Technician Manpower Associates, 1954).

The purpose of this publication is to clarify and relate the factors of industry's development of a policy of managing its technicians more effectively, with emphasis on specific means of teaching technicians properly.

The basic data on how industry uses and views technicians were gathered through personal interviews with company executives and through questionnaires sent to eighty business firms in the Boston area. In addition, questionnaires were sent to educators, union leaders, and government officials. Students attending Wentworth Technical Institute, Boston, provided data as to how the technical student views his career.

Conclusions

The report concludes that a great many companies are obviously content to use technicians as mere appendages to the technical aspects of the operation; that these companies are not getting the most for their money; and that a great supply of engineering and productive knowledge is not being fully tapped.

In defining the job of the technicians, the authors considered the following factors as essential which characterize most technicians: proficiency in craft and manipulative skills, and scientific and engineering knowledge. Technicians may be classed into two basic categories according to the scope (different skills and knowledge necessary) and the level (extent of knowledge and intellectual ability required) of their job: (a) Industrial technicians, (b) Engineering technicians.

The industrial technician does not require extensive knowledge of science and engineering to perform his work. He uses more craft and manipulative skills than engineering knowledge. Some technical occupations are very limited in scope and level. This group includes such jobs as product inspection (dealing with few specific products and limited number of inspection instruments),

routine testing (worker checks specific items of performance following established standards). Such jobs differ not much from that of the craft worker but are differentiated by the necessity that the technician has to apply some science and engineering knowledge. Laboratory technicians are an example.

The engineering technician requires more depth and understanding of engineering and scientific principles in the performance of his duties. He uses few manipulative skills. Other titles for engineering technicians are: technologists, senior technicians, engineering aides.

Some occupations of the engineering technicians require only limited skills and specific knowledge, but demand a thorough understanding of overall operations, engineering and scientific principles. An example is an electronics technician who designs amplifiers. He needs extensive knowledge of the electricity principles involved, but is directed toward producing a single component.

The greatest attention in the report was given to the field of research, design and development, where technicians generally act as direct support personnel for engineers and scientists. Since they are the supporting group for highly trained and highly paid personnel, much attention has been devoted to them as a means of increasing productivity of R & D efforts through releasing higher trained personnel for creative scientific or engineering work.

The report takes up the following aspects of special import to management: (1) training of technicians; (2) the technician and collective bargaining; (3) hiring practices and procedures; (4) in-company administration of technicians; (5) management looks at the role of the technician. Of particular interest to educators would be the section on "The Technician Views his Career" which is supported by a study of the sample of students attending Wentworth Institute located in Boston. A detailed analysis of their findings is reported.

Another section of value to educators is the section on "The U. S. Government as a User of Technicians."

4. Brandon, George L., *Twin Cities Technicians: A Limited Survey of Industrial Technicians.* (Lansing: College of Education, Michigan State University, 1958), 70 pp.

The pilot program gathers basic data about the work of the industrial technician, his role, status, and needed performance skills. The survey is conducted in the Benton Harbor-St. Joseph, Michigan, community. The study is designed to help educational planners in the technical area throughout the State of Michigan. In the process of the research, a guide for preparation of interviewers and an interview instrument were developed.

Personal interviews with industrial personnel of the Benton Harbor-St. Joseph area were conducted by the Department of Vocational Education of the Michigan State University. Forty-five interviews in fifteen plants representing 281 industrial technicians were held. The objectives were to locate and identify the technicians, to describe the job and work activities, and to discover the related understandings needed by industrial technicians.

In the fifteen plants contacted in the area during the years 1956–57, 281 indus-

trial technicians were employed. They were classified as technicians in maintenance (25 percent), in mechanical activities (18 percent), production (18 percent), electrical-electronics (14 percent) and laboratory (8 percent). Of the total number employed, seven were electronic technicians whose work activities included graphics and equipment. Five of them were especially active in constructing experimental equipment, performing experiments, repairing, operating, testing, adjusting and evaluating equipment and troubleshooting. Most technicians never fabricate or install equipment, or set it up for production purposes, it was found.

Work activities of industrial technicians were categorized as concerned with: (1) equipment, (2) instruments, (3) production, (4) machines and hand tools, (5) drawing, (6) energy and power, (7) working with other personnel. The most common job activities of the instrument group reported were inspection and troubleshooting (... on the whole, data are outstanding, indicating that technicians seldom operate in production functions. . .).

With reference to the related mathematical understandings needed, the report indicates that the responses reflect a greater use of learning in the beginning areas of mathematics. Relatively lesser need is shown for an understanding of calculus and descriptive geometry. "... two-thirds of the technicians use an understanding of beginning algebra."

In this report there are some implications for education. Research may clarify to a considerable extent the determination of a realistic length of training programs for technicians. Although a period of two years seems to be the accepted length of time, there are few data to support or deny appropriately the length or shortness of the period.

Twin Cities technicians work with the tools, machines, instruments, processes and equipment of modern industry. Consideration of their many job functions and responsibilities suggests a direct experience program of large dimensions. Laboratory curricula may well include (1) a common or basic core of experience for all industrial technicians and (2) specialized courses for the technician of the various classifications.

"The separation of laboratory experience and related technical information is arbitrary and artificial—and sometimes unfortunate. In preparation of technicians, the dichotomy of job skills and "know how" is unrealistic."

5. Buller, John L., *Orange Coast College Electronic Computer Survey* (Orange Coast College, California, 1960).

The study was carried on for and within the Orange Coast College community, in Orange County, California. The problem was to determine changes or modifications needed in the present college program of training for the electronic technician in order to qualify students for the computer field and to identify sound means for selecting prospective technician students.

Data were obtained from personal interviews with personnel managers for computer industries in Orange County from questionnaires, school visits, and a testing program for first-year technical students at Orange Coast College.

Conclusions

About a dozen electronics companies in Orange County are engaged in some phase of digital/analog work, with approximately 303 electronic technicians now employed. The projected need for technicians with specialized computer training is estimated at 232. Respondents indicated that 40 percent of this need could be filled by graduates of a junior college technical program. Investigating the activities of a computer programming technician, the report concludes that there is a definite need for scientific computer programming technicians, and that this training is within the scope of the Orange Coast College occupational curriculum.

After an analysis of available tests which could be used for the purpose of identifying aptitudes in the technical areas, the Employee Aptitude Survey was selected. This test is published by Psychological Services, Inc., Los Angeles, and is a group of ten objectively scored tests, each measuring a different type of mental aptitude. The test was given to a sample which included students completing their first year in one of the technical programs. From data collected on tests, it appears possible to select specific tests from the Employee Aptitude Survey which will indicate success in a given technical program and to establish "guidance scores for the purpose of vocational counseling."

Definition of Technician—Electronic Computer Technician.

"The duties of the Electronic Computer Technician go well beyond routine testing, repairing, adjusting, assembling or installing of electronic equipment. Specifically these duties will vary depending upon the activities of his employer. The job classifications of the electronic computer technician, however, indicate that he should be able to perform, to varying degrees, the following jobs:

1. Conduct electrical, mechanical, and environmental tests of prototype components or complete units of analog/digital computer systems to evaluate conformance with engineering specifications and to recommend design or construction changes;

2. Lay out experimental computer circuits from engineering sketches using knowledge of computer logic, transistors, semiconductors, circuit analysis, and other electronic computer technical skills;

3. Prepare test data and measure the operating characteristics under each of the test conditions to which the component or system is subjected;

4. Analyse test data and write reports for engineering department or other similar purposes;

5. Employ drafting techniques and equipment for making drawings and schematics of final circuits for engineer's approval, and in some cases for technical manuals;

6. Perform tests to evaluate functional operation of manufactured components or systems using pulse and sweep generators, dual beam oscilloscope, frequency analysers, and other similar electronic equipment;

7. Install computer prototype or production models in customer's plant or laboratory and instruct personnel in operation and maintenance of units."

6. Department of Health, Education, and Welfare, U.S. Office of Education, *The Technician, What Has He To Do, What Must He Know* (A working paper prepared by the Division of Vocational Education, Trade and Industrial Education Branch, 1957).

The paper is directed toward the national industrial scene to get at the problems relating to the nature of the work of the technician. The attempt is to discover a pattern of practices and a core of skills required as well as the nature of interpersonal relationships within industry. The aim of the national study, initiated by the Trade and Industrial Education Branch of the Vocational Education Division was to provide guidelines for local community studies of the technician. The paper included a five-point scale for analysing the following work activities of the technician: (1) working with equipment, (2) working with instruments or gages, (3) working with production, (4) working with materials and hand tools, (5) working with drawings, reports, records, handbooks, (6) working with energy and power, (7) working with personnel.
Part 2 of the paper presented the same five-point scale to analyse the functional understandings used by a technician, including mathematics, science, communications, and interpersonal relationships.

7. Emerson, Lynn A., *Vocational-Technical Education for American Industry* (Circular No. 530, U.S. Department of Health, Education, and Welfare, U.S. Office of Education; Washington: Government Printing Office, 1958).

Dr. Lynn A. Emerson, Professor Emeritus in Industrial Education, Cornell University, acting as special consultant to the Division of Vocational Education, Office of Education, prepared the bulletin. The content of the report is limited to the field of vocational-technical education for American industry; it does not deal with education for the large number of vocational-technical occupations found in agriculture, business, health and medical services, and other fields.
The bulletin defines vocational-technical occupations giving scope and level of the occupations, distinguishes the technical from the skilled occupations. Chapter 2 presents education for vocational-technical occupations, giving growth of technical education and needs for new programs. The bibliography includes selected references with annotations and organizations interested in technical education.
Three definitions of the technician are given. Basically, these three definitions are similar, but they are all given because the differing verbal descriptions may help to provide a clearer picture of the job of the technician.

(1) A general term applied to an individual who assists with technical details in a trade or profession. Uses tools, instruments, and/or special devices to design, illustrate, fabricate, maintain, operate and test objects, materials, or equipment. Performs mathematical and scientific operations reporting on and/or carrying out a prescribed action in relation to them. Examines and evaluates plans, designs, and data; determines action to be taken on the basis of analyses; assists

in determining or interpreting work procedures and maintaining harmonious relations among groups of workers.

(2) The technician is a person who works at a job which requires applied technical knowledge and applied technical skill. His work in this area is somewhat akin to that of the engineer, but usually the scope is narrower. His job also requires some manipulative skills—those necessary to handle properly tools and instruments needed to perform the technical tasks. In his special field, he has considerable technical knowledge of industrial processes, and in this field, he knows how to apply the necessary principles of the physical sciences and of mathematics. In general he uses instruments, in contrast with tools. His contribution is mainly through mental effort in contrast with muscular exertion.

(3) The scientific or engineering technician usually works in one of the broad fields: research, design or development—where he generally acts in direct support of an engineer or scientist; production, operation, or control—where the technician usually follows a course laid out by the engineer or scientist, though he may not work under close direction; installation, maintenance or sales—where he frequently performs tasks that would otherwise be done by an engineer or scientist. In performing these functions, the technician thinks out problems for himself. He uses college level mathematics and the principles and functions. He effectively communicates scientific or engineering ideas mathematically, graphically and linguistically.

8. *Industrial Technicians in Michigan* (Michigan State Department of Education, Trade and Technical Education Branch) 1960.

Emphasis is on the industrial technician. The bulletin was prepared by the Committee of Trade and Technical Education of the Michigan State Department of Education. Data were drawn from previous State studies and not based on special surveys. The definition of the engineering technician as given by Ross G. Henninger, Ohio Mechanics Institute, and the definition for the industrial technician are the same as that considered by the President's Committee on Scientists and Engineers.

The growth in the number of technicians in the Michigan labor force is depicted in the following ratio changes: 1940, ratio of one technician to 600 workers; in 1960, one to 176; projected into 1970, a ratio of one to 98. The report gives several sample curricula for electricity and electronics courses.

9. *Industrial Technician and Technical Education Needs, 1960* (Board of Education, Syracuse, New York, 1960).

The purpose of the study was to discover community reaction to the need for a County School of Technology. Conducted in the spring and summer of 1959, it included an industrial survey by personal interview of 33 Syracuse area industries. These represented 67 percent of the employed labor force and all known major employers of technicians. Eighty percent of high school seniors and sophomores participated in the study. A return postcard questionnaire was sent out to 5,000 voters from the 1958 County list, with a 29 percent return. Within the number of highly skilled technicians, there existed 42 different titles.

Of these 42 titles, six were in electronics. The most common characteristics of the work activities of the total group of technicians studied were described as connected with installing equipment (30 percent performed in this area), experimenting, repairing, designing and setting up equipment for production. Fifty percent of the technicians remodel or adapt equipment to new needs, while one-third of the group engages in maintenance of equipment. Most common activities are: working with instruments, inspecting, measuring, and making computations. More than 50 percent use instruments for these purposes and nearly the same number of technicians use instruments for troubleshooting. There were six classifications for electronic technicians, representing 682 technicians, or 82 percent of the total number studied.

The study gives most complete details on the specific activities of the six classifications of technicians. With reference to the functional mathematical understandings needed by the total group of technicians, there were some notable conclusions. Based on data from personal interviews, a strong need was expressed for functional understandings of computing ratios, solving equations, substituting in formulas, solving formulas, and interpreting reports. This appears to be a strictly local study with little or no general import.

10. Lawrence H. Stewart and Arthur D. Workman, *Mathematics and Science Competencies for Technicians: A Study of the Training of Electronics and Chemical Technicians with Special Emphasis on Critical Mathematics and Science Requirements* (Bulletin of the California State Department of Education, Volume 29, No. 1[illegible], 1960).

The study attempts to identify mathematics and science competencies needed by electronics and chemical technicians and to develop ways in which the necessary provisions for required competencies may be made in the curricula of training programs. The study was conducted in the Greater San Francisco Bay Area under the direction of the University of California.

The data were obtained from 197 technicians and 62 first-line supervisors in 13 different electronics firms, and from 81 technicians and 31 supervisors in seven different chemical companies. All firms participating were located in the Greater San Francisco Bay Area. Two samples of technicians and supervisors were employed in the collection of critical incidents related to mathematics and science requirements. The 20 industrial firms represented in the survey varied in size from those employing less than 20 technicians to those employing more than 500 technicians. Some of the firms concentrated primarily upon research and development, others upon production.

Another questionnaire designed for junior college instructors of electronics was administered to instructors in twelve junior colleges in northern California. This aspect of the study was intended to elicit information regarding the instructor's background, the mathematical and scientific skills he considered essential to technicians, his recommendations for screening students for technical training programs, and his opinion as to the major problems involved in training technicians.

The critical incident technique developed largely by J. C. Flanagan, American

institute for Research, requires the "expert" qualified to judge the effectiveness of a particular type of behavior. In this case "experts" were technicians and their supervisors. Each was asked to render a specific description of a behavioral situation or incident designed to illustrate effective or ineffective behavior. Reports of incidents were couched in terms of mathematics and science requirements.

General characteristics of the electronic and chemical technicians reported by the study were found to be: mean age for electronic technicians, 32.6 years, with a range of 25–39 years; for chemical technicians, 35 years, with a tendency for both technicians and supervisors in the category to be three years older than the average.

As for formal education the electronic technicians averaged 13.1 years and 13.9 years for electronics supervisors. Approximately 56 percent of the technicians have had formal education beyond high school. More technicians receiving education beyond high school attend junior colleges than four-year institutions and more supervisors than technicians attended either junior colleges, four-year institutions, or both.

The mean educational level of 13.6 years for the chemical technicians is only slightly higher than their counterparts in the electronics area. On the other hand, the supervisors are more highly trained than personnel in the other groups. More than one-half of these have completed requirements for the doctorate. Almost 90 percent reported attendance at a college or university, but none indicated junior college work.

For electronic technicians, the mean number of years of experience is 7.1, with approximately 42 percent having less than five years of experience; slightly more work experience for chemical technicians, i.e., 7.6 years.

With reference to the origins of interest in electronics, two sources were mentioned most by electronics technicians. These were self-interest activities, such as hobbies and reading, and experiences in the Armed Forces. Few of the electronic technicians (14.7 percent) listed school experience as responsible for their interest in electronics.

Slightly more than one-fifth reported receiving their training solely in schools, either college or high school. Another 21.3 percent indicated military service schools. Only one in ten received his entire training on the job.

Perceived Mathematics and Science Requirements. All the technicians and supervisors were asked to indicate how much mathematics and science training they considered necessary to prepare a technician adequately for his job. One-fourth of the electronic technicians and their supervisors perceived training in elementary algebra as essential. As for the chemical technicians, over 40 percent of them and 61 percent of their supervisors indicated that a simple algebraic skill was adequate. Only 16 percent of these supervisors indicated mathematics training from basic courses through trigonometry as necessary.

Formal Training in Mathematics. Slightly more than one in five of the electronic technicians reported having taken calculus; 28.9 percent having received training through trigonometry. Approximately one out of ten reported mathematics training of a type more advanced than calculus. Statistics reflected the desire of technicians and supervisors for further training. Both reported plans for further

work in mathematics and science, especially the electronic technicians. Implied is the discernment of greater opportunities for advancement in the electronic field.

Implications for Education. "One implication readily apparent from these data is the need for educational institutions not only to offer training curricula for new entrants into the technical field, but also to provide considerable advanced work scaled to the needs of technicians already on the job.

In general, the data discussed in this chapter indicate that most technicians do not require high-level mathematical and scientific skills. There is some indication of the need for practically oriented skills, i.e. toward laboratory techniques rather than toward abstract theory. Furthermore, the data suggest that perhaps many technicians possess higher-level skills than are being tapped by their present job. The disclosure that a large number of technicians plan to expand their capabilities by taking additional formal course work portends a greater supply of more highly trained technicians. But there is some evidence that the skills already available are not fully exploited. Does this mean that there will be an even greater waste of manpower resources? This problem should become a matter of most serious concern on the part of both training institutions and industry."

11. *Technical Education: Technicians for Florida Industries* (Florida *State Department of Education publication,* 1959).

The study is concerned with the number of technicians employed, their duties and responsibilities as outlined by the employer. In addition, the study attempts to identify prerequisites in algebra, trigonometry, and drafting from which employee proficiency may be measured. Technicians in nine occupational categories were studied. Included were aeronautics, agriculture, chemistry, construction, drafting, electricity, electronics, mechanics and metallurgy.

Method involved using local directors of vocational education to establish a list of the industries contacted. Some industries were contacted by mailed questionnaire, others were contacted in person. Involved were 585 enterprises employing a total of 11,987 technicians.

Findings. Of all employed personnel studied, 36.6 percent were classified as electronic technicians. There will be a projected need for 6,220 technicians by 1962 for the State of Florida (one in three will be an electronic technician). A look at in-service training programs revealed that three out of ten firms sponsored some type of training program. The group employing from one to five technicians constituted over 41.6 percent of the total, the group employing from eleven to twenty technicians constituted 11.1 percent of the total, and the group employing from 21 to 50 technicians constituted 51.5 percent of the total.

12. U.S. Department of Labor, Bureau of Labor Statistics, *Employment Outlook for Technicians* (Bulletin No. 1131; Washington: Government Printing Office, 1953).

Nature of Work. The definition used is that of Dr. Lynn A. Emerson, Cornell University. All jobs held by technicians who work with engineers and scientists have some common characteristics—notably that they require a knowledge and

practical application of mathematics and physical science—the nature of work performed differs considerably among occupations.

Engineering Aides. In general they work under the supervision of an engineer and perform specialized functions requiring less cultural and theoretical training than is provided by professional engineering courses. Work usually requires a knowledge of some specialized field. Aide may assist engineer in production planning by designing and analysing layouts. When production begins he may make tests, record data, make computations, work on production methods, check material. He may also act as liaison man between engineering department and drafting department, tool room and production department.

In the field of research, aides perform tests with regard to such matters as stress, strain, motion and impact. They may set up, calibrate, and operate instruments such as torsion meters; may also test and calibrate electric controlled devices employing vacuum tube circuits, and make calculations with respect to weight centers of gravity, etc.

Electronic technicians. Their background of electronic theory, physical science and mathematics enables them to perform jobs above routine operating, maintenance and repair level. Their work requires them to make practical application of theoretical knowledge. The practical part may call for use of such basic tools as pliers, screw drivers, wrenches, soldering irons—whereas the theoretical part may call for use, understandings and interpretations of results obtained from instruments such as oscilloscope, signal generators, ohmmeters, ammeters, voltmeters, multitesters, and Q-meters. Their work often calls for a combination of manual skills in handling simple tools and a knowledge of complex testing equipment. They must be able to read and interpret layout and other diagrams, use mathematical formulas for circuit work, and wire intricate electronic units. Electronic technicians working in laboratories construct, test, install, modify, operate and under certain conditions design experimental electronic apparatus. They may be called upon to offer ideas and suggestions, devise practical solutions to problems of design, select suitable materials and methods of construction, evaluate the operating characteristics of the equipment and in other ways contribute to the research and development process.

In the industry electronic technicians may perform "trouble-shooting" functions or do the more complicated types of testing and inspection work. An important function of electronic work with production is building of testing equipment.

Past Trends. Employment of technicians has increased markedly over the past four decades. Among the technicians allied with engineers and scientists, draftsmen were the first group to become established as a separate occupation, and they still outnumber every other group of technicians. The number of draftsmen in the country rose from 12,000 in 1910 to 88,000 in 1940. A further sharp increase in employment of technicians has taken place since 1940. One reason for this conclusion is the rise in the number of employed professional engineers (from 245,000 in 1940 to more than 400,000 in 1952). Several studies have been made by different organizations of the relative numbers of technicians, engineers, and scientists employed in certain industries. These studies indicate an extremely wide variation in the ratio of technicians to engineers and scientists, due in part

to the lack of uniform definitions of technical and other related jobs. The ratio was found to vary from 20 technicians for each engineer to 1.7 per engineer in different industries. It also differed considerably among plants in the same industry.

Outlook. Current announcements (1953) by the U.S. Civil Service Commission of job opportunities emphasize the Federal Government's need for additional technicians. In May 1952, the Commission listed engineering aide, engineering draftsman, junior scientist, tool designer, electronic equipment repairer, and electronic mechanic among the personnel for whom there was urgent need in specified localities. The demand for technicians will probably be great as long as the defense program continues. The current shortage of scientists and engineers has given renewed impetus to the trend, notably since World War II, toward greater use of technicians. In some cases scientific jobs are being "diluted" and "broken down" so that technicians may be used for some specialized activity. The need for better utilization of fully trained professional personnel is receiving recognition from many sources and, to this end, the employment of greater numbers of technicians is recommended.

It is expected that the greatest demand for technicians in the next few years will be in t defense-related industries. Other industries important in defense-connected research and production such as the machine tool, industrial chemicals, and petroleum industries are therefore expected to need additional technicians. The Federal Communications Commission announced in 1952 that 2,053 new television stations would be allowed to open, and this will further intensify shortages of trained electronics technicians, because sizable numbers will be needed to maintain and service the additional stations when they are established.

Employment of technicians is likely to continue to expand over the long run. Some of the factors which are expected to affect favorably the long-run employment for them are the general advance of scientific knowledge and its practical application in industrial operations; and the increasing use of technically trained personnel in sales jobs, supervisory jobs, and other types of work. Further, it is expected that high levels of expenditures for research and development will persist over the long run. More and more companies are establishing research programs and existing programs are being expanded to meet the strong competition in developing new products and processes. In addition to the new positions created by growth in the field, many employment opportunities for technicians will occur each year because of deaths, retirements, or transfer of experienced workers. However, technicians face special competitive problems when jobs become scarce, because they are in occupations which can be filled by persons with a wide variety of backgrounds. In the past, during periods of considerable unemployment, the most serious contenders for technician jobs have been the professional workers. The possibility of greater flexibility and broader background from the four-year college graduate may influence the employer's preference. The technician, then, would be well advised to consider taking additional courses of general nature, as well as specialized courses in his field, to prepare himself better to meet competition.

13. U.S. Department of Labor, Bureau of Labor Statistics, *Mobility of Electronic Technicians 1940–1952* (Bulletin No. 1150; Washington: Government Printing Office, 1954).

The U.S. Bureau of Labor Statistics with the support of the Air Force undertook a series of studies of the mobility of workers in critical occupations with four primary objectives: (1) to identify personal characteristics of the workers in an occupation and to discover how they will affect the future supply and mobility of these workers; (2) to locate the sources from which fully or partially trained workers may be drawn; (3) to discover sources of training for these workers; (4) to get answers on the mobility of workers between occupation specialties, establishments, industries, and areas, and factors affecting this movement.

The main object of this particular study was to learn how men find their way into electronic technician jobs, and how they move among different types of electronic establishments, employers, and labor market areas. The data were gathered by personal interview survey of 1,926 electronic technicians employed in eight of the Nation's largest metropolitan areas: Atlanta, Baltimore, Boston, Chicago, Detroit, Los Angeles, New York, Philadelphia. The survey conducted in April–May, 1952 required a great deal of detailed information about workers' personal background and work history during a twelve-year period from January, 1940 to April–May, 1952.

Questionnaires. Two questionnaires were used. One was mailed to each industrial establishment soliciting information that the employer would supply, and an employee questionnaire was used for information obtained by interviewing the individual technician. Both were pretested in the Philadelphia and Baltimore areas. Establishments provided data on hiring methods, training conducted in plants, job breakdowns, plant employment, number of technicians employed and job descriptions for electronic technicians.

Sample Design. A sample of 1,800 technicians was selected from six types of establishments that employ 90 percent of all civilian electronic technicians in the United States. The survey was restricted to eight of the largest metropolitan areas, representing every geographic area. Thus, the universe from which the sample of electronic technicians was drawn includes all establishments located in these cities which are engaged in the six types of establishments: (1) Repair of radio and/or television receivers; (2) Radio and/or television broadcasting; (3) Manufacturing of aircraft; (4) Manufacturing of other electronic equipment; (5) Manufacturing of radio and/or television receivers; (6) Research and development.

The work history analysis used in this study is more comprehensive than that used in previous studies of occupational mobility. Instead of selecting from a complete work history period specific types of activity or specific points in time, *this study considers the work history period in its totality*, showing each respondent's task in each month of the twelve years in terms of type of labor force status. This method permits a detailed tracing of the steps through which new men enter a skilled-worker category and, at the same time, allows the usual analysis of the movements of workers after they are qualified.

Collection. Individual technicians to be interviewed were selected from the

establishments by obtaining a complete list of electronic technicians employed at each and selecting randomly a proportion of the total that would give the plant the proper representation. The criterion was a minimum of one year of school or on-the-job training in electronics. The sample of 1,926 electronic technicians was one of the largest groups of workers in a single occupation that had ever been studied. This afforded an opportunity for detailed analysis without sacrifice of statistical reliability. Chi square test was used to guard against imputation of significance to variations which could be due to chance.

Findings. As to the role of the electronic technician, the study noted that the operation of electronic equipment is based upon complex laws of physics. For this reason, the manufacture, installation, and maintenance of electronics devices require the services of skilled workers who understand these physical science principles. "Electronic technicians perform specialized tasks involving the application of electronic theory in the manufacture, installation, maintenance, and repair of electronic equipment. The particular job duties of electronic technicians vary with the products and services of the establishments they work in . . . nevertheless, there is a body of knowledge and skills common to all these groups."

Generally speaking, the electronic technician diagnoses the trouble in a piece of equipment by studying its "symptoms," makes tests to verify or correct his diagnosis, and then makes the necessary repairs. He uses meters and other testing components and circuits. He replaces defective parts, using electrician's tools such as pliers, screw drivers, wrenches, and soldering irons. After making repairs, he adjusts the equipment to proper operating conditions.

This description applies most specifically to repairmen, but those technicians who construct, install, test, and maintain electronic devices must also perform some of the above operations. In manufacturing, the emphasis is on testing, inspecting, and repair. In research laboratories, construction of equipment, from blueprints or wiring diagrams, is one of the main jobs of the technician. In aircraft plants, electronic technicians are often concerned with fabrication and installation of electronic equipment.

Estimated Number Employed. The estimated number of electronic technicians in the civilian economy was 100,000 in April–May, 1950, in the United States. Types of establishments in which they were employed included: repair of radio and/or television, 70,000; broadcasting, 13,000; manufacturing aircraft, 3,500; radio, 1,500; research, 1,500; and other, 7,000.

On the whole the electronic technicians were a young group of skilled workers who changed jobs relatively often from January, 1940 to April, 1952. The most mobile workers were young men with only one or two years of experience in the field. Most electronic technicians showed marked aptitude for the physical sciences. Electronic training in technical schools was the most common type of training for this occupation, though many technicians, particularly the older men, had acquired much of their skill at home through reading and hobby work.

Mobility. The average electronic technician changed jobs once every four years during the twelve-year work history under study. About 55 percent had held civilian jobs other than electronic technician during this period. Sixty-one percent had served in the Armed Forces, one-half of them as electronic technicians. Less than half had held jobs occupied in 1952 for more than 36 months.

The tenure was shortest in aircraft manufacturing and research, and longest in broadcasting. The electronic technicians moved freely among the different types of electronic establishments. Those in research had held the highest proportion of electronic technician jobs in other fields. Radio and television repair work was often a first job in which respondents acquired experience and skill. Electronic technicians performed a wide variety of job duties in the period studied. About 20 percent of the electronic technicians moved from one city to another in changing jobs. Twelve percent made one area shift. Five percent made two, three percent made three to five shifts in the twelve-year period. The most common reason given for the shifts was to take a better job. Twelve percent left because of lay-offs.

Though the job changers included a lower proportion of married men and fathers, and a slightly higher proportion of high school graduates, these differences can be attributed to age and other factors. No apparent influence of marriage, fatherhood or education on job changing is apparent in the findings.

Training. Technical school courses were the most important type of training. More than half of the technicians had attended full time civilian technical schools, and one-third received training in Armed Forces schools. About five percent had been apprentices and fifteen percent reported other on-the-job training. Most of the men who attended full time civilian technical schools took courses lasting 12, 18 or 24 months. Those attending Armed Forces technical schools usually took six or twelve months' courses.

Personal Characteristics. The majority were high school graduates who had had a definite aptitude for mathematics and the physical sciences. More than half of the electronic technicians came into this field directly from school or the Armed Forces. Electronics was their first regular occupation. Less than one-third of the men in the survey had worked as electronic technicians before 1940.

Half of the technicians manifested in their youth an interest in electronics which led them into this field. Other men were influenced by Armed Forces training, or through personal influence.

The median age was 33, four out of five were married, and three-fourths of the married men were fathers.

Technicians were versatile in terms of ability to make major repairs on different types of equipment; over half of them were able to repair four or more types.

Manpower Implications. Direct quotes from the report follow:

> "It is, therefore, likely that the attractiveness of this field for new entrants in the labor market and the strong job attachments of those already working as technicians will insure a gradually increasing supply of electronics technicians in the years ahead.
>
> "The youthfulness of electronic technicians indicates that losses due to death and retirement will be relatively slight. As a group, electronic technicians are above average in their propensity to change jobs. . . . Once a man became a skilled electronic technician, he was disposed to remain in the electronics field, though he showed considerable willingness to change jobs within it. Since it might be difficult to establish a large-scale, long-term training program after the mobilization period began and since the graduates might not be

available in time to participate in the mobilization effort, such a program should be initiated in advance of mobilization.

"The survey findings can aid considerably in guiding the establishment of training programs to develop all-around electronic technicians. They indicate that there are a number of specific aptitudes and interests that should be used as the basis of selection of trainees. Most of the men who succeeded in this field liked mathematics and physical sciences and had shown an interest in radio and electronics long before they entered the labor market. Theoretical knowledge and background is much more important than in most other skilled occupations and the experience of civilian and Armed Forces Schools indicates that some men can master the necessary theoretical concepts much more easily and rapidly than others. A careful selection system which would attempt to induct into training those who were 'most likely to succeed' would be a major factor in assuring the effectiveness of any training program.

"The findings also provide information on the methods and content of an effective training program. Electronic technicians and their employers were asked for specific suggestions about the best ways of training electronic technicians. The most frequent response was that an ideal program would combine classroom instruction in electronics theory, repair and service procedures and related topics with actual work in a particular job on a concurrent, daily basis.

"Logically a program for training electronics technicians should be started before mobilization actually begins. In practice, however, such a program would face many difficulties. . . . establishing a broad program of training for these groups would provide a large new pool of skilled workers who would be available for electronic technician's work in a mobilization period. Although this program would give many workers training beyond the minimum requirements for the jobs they actually hold, it would be more desirable than training large numbers of men to be technicians, beyond the needs of the peacetime economy. This is emphasized by the fact that formal training alone is not sufficient to qualify a man for electronic technician's work, especially when it is not combined with actual job experience. . . ."

Appendix B

FORMS

Scale for Determining Technical Workers to be Interviewed

The process of determining the number of workmen to be interviewed at each company will be on the basis of the total number of personnel (that fall within the classifications covered by the study), according to the following scales:

Total Number of Technical Employees	*Number Drawn for Sample*
from 1 — 2	0
3 — 5	1
6 — 10	2
11 — 25	3
26 — 50	4
51 — 100	5
101 — 150	6
151 — 200	7
201 — 250	8
251 — 300	9
300 or more	10

INTERVIEW SCHEDULE FOR TECHNICAL WORKERS

1. I.D.. 2. Company...
3. Job classification..
4. Born (year only)........................... 5. What mathematics courses have you taken in high school?...
in college?...
6. Job history..
....
....
....

7. Where did you receive your training?..
8. State name and relationship of anyone who influenced you to enter this area of employment:..
9. Was there any particular circumstance that influenced you to enter this area of employment?..
10. Education: H.S., A.A., etc.:..
11. What precisely do you do?..

....

....

....

DIRECTIONS FOR THE Q-SORT

(Technical Workers)

The problems on the cards are to be sorted according to the extent to which they are similar to problems that you encounter as part of your job. To do this most readily, the following procedures would be useful:

1. Read through all the problems to become familiar with the material.
2. Sort the problems into two groups:
   a. one group of problems which are most like those you encounter;
   b. one group of problems which are least like those you encounter.
3. The final distribution will be as follows:

   MOST SIMILAR　　　　LEAST SIMILAR

   3 — 4 — 7 — 12 — 14 — 12 — 7 — 4 — 3
4. In other words, these problems should be sorted into nine piles ranging from the first pile of three problems most like those you encounter in your work to the last pile of three problems least like those you encounter in your work.
5. It is probably easiest to begin with the problems most like those you encounter. Read through and select the *three* most similar and place them in one pile; then select the *four* next in similarity to those you encounter and place them in the second pile, etc. At some point, you might shift to the group of problems least like those you encounter and select the *three* problems least like those you encounter, then the next *four*, etc.
6. After you have sorted the problems, check carefully your whole distribution to be sure that you have made no mistakes. Make certain that your sort follows the distribution indicated.
7. Please report your sortings on the attached form.

DIRECTIONS FOR THE Q-SORT

(Instructors)

The problems on the cards are to be sorted according to the extent to which they are similar to problems that you would expect your graduates to encounter as part of their job. To do this most readily, the following procedures would be useful:

1. Read through all the problems to become familiar with the material.
2. Sort the problems into two groups.
   a. one group of problems which are most like those you would expect your graduates to encounter.
   b. one group of problems which are least like those you would expect your graduates to encounter.
3. The final distribution will be as follows:

   MOST SIMILAR LEAST SIMILAR

   3 — 4 — 7 — 12 — 14 — 12 — 7 — 4 — 3
4. In other words, these problems should be sorted into nine piles ranging from the first pile of three problems most like those you would expect your graduates to encounter to the last pile of three problems least like those you would expect your graduates to encounter as part of their job.
5. It is probably easiest to begin with the problems most like those you would expect your graduates to encounter. Read through and select the *three* most similar and place them in one pile; then select the *four* next in similarity to those you would expect your graduates to encounter and place them in the second pile, etc. At some point, you might shift to the group of problems least like those you would expect your graduates to encounter and select the *three* problems least like those you would expect your graduates to encounter, then the next *four*, etc.
6. After you have sorted the problems, check carefully your whole distribution to be sure that you have made no mistakes. Make certain that your sort follows the distribution indicated.
7. Please report your sortings on the attached form.

Q-SORT REPORTING FORM

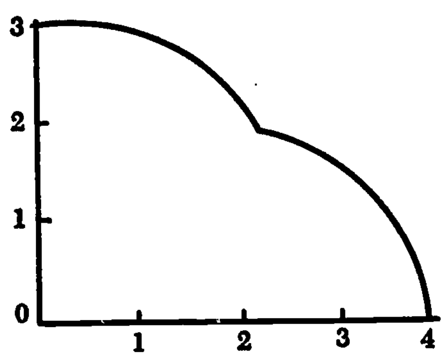
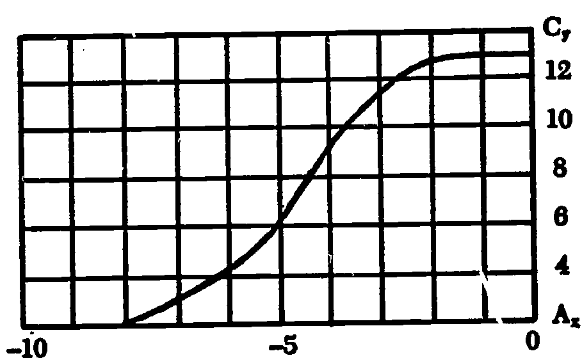
ID..

Each card has an identification number in the upper right hand corner. List the number on each card in the proper group below.

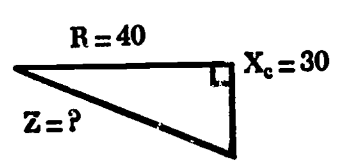
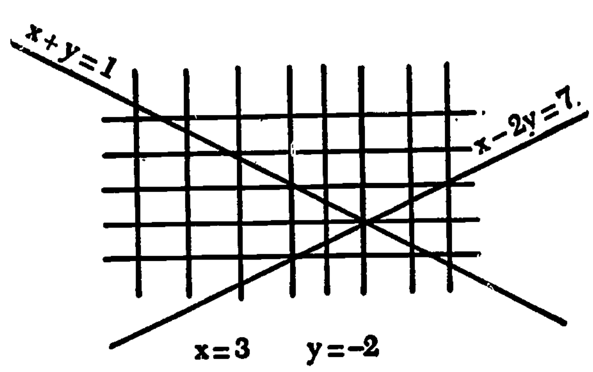
				....				
				....				
			....	....	....			
			....	....	....			
			....	....	....			
			....	....	....			
			....	....	....			
		....	....	....	....	....		
		....	....	....	....	....		
		....	....	....	....	....		
	....	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....
3	**4**	**7**	**12**	**14**	**12**	**7**	**4**	**3**

Most Similar | **Least Similar**

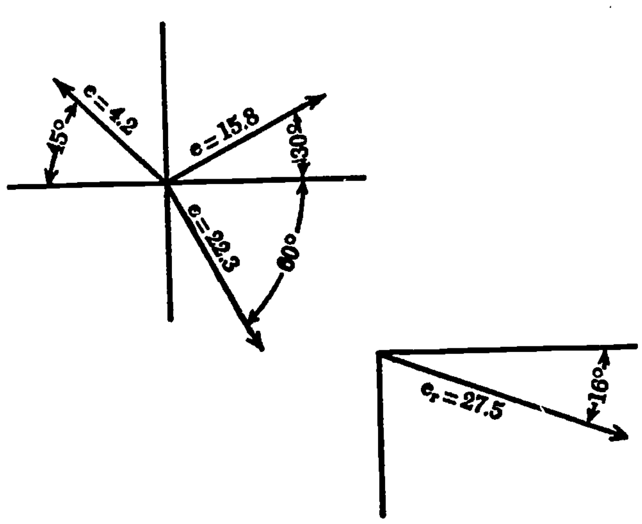
SAMPLE OF Q-SORT PROBLEMS

The Problem	*Number Assigned to Q-sort Card*	*Mathematical Skill or Concept*
14°27′ 22°35′ 36°62′ = 37°02′	3	Addition of degrees and minutes
A = approximately 9 sq. units	35	Area approximation
When $A_x = -3$, $C_y = 11$	57	Graph interpretation

SAMPLE OF Q-SORT PROBLEMS

The Problem	*Number Assigned to Q-sort Card*	*Mathematical Skill or Concept*
1 3· 7 $\sqrt{1\,87\cdot 69}$ 1 87 69 1869 1869	63	Square roots—long-hand method
$(6 \times 10^2)^2$ 36×10^4 3.6×10^5 or 360,000	54	Raising to a power with exponents
 $Z = \sqrt[2]{40^2 + 30^2}$ $Z = \sqrt[2]{2500}$ $Z = 50$	52	Pythagorean Theorem
	56	Graphic solution of equation

SAMPLE OF Q-SORT PROBLEMS

The Problem	*Number Assigned to Q-sort Card*	*Mathematical Skill or Concept*
$x = \frac{-2 \pm \sqrt{2^2 - 4 \cdot 5 \cdot (-3)}}{2 \times 5}$ $x = \frac{-2 \pm \sqrt{64}}{10}$ $x = \frac{-2 \pm 8}{10}$ $x = 3/5 \text{ or } -1$	45	Quadratic formula
$5.96 \times 888 \times 0.00604$ $\log 5.96 = 0.7752$ $\log 888 = 2.9484$ $\log .00604 = 7.7810 - 10$ log product $11.5046 - 10$ $5.96 \times 888 \times 0.00604 = 31.97$	7	Multiplication with logs
$1101_2 = 8_{10} + 4_{10} + 0_{10} + 1_{10} = 13_{10}$	8	Binary Arithmetic
	19	Addition of vector in polar form

SAMPLE OF Q-SORT PROBLEMS

The Problem	*Number Assigned to Q-sort Card*	*Mathematical Skill or Concept*
$\text{Sin}\,\frac{\theta}{2}=\pm\sqrt{\frac{1-.5446}{2}}$ $\text{Sin}\,\frac{\theta}{2}=\pm\sqrt{.2277}$ $\text{Sin}\,\frac{\theta}{2}=.476$	62	Functions of half angles
$A=\int y\,dx$ $A=\int\frac{1}{(2x-6)}dx$ $A=\frac{x^2}{4}-6x-c$	30	The integral as an area
$(5x^3+7x^2+9)$ $y=(5x^3+7x^2+9)^2$ $\frac{dy}{dx}=2(5x^3+7x^2+9)\,(15x^2+14x)$	40	The differential

UNIVERSITY OF CALIFORNIA

DIVISION OF VOCATIONAL EDUCATION
LOS ANGELES 24, CALIFORNIA

February 2, 1961

Dear Sir:

Enclosed you will find a number of very brief questionnaires relating to newly published textbooks which are designed to be self-instructional, i.e. the student should be able to master the contents without additional instruction.

I shall appreciate receiving the completed questionnaire at the address given below:

William John Schill, Research Consultant
Technical Occupations
Division of Vocational Education
123 Moore Hall, 405 Hilgard Avenue
Los Angeles 24, California.

Yours truly,

WILLIAM JOHN SCHILL
Research Consultant
Research in Technical Occupations

WJS:et
encl.

UNIVERSITY OF CALIFORNIA
DIVISION OF VOCATIONAL EDUCATION
RESEARCH IN TECHNICAL OCCUPATIONS
LOS ANGELES

QUESTIONNAIRE

Title:	Adventures in Algebra.
Author:	Norman A. Crowder and Grace C. Martin.
Publisher:	Doubleday & Company, Inc. Garden City, N.Y.
Date:	1960.
Contents:	1. Elementary processes of algebra. 2. Concept of numbers from the positive integers to the entire set of numbers. 3. Repetition of classic proofs to establish the requirement for numbers other than positive whole numbers.

Please Answer the Following Questions Relative to the Book Described Above:

Have you read this book? .... Yes .... No

If "yes" a) Do you see any application of this book to instructions in electronics, or mathematics related to electronics? .... Yes .... No

b) Have you used it in your instruction program? .... Yes .... No

c) Do you think this book was an asset? .... Yes .... No

UNIVERSITY OF CALIFORNIA

DIVISION OF VOCATIONAL EDUCATION
LOS ANGELES 24, CALIFORNIA

March 15, 1961

Dear Sir:

Enclosed are brochures covering commercially prepared instructional materials with a questionnaire for each of these brochures.

I shall appreciate receiving the completed questionnaire at the address given below:

William John Schill, Research Consultant
Technical Occupations
Division of Vocational Education
123 Moore Hall, 405 Hilgard Avenue
Los Angeles 24, California.

Yours truly,

WILLIAM JOHN SCHILL
Research Consultant
Research in Technical Occupations

WJS:et
encl.

UNIVERSITY OF CALIFORNIA
DIVISION OF VOCATIONAL EDUCATION
RESEARCH IN TECHNICAL OCCUPATIONS
LOS ANGELES

QUESTIONNAIRE

Teaching Aid: The Electronic Educational System of "Packaged Unit" Training Aids:

A. Basic Electronics Kit BE-4

B. Basic Electricity Basic Electronics and Radio Kit BE-5

Manufacturer: Science Electronics, Inc.
195 Massachusetts Avenue
Cambridge 39, Massachusetts

Are You Acquainted With the Above Described, or Similar, Teaching Aids?

If "yes" please indicate by checking the appropriate blank:

A (above) ....
B (above) ....
OTHERS ....

1. Do you see any application to instructions in electronics or mathematics related to electronics? .... Yes .... No

2. Have you used it (them) in your instruction program? .... Yes .... No

3. Do you thing the aid(s) was (were) an asset? .... Yes .... No

SAMPLE PROBLEMS FROM MATHEMATICS ACHIEVEMENT TEST

$\frac{3}{7} + \frac{2}{9} =$

1. 5/8
2. 5/16
3. 6/63
4. 41/63
5. None of the above

Find the lowest common denominator of 3/5—9/16—5/18

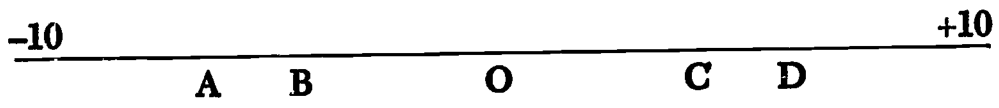
1. 180
2. 360
3. 720
4. 440
5. None of the above

Structural concrete requires a mixture of 1 part cement, 3 parts sand, and 5 parts aggregate. If cement weighs 90 lbs per cubic foot, sand 100 lbs per cubic foot, and aggregate 120 lbs per cubic foot, the weight ratio for concrete would be:

1. 90 : 100 : 120
2. 45 : 100 : 240
3. 45 : 150 : 300
4. 90 : 300 : 700
5. None of the above

SAMPLE PROBLEMS FROM MATHEMATICS ACHIEVEMENT TEST

Use the scale below for problems 17 and 18



Which literal number most nearly represents –4?

1. A
2. B
3. C
4. D
5. None of the above

Table of Squares, Cubes, Square Roots, and Cube Roots

Number n	n^2	n^3	$\sqrt{n}$	$\sqrt[3]{n}$
15	225	3375	3.8730	2.4662
20	400	8000	4.4721	2.7144
25	625	15625	5.0000	2.9240
30	900	27000	5.4772	3.1072
35	1225	42875	5.9161	3.2711
40	1600	64000	6.3246	3.4200
45	2025	91125	6.7082	3.5569
50	2500	125000	7.0711	3.6840

The following question is based on the table above.

What is the square of 4.5?

1. 20.25
2. 202.5
3. 2025
4. 6.7082
5. None of the above

SAMPLE PROBLEMS FROM MATHEMATICS ACHIEVEMENT TEST

The diameter of one circle is three times as great as that of another. How does the area of the larger circle compare with that of the smaller?

1. It is 3 times as great.
2. It is 6 times as great.
3. It is 9 times as great.
4. It is 12 times as great.
5. The correct comparison is not given.

Two angles of a triangle are each 45°. What is the size of the third angle?

1. 45°
2. 90°
3. 100°
4. 180°
5. None of the above.

A motor turns 10°8′3″ per second. How many revolutions does it make per minute?

1. 1.69
2. 16.9
3. 1.96
4. 19.6
5. None of the above.

In any circle the ratio of the radius to the diameter is:

1. 2/1
2. 1/2
3. $1/\pi$
4. $\pi/1$
5. None of the above.

If a square has a side of "x" length, the perimeter would be?

1. x^2
2. 4x
3. $4x^2$
4. 2x
5. None of the above.

SAMPLE PROBLEMS FROM MATHEMATICS ACHIEVEMENT TEST

$200 =$

1. 2×10^1
2. 2×10^2
3. 2×10^3
4. 2×10^{-2}
5. None of the above

$0.3 =$

1. 3×10^1
2. $.3 \times 10^1$
3. 3×10^{-1}
4. 3×10
5. None of the above

$(x^2 + y)(x - y) =$

1. $x^3 - x^2y + xy - y^2$
2. x
3. $x + y - y$
4. x^3
5. None of the above

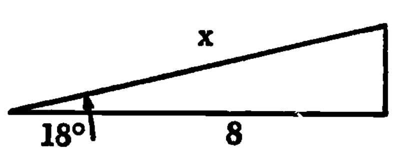
$\sqrt{2} - 6\sqrt{2} =$

1. $6\sqrt{4}$
2. 12
3. 14
4. $7\sqrt{2}$
5. None of the above

Given the Cosine of $18° = .9511$

Solve for x

1. $x = 7.6$
2. $x = 8.4$
3. $x = 18.4$
4. $x = 25.9$
5. None of the above



Appendix C

DATA

DATA FROM INTERVIEWS WITH TECHNICAL WORKERS

ID No.	Age	Mobility*	Education	Interest developed	Personal influence	Received training	Mathematics	Job classification
1	28	UM	A.A.	Service	None	Service	Beyond	Research and development
2	26	UM	A.A.	Hobby	None	Service	Algebra	Communications
3	36	S	H.S. +	School	Family	On own	Trigonometry	Research and development
4	28	HM	H.S.	Service	None	Service	Trigonometry	Design draftsman
5	30	S	A.A. +	None	None	Public school	Beyond	Research and development
6	35	S	A.A. +	Hobby	None	Service	Differential calculus	Research and development
7	22	S	H.S. +	Hobby	Family	Public school	Trigonometry	Test
8	34	S	A.A.	Hobby	None	Industry	Integral calculus	Research and development
9	25	S	H.S. +	Service	None	Service	Differential calculus	Test
10	33	HM	H.S. +	Service	None	Service	Trigonometry	Research and development
11	23	S	H.S. +	Service	None	Industry	Integral calculus	Test
12	26	S	H.S. +	Hobby	None	Industry	Integral calculus	Research and development
13	24	S	A.A.	Hobby	None	Industry	Trigonometry	Test
14	27	UM	A.A.	Service	None	Industry	Integral calculus	Computer
15	32	UM	A.A. +	None	None	Public school	Integral calculus	Field service
16	26	S	H.S. +	None	None	Public school	Integral calculus	Field service
17	28	HM	H.S. +	Service	None	Service	Less than algebra	Field service
18	42	S	H.S. +	Hobby	Friend	Service	Algebra	Communications
19	37	S	A.A.	Service	None	Service	Intermediate Algebra	Communications
20	34	S	A.A. +	Service	Family	Industry	Trigonometry	Test
21	29	HM	A.A.	None	Family	Private school	Analytical geometry	Instrument maintenance
22	41	HM	A.A.	Hobby	None	Industry	Trigonometry	Instrument maintenance
23	26	S	H.S. +	Service	Friend	Industry	Differential calculus	Research and development
24	27	HM	A.A.	Service	None	Private school	Trigonometry	Television and radio
25	34	S	H.S.	None	Family	Industry	Algebra	Research and development
26	55	S	H.S. +	Hobby	Family	Industry	Trigonometry	Television and radio
27	28	S	A.A.	None	None	Private school	Trigonometry	Research and development
28	22	UM	A.A. +	Hobby	None	On own	Integral calculus	Research and development
29	39	UM	A.A. +	Hobby	Teacher	Industry	Differential calculus	Test
30	28	HM	A.A.	None	None	Industry	Analytical geometry	Test
31	26	HM	H.S.	Hobby	None	Service	Algebra	Test
32	35	UM	H.S. +	Service	Teacher	Service	Trigonometry	Test
33	43	HM	H.S. +	None	None	Service	Less than algebra	Research and development
34	46	S	A.A.	Job	Family	Private school	Higher algebra	Test
35	28	S	H.S. +	Job	None	Industry	Trigonometry	Test
36	32	S	H.S. +	Hobby	Family	On own	Trigonometry	Test
37	36	HM	H.S.	None	Family	Service	Trigonometry	Test
38	24	S	H.S. +	Service	None	Industry	Solid geometry	Test
39	36	HM	H.S. +	None	Family	Service	Solid geometry	Test
40	41	S	H.S. +	Hobby	None	Industry	Trigonometry	Instrument maintenance
41	36	S	A.A. +	None	None	Industry	Trigonometry	Test
42	21	UM	A.A. +	Teacher	None	Public school	Integral calculus	Research and development
43	47	S	A.A. +	None	None	Industry	Integral calculus	Research and development
44	44	S	A.A. +	Hobby	None	Industry	Differential calculus	Research and development
45	23	HM	H.S.	None	None	Industry	Algebra	Test
46	30	S	A.A.	None	None	Industry	Integral calculus	Research and development
47	48	S	A.A.	Service	None	Service	Trigonometry	Research and development
48	35	S	A.A. +	None	None	Industry	Trigonometry	Television and radio
49	31	S	A.A. +	None	Friend	Private school	Analytical geometry	Television and radio
50	27	HM	H.S.	Service	None	Industry	Less than algebra	Plant maintenance
51	24	S	A.A.	Service	None	Industry	Trigonometry	Test
52	35	UM	A.A. +	None	None	Private school	Beyond	Computer
53	37	S	A.A.	None	Family	Private school	Solid geometry	Plant maintenance
54	28	HM	A.A. +	Service	None	Service	Differential calculus	Test
55	42	S	H.S. +	Hobby	Teacher	Service	Less than algebra	Test
56	41	S	A.A.	Service	None	Private school	Integral calculus	Computer
57	32	HM	H.S. +	Hobby	Family	Service	Algebra	Test
58	35	S	A.A. +	None	None	Private school	Analytical geometry	Research and development
59	24	UM	H.S. +	Service	None	Industry	Integral calculus	Test
60	36	HM	A.A. +	Hobby	None	Industry	Trigonometry	Design draftsman
61	28	HM	A.A.	Job	None	Industry	Analytical geometry	Research and development
62	25	HM	A.A.	Hobby	Friend	On own	Algebra	Research and development

* Mobility: S = stable; UM = upwardly mobile; HM — horizontally mobile.

DATA FROM INTERVIEWS WITH TECHNICAL WORKERS—*Continued*

ID No.	Age	Mobility*	Education	Interest developed	Personal influence	Received training	Mathematics	Job classification
63..........	27	UM	A.A. +	Service	None	Public school	Beyond	Research and development
64..........	30	UM	A.A. +	Service	None	On own	Beyond	Research and development
65..........	23	UM	A.A. +	Service	None	Public school	Beyond	Research and development
66..........	28	UM	H.S. +	School	Teacher	Industry	Higher algebra	Test
67..........	30	HM	A.A. +	Hobby	None	On own	Analytical geometry	Test
68..........	28	UM	A.A. +	Service	None	Industry	Integral calculus	Research and development
69..........	41	S	H.S. +	Service	None	On own	Trigonometry	Research and development
70..........	45	S	A.A. +	Job	None	On own	Trignometry	Test
71..........	26	S	H.S. +	Hobby	Friend	Industry	Intermediate algebra	Research and development
72..........	30	S	A.A.	Service	None	Public school	Integral calculus	Design draftsman
73..........	32	S	A.A. +	School	Teacher	Industry	Trigonometry	Instrument maintenance
74..........	48	S	H.S. +	Hobby	Teacher	Industry	Trigonometry	Test
75..........	23	S	H.S. +	None	Family	Industry	Trigonometry	Test
76..........	29	UM	A.A. +	Hobby	None	Private school	Beyond	Research and development
77..........	29	HM	A.A.	Hobby	None	Private school	Trigonometry	Test
78..........	24	HM	A.A.	Service	None	Service	Trigonometry	Research and development
79..........	34	S	H.S. +	Service	None	Industry	Trigonometry	Test
80..........	34	S	H.S. +	Service	None	Industry	Trigonometry	Test
81..........	27	HM	H.S.	Service	None	Service	Trigonometry	Communications
82....	45	UM	A.A. +	Hobby	Friend	Service	Integral calculus	Communications
83..........	40	S	H.S. +	Hobby	Friend	Industry	Analytical geometry	Communications
84..........	40	S	A.A.	Hobby	Teacher	Industry	Trigonometry	Communications
85..........	44	S	H.S.	Job	None	Industry	Intermediate algebra	Test
86..........	42	S	A.A.	School	Friend	On own	Higher algebra	Test
87..........	30	S	A.A. +	Service	None	Public school	Integral calculus	Test
88..........	29	S	H.S.	Job	Family	Private school	Higher algebra	Instrument maintenance
89..........	23	HM	H.S.	Service	None	Industry	Algebra	Plant maintenance
90..........	30	S	A.A.	School	None	Industry	Analytical geometry	Research and development

* Mobility: S = stable; UM = upwardly mobile; HM = horizontally mobile.

TECHNICAL WORKERS INTERVIEW DATA CALCULATIONS

N = 90	Mean	Sum X	Sum X^2	Std. Dev.
Age	32.37	2.913	99,193	7.43
Mobility	1.72	155	335	.87
Education	3.72	335	1,351	1.08
Interest	1.44	130	298	1.11
Personal influence	.74	67	205	1.32
Training	3.52	317	1,321	1.51
Mathematics	8.38	754	7,004	2.77

CORRELATION OF INTERVIEW DATA

All Technical Workers

N = 90

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000						
Mobility	−.292*	1.000					
Formal education	.028	−.106	1.000				
Interest developed	.143	−.126	−.027	1.000			
Personal influence	.243†	−.189	−.121	.185	1.000		
Training received	−.057	−.195	.007	−.033	−.017	1.000	
Formal mathematics	−.094	−.146	.622*	−.084	−.215	−.023	1.000

Test
N = 32

Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics	
1.000	−.169	−.018	.431†	.425†	−.291	−.242	Age
	1.000	−.172	−.331	−.208	−.232	−.142	Mobility
		1.000	.153	−.100	−.013	.605*	Formal education
			1.000	.273	−.181	−.093	Interest developed
				1.000	−.219	−.154	Personal influence
					1.000	.068	Training received
						1.000	Formal mathematics

* = significant at 1%.
† = significant at 5%.

CORRELATION OF INTERVIEW DATA

PLANT MAINTENANCE

N = 3

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000						
Mobility	−.961	1.00					
Formal education	.961	−1.00	1.00				
Interest developed	−.961	1.00	−1.00	1.00			
Personal influence	.961	−1.00	1.00	−1.00	1.00		
Training received	−.961	1.00	−1.00	1.00	−1.00	1.00	
Formal mathematics	.817	−.445	.945	.945	.945	−.945	1.00

INSTRUMENT MAINTENANCE

N = 5

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000	.089	.064	−.066	.598	.802	.000
Mobility		1.000	.320	−.739	−.373	−.167	.646
Formal education			1.000	−.384	.537	.480	.620
Interest developed				1.000	.275	.123	−.953
Personal influence					1.000	.000	.000
Training received						1.000	.000
Formal mathematics							1.000

* = significant at 1%.
† = significant at 5%.

CORRELATION OF INTERVIEW DATA

RESEARCH AND DEVELOPMENT

N = 29

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000						
Mobility	−.449*	1.000					
Formal education	−.106	.176	1.000				
Interest developed	−.204	.215	−.262	1.000			
Personal influence	−.090	.038	−.316	.043	1.000		
Training received	.126	−.354	−.088	.069	.139	1.000	
Formal mathematics	−.199	−.014	.583*	−.253	−.509*	.099	1.000

COMMUNICATIONS
N = 8

Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics	
1.000	−.629	.088	.405	.825*	−.195	.367	Age
	1.000	.068	−.311	−.508	−.180	2.76	Mobility
		1.000	.218	−.224	.378	.465	Formal education
			1.000	.570	.577	.178	Interest developed
				1.000	−.066	.304	Personal influence
					1.000	.103	Training received
						1.000	Formal mathematics

* = significant at 1%.
† = significant at 5%.

CORRELATION OF INTERVIEW DATA

Computer
N = 3

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000						
Mobility	−.822	1.000					
Formal education	.082	.500	1.000				
Interest developed	−.082	−.500	1.0*	1.000			
Personal influence	.000	.000	.000	.000	1.000		
Training received	−.997†	.866	.000	.000	.000	1.000	
Formal mathematics	.082	.500	1.000	−1.000	.000	.000	1.000

Field Service
N = 3

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000	.327	.945†	−.189	.000	.189	.189
Mobility		1.000	.000	.866	.000	−.866	−.866
Formal education			1.000	−.500	.000	.500	.500
Interest developed				1.000	.000	−1.000	−1.000
Personal influence					1.000	.000	.000
Training received						1.000	1.000
Formal mathematics							1.000

* = significant at 1%.
† = significant at 5%.

CORRELATION OF INTERVIEW DATA

Radio and Television

N = _

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000						
Mobility	.000	1.000					
Formal education	−.149	.000	1.000				
Interest developed	.000	.000	.000	1.000			
Personal influence	−.111	.000	.249	.000	1.000		
Training received	.991*	.000	−.246	.000	−.046	1.000	
Formal mathematics	−.428	.000	.957*	.000	.298	−.510	1.000

Design Draftsman

N = 3

	Age	Mobility	Formal education	Interest developed	Personal influence	Training received	Formal mathematics
Age	1.000	.277	.891*	.000	.000	.996*	−.277
Mobility		1.000	−.189	.000	.000	.189	−1.000
Formal education			1.000	.000	.000	.929†	.189
Interest developed				1.000	.000	.000	.000
Personal influence					1.000	.000	.000
Training received						1.000	−.189
Formal mathematics							1.000

* = significant at 1%.
† = significant at 5%.

CORRELATIONS FOR RESULTANT Q-SORTS

	Instructors	Rec. order of instr.	Total Tech. worker	Computer	Communications	Design draftsman	T.V. and radio	Research and development	Instrument maintenance	Plant maintenance	Field service	Test
Test	.924	.717	.870	−.241	.549	.470	.443	.872	.648	.613	.466	1.00
Field service	.715	.633	.413	−.123	.028	.217	.392	.425	.336	.154	1.00	
Plant maintenance	.869	.825	.739	−.364	.676	.573	.296	.715	.526	1.00		
Instrument maintenance	.884	.749	.779	−.249	.636	.285	.299	.731	1.00			
Research and development	.960	.833	.993	−.115	.676	.640	.397	1.00				
Television and radio	.711	.584	.435	−.202	.217	.202	1.00					
Design draftsman	.837	.735	.676	−.470	.395	1.00						
Communications	.855	.761	.719	−.502	1.00							
Computer	.373	.191	−.225	1.00								
Total technical workers	.762	.523	1.00									
Rec. order of instructor	.619	1.00										
Instructors	1.00											

MEAN CORRELATIONS OF Q-SORT DATA BY JOB CLASSIFICATION

Job classification	N	Mean correlation
Research and development	29	.382
Test	32	.344
Communications	8	.384
Plant maintenance	5	.527
Radio and television	4	.637
Design draftsman	3	.547
Computer	3	.215
Field service	3	.587
Instrument maintenance	3	.590
Total	90	
Instructors	29	.528

DATA FROM INTERVIEWS WITH INSTRUCTORS

ID No.	Age	Mobility*	Education	Interest developed	Personal influence	Received training	Mathematics	Job classification
103	22	UM	B.A.	School	None	Service	Beyond	Research and development
106	42	S	H.S. +	None	None	None	Differential calculus	Plant maintenance
121	32	HM	A.A. +	Service	Teacher	Service	Integral calculus	Electrician
123	29	S	A.A.	Service	None	Service	Differential calculus	Field service
125	32	S	M.A.	Hobby	Teacher	Public school	Integral calculus	Television and radio repair
127	46	S	M.A. +	Service	None	Service	Integral calculus	Instrument maintenance
128	40	HM	A.A.	Hobby	None	Service	Algebra	Television and radio repair
129	30	HM	A.A. +	Service	None	Service	Solid geometry	Research and development
130	40	UM	A.A. +	None	Family	Service	Differential calculus	Television and radio repair
131	40	UM	B.A.	None	None	Service	Analytical geometry	Television and radio repair
132	56	S	A.A.	None	Teacher	Public school	Trigonometry	Plant maintenance
133	32	UM	B.A.	Friend	Teacher	Public school	Differential calculus	Test
134	33	UM	M.A.	Hobby	Teacher	Service	Analytical geometry	Television and radio repair
135	27	S	H.S.	None	Family	Public school	Differential calculus	Field service
137	34	HM	B.A.	None	None	Service	Integral calculus	Electrician
138	37	UM	B.A.	Hobby	Friend	Service	Differential calculus	Television and radio repair
139	49	S	M.A. +	Hobby	None	Service	Integral calculus	Electrician
140	27	HM	B.A.	School	None	Public school	Differential calculus	Research and development
141	50	S	M.A.	Hobby	None	On own	Differential calculus	Electrician
142	54	HM	B.A.	Hobby	None	Public school	Integral calculus	Television and radio repair
143	32	HM	A.A. +	Service	None	Service	Integral calculus	Television and radio repair
144	59	S	M.A.	Hobby	Friend	On own	Integral calculus	Television and radio repair
145	46	HM	B.A.	None	None	Industry	Analytical geometry	Computer
146	53	UM	B.A.	Family	Teacher	Public school	Integral calculus	Television and radio repair
147	28	HM	A.A.	Hobby	Teacher	Industry	Trigonometry	Communications
148	51	S	B.A.	Hobby	None	Service	Integral calculus	Field service
149	29	HM	A.A.	None	Friend	Service	Analytical geometry	Television and radio repair
150	33	S	H.S. +	None	None	Service	Trigonometry	Communications

* Mobility: S = stable; UM = upwardly mobile; HM = horizontally mobile.

INSTRUCTOR INTERVIEW DATA CALCULATIONS

N = 29	Mean	Sum X	Sum X^2	Std. dev.
Age	38.90	1,128	46,772	10.17
Mobility	2.00	58	138	.88
Education	5.45	158	920	1.45
Interest	1.31	38	84	1.11
Personal influence	1.21	35	113	1.59
Training	2.34	68	188	1.01
Mathematics	9.72	282	2,838	1.85

DATA ON STUDENTS IN BAKERSFIELD STUDY

ID	Group*	Scat-V	Scat-Q	Scat-T	Age	Yrs. H.S. math	Avg. H.S. grade	Pre	Post
9	1	293	310	300	19	4	B	52	59
63	3	279	294	286	19	3	C	48	53
93	3	281	319	298	19	3	C	47	53
64	3	287	291	289	21	2	C	40	40
10	1	293	308	299	19	3	B	56	60
92	1	293	316	303	20	4	C	58	62
5	1	299	316	306	19	2	C	58	69
8	1	308	311	309	19	2	C	25	38
17	1	286	296	290	20	2	B	45	54
2	1	286	321	301	19	4	B	56	71
4	1	286	316	299	25	1	C	46	55
1	1	298	327	309	19	4	C	59	59
21	1	269	288	280	19	1	C	41	44
16	1	292	307	298	19	3	C	46	60
33	1	295	310	301	19	2	C	40	49
28	1	286	317	299	23	1	C	49	67
34	1	288	308	297	19	2	D	40	40
18	1	277	296	286	20	3	C	44	53
13	1	298	305	301	20	2	B	41	43
23	1	298	283	291	19	1	D	34	48
22	1	286	284	285	19	1	B	31	24
26	1	292	323	304	19	1	C	49	52
7	1	286	313	297	20	3	C	51	58
16	1	286	297	291	19	2	C	41	46
14	1	277	300	289	19	2	C	47	46
3	1	317	319	319	19	3	C	60	64
44	1	292	294	293	23	2	C	26	31
19	1	277	288	283	20	1	B	36	45
20	1	260	292	280	21	1	C	27	44
75	3	292	308	299	18	3	C	44	67
62	3	284	297	290	19	4	C	46	60
71	3	295	316	304	19	2	C	39	58
74	3	266	310	289	19	1	D	48	49
12	1	294	307	299	19	2	C	32	37
54	3	279	307	292	23	2	C	51	49
70	3	283	316	297	19	3	B	56	57

* 1 = electronics majors in the control group.
3 = non-electronics majors in the control group.

DATA ON STUDENTS IN BAKERSFIELD STUDY

ID	Group*	Scat-V	Scat-Q	Scat-T	Age	Yrs. H.S. math	Avg. H.S. grade	Pre	Post	% Comp.
46	2	279	289	284	18	3	C	38	48	46
90	4	292	317	303	21	2	C	37	50	61
94	4	303	292	299	20	3	C	48	64	63
91	4	286	281	284	20	2	C	28	43	56
89	4	251	289	275	22	4	B	47	48	43
38	2	263	305	286	19	1	D	34	40	47
47	2	263	305	286	18	3	C	45	49	74
25	2	284	330	303	19	3	C	57	66	47
43	2	260	296	281	19	1	C	33	35	36
41	2	290	299	294	25	2	B	27	35	86
30	2	294	314	303	19	4	C	59	68	67
48	2	302	268	289	19	1	C	32	33	68
29	2	301	317	308	19	4	C	54	57	77
36	2	286	302	293	20	4	C	42	55	67
37	2	271	305	289	19	3	C	40	52	55
31	2	287	314	299	19	4	C	52	64	93
40	2	303	299	301	19	2	C	50	61	80
52	4	290	311	299	19	3	C	46	52	62
56	4	296	304	299	20	1	C	42	51	77
83	4	295	244	295	19	3	C	51	57	46
81	4	277	299	288	19	3	D	38	49	72
59	4	254	302	283	19	1	C	38	42	88
53	4	271	310	291	19	2	C	39	49	83
61	4	269	299	285	19	2	D	60	57	79
65	4	286	290	286	22	1	B	44	53	47
84	4	284	291	287	21	4	C	31	44	61
73	4	271	310	291	19	1	C	27	32	67
78	4	281	302	291	19	2	D	29	42	54

* 2 = electronic majors in the experimental group.
4 = non-electronics majors in the experimental group.

SPLIT-HALVES CORRELATION ON MATHEMATICAL PRE-TEST

Odds		Evens	
$\sum X =$	1401	$\sum Y =$	1456
$N =$	66	$N =$	66
$\sum X^2 =$	31,179	$\sum Y^2 =$	33,994
$M_x =$	21.33	$M_y =$	22.06
$\sigma_x =$	$\sqrt{28.42}$	$\sigma_y =$	$\sqrt{21.82}$
$\sum XY =$	32,260		

$$r = \frac{\frac{\sum XY}{N} - M_x M_y}{\sigma_x \sigma_y} = .824^{xxx}$$

KRUSKAL-WALLIS (H) ONE-WAY ANALYSIS OF VARIANCE
(For Student Groups in Bakersfield Study)

Categories	H	Degrees of freedom
Control group compared with experimental group on SCAT verbal scores	1.79	1
Control group compared with experimental group on SCAT quantitative scores	2.53	1
Control group compared with experimental group on SCAT total score	2.02	1
Control group compared with experimental group on high school grade points earned in mathematics	.14	1
Control group compared with experimental group on pre-test scores	1.68	1
Control group compared with experimental group on gain in mathematics achievement	.83	1
Control electronics majors, control non-electronics majors, experimental electronics majors, and experimental non-electronics majors compared on gain in mathematics achievement	1.18	3
Electronics majors compared with non-electronics majors on gain in mathematics achievement	.26	1
Electronics majors compared with non-electronics majors on SCAT total	2.45	1
Electronics majors compared with non-electronics majors on pre-test scores	.27	1

COMPARING THE DIFFERENCE OF THE MEAN FOR TOTAL STUDENT GROUP ON PRE-AND POST-TEST

t-test	t=4.31 (Significant of 1%)

SPLIT-HALVES CORRELATION ON MATHEMATICAL PRE-TEST

Odds		Evens	
$\sum X =$	1401	$\sum Y =$	1456
$N =$	66	$N =$	66
$\sum X^2 =$	31,179	$\sum Y^2 =$	33,994
$M_x =$	21.33	$M_y =$	22.06
$\sigma_x =$	$\sqrt{28.42}$	$\sigma_y =$	$\sqrt{21.82}$
$\sum XY =$	32,260		

$$r = \frac{\frac{\sum XY}{N} - M_x M_y}{\sigma_x \sigma_y} = .824^{xxx}$$

KRUSKAL-WALLIS (H) ONE-WAY ANALYSIS OF VARIANCE
(For Student Groups in Bakersfield Study)

Categories	H	Degrees of freedom
Control group compared with experimental group on SCAT verbal scores	1.79	1
Control group compared with experimental group on SCAT quantitative scores	2.53	1
Control group compared with experimental group on SCAT total score	2.02	1
Control group compared with experimental group on high school grade points earned in mathematics	.14	1
Control group compared with experimental group on pre-test scores	1.68	1
Control group compared with experimental group on gain in mathematics achievement	.83	1
Control electronics majors, control non-electronics majors, experimental electronics majors, and experimental non-electronics majors compared on gain in mathematics achievement	1.18	3
Electronics majors compared with non-electronics majors on gain in mathematics achievement	.26	1
Electronics majors compared with non-electronics majors on SCAT total	2.45	1
Electronics majors compared with non-electronics majors on pre-test scores	.27	1

COMPARING THE DIFFERENCE OF THE MEAN FOR TOTAL STUDENT GROUP ON PRE-AND POST-TEST

t-test	$t=4.31$ (Significant of 1%)