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AN ANALYSIS OF THE EFFECTIVENESS OF
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An analysis of the effectiveness of alternative
systems approaches and instructional methods
for teaching the metric system

by

Wan-Lee Cheng

A Dissertation Submitted to the
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CHAPTER I. INTRODUCTION

A measurement system is a communication tool; a language which people in business, industry, and everyday life use to communicate with one another. In earliest times, men simply arrived at a mutual understanding and settlement of a change of commodities. As human civilization evolved, a much more complex society required an improved measurement system of units. People no longer lived, worked, and traded in a restrictive geographical area. The simple methods for exchanging information were not sufficient for multiple daily activities and complicated human relations. This complexity of information exchange necessitated a unified and workable measurement system or one that could be easily translated. Towns, states, and finally the entire nation adopted identical systems to exchange, measure, and describe the things they encountered.

As modern transportation rapidly developed, closer international relations were no longer part of an imagined future. For many reasons — travel, business, trade, friendship, etc., — people needed to communicate with other people in the world. It became necessary to establish a global standard for better and fairer correspondence among human beings. The English and the European metric units constituted the two principle measuring systems used in the world prior to the decade of the sixties. However, people who were accustomed to other systems felt that it was not necessary to suffer the inconvenience of

adapting to several different systems. The International Standards Organization was established to solve this problem. A consortium of more than 50 countries of the world comprised and developed an international and universal standard termed the SI (System Internationale) metric system. To date (1976), only about ten countries have not adopted this system.

The United States is one of these ten countries, but it is the only major industrial country among them. Calvin Grieder has pointed out that "The U.S. is the only major country still clinging to the English system, along with half a dozen small nations" (1971, p. 26). Many difficulties in such areas as business, importing-exporting, industrial skills exchange, and cultural communication have been encountered in the world market because of the different measuring units. With the change-over of the three major English system partners — Great Britain, Canada, and Australia — from their original units to the international standards, more and more Americans have become aware that it is time for this country to change to the metric system as well. Grieder (1971) also stated that:

In an era when the growing interdependence of nations and peoples is unquestioned, the retention of the English system means simply cutting ourselves off from the rest of the world, particularly, in science, technology, and commerce. (p. 26)

Many sources indicate that the United States will be unable to resist this worldwide floodtide of change to the metric system. Sooner or later the metric system must be used in this society. The experiences of other countries indicate that proper planning and early introduction of the new system substantially reduce the frustration and pain of the transition period. F. Lincoln Rolphs, an educator and chairman of the British metrication board, found that a short period of transition and early decision making would be better for the new generation and the entire society. Rolphs (1971) said:

It may well be that the old imperial units will linger, but it is surely obvious that the longer the period of transition, the more expensive and confusing the change will be An early decision and an early date would be of advantage to the rising generation which will have to bear quite enough of the heavy burden of our legacy. (p. 4)

Many large industrial firms have been adopting the metric system for their products and giving metric training to their employees. The American National Standards Institute has also recognized the need for early planning to shift to the metric system and has formed the American National Metric Council to assist in initiating the new system.

Of course, people in the teaching profession play a most important role in conveying new knowledge. The success of

metric education of the next generation, the community, and even the whole nation depends to a great extent on the inclusion of proper instructional strategies and approaches for conveying metric concepts. Many suggestions have been made by educators in different fields. In the transition from the English measurement, education would play an important role to help people learn and adopt the use of the SI metric system. To do this, many instructional materials will have to be developed and those already developed must be recognized. Many instructional materials have already been developed for teaching and training purposes. Two resources with wide field distribution are the Metric Manual by J. J. Keller and Associates, Inc. and the packages produced by the Center for Metric Education at Western Michigan University. However, no research conclusions on an effective way for teaching the new metric system have been reached. It is essential to discover and communicate to educators the research findings relative to the most suitable instructional methods and systems approach for introducing metric instruction.

The ensuing study was concerned with two systems approaches for conveying metric content, the direct approach and the conversion approach. In addition, it examined two alternative sensory-based instructional methods: (1) the visual learning PAC, and (2) the audile learning PAC. The experimental data analyzed through statistical inference procedures in

the final phases of this study were used to test hypotheses regarding the suitability of system approaches and instructional methods for presenting metric content.

Statement of Problem

Previous investigative research directed toward the implementation of the metric system in education led the researcher to the statement of the problem for this study.

The problem of this study was to determine the effectiveness of two selected systems approaches and two sensory-based instructional methods for introducing the metric system to students enrolled in the courses of Industrial Education Curriculum.

Statement of Purpose

The purpose of this study was to provide direction to teacher-educators regarding systems and methods for introducing metric content. The specific purposes which encouraged the initiation of this study were the following:

1. To enable teacher-educators to better understand systems approaches for presenting metric concepts.
2. To assist teacher-educators in the selection of appropriate sensory-based instructional methods for presenting metric content to the student.
3. To provide supportive research data regarding the more effective strategy for implementing metrication in this country.

Need for the Study

The time is right for Americans to evaluate approaches and methods for introducing metrics in the classroom. Although the Metric Conversion Act of 1975 which has been signed into law is a relatively weak bill, business, education, industry, and the general public throughout the nation have begun to adopt the conversion process. The American National Standards Institute formed the American National Metric Council in 1973 to provide a focus for assisting and serving the needs of various sectors of society in converting to the metric system of measurement. Also, a 17-member United States Metric Board will soon be established to coordinate the voluntary conversion to the metric system. More and more companies and manufacturers, such as the General Motors Corporation, Eastman Kodak Company, International Business Machines Corporation, the Coca Cola Company, John Deere and Company, and numerous others, have converted product specifications to metric standards. Consumer goods are also gradually being labeled in dual measures. Weather forecasts of some broadcasting and television stations have begun to use both Celsius and Fahrenheit temperature systems. Many schools from elementary to college levels have added the content of metric measurements to their curricula. All available evidence from business, industry, and education suggests that a change to the metric system of weights and measures will occur in this country rather rapidly.

Since this change appears to be inevitable, the only question remaining is how educators should introduce and convey the new system to the American society most effectively. The major responsibility for social, cultural, and technological change always tends to fall upon the educators. Preservice and inservice training of teachers, community awareness, and elementary and secondary instruction in metrics are all important factors in bringing about needed social changes. A successful transition to metrics fully depends on the effectiveness of instructional materials and strategies. Congressman Marvin L. Esch has said

Perhaps no other sector of society will feel the impact of metrication to the degree of the educational system. The pervasiveness of the change will effect students from kindergarten through the post-graduate level, as well as educators and parents. (1974, p. 55)

Since the necessity of converting to the metric system is not limited entirely to any single sector of society, the traditional work of mathematics teachers can not be expected to accomplish the entire task. All teachers and educational personnel should be involved in this changeover responsibility. John Izzi (1974), in his "Toll Gate Metrication Project," stated:

Although the teaching of measurement systems is traditionally the work of mathematics teachers, this

changeover must be effected by each teacher and school administrator regardless of his interest or area of specialty. (p. 73)

Many educators have become aware of the importance of introducing metric units to students. They have stated many opinions regarding the application of metric concepts or practices in different fields. These opinions have followed the gamut of topics from how to make the change to metrics, to how to utilize the original facility in teaching metrics. Many publishers and producers of instructional materials have rushed to satisfy the demand for metric teaching materials. However, there is little research data to indicate which instructional strategies or methods will be effective in presenting metric concepts. It seems that most educators are hurrying to introduce the metric system to their students without considering what instructional methods will produce superior results. Poor choices may result in counterproductive outcomes if improper presentation of the content causes the student to resist or be confused, thus creating many more problems.

Murphy and Polzin (1969), in "A Review of Research Studies on the Teaching of Metric System," emphasized the importance of research for teaching the metric system.

While the final decision in the metric controversy will not be made by educators, it is still their responsibility to understand the major trends and bring

their methods of teaching and the school curriculum into a closer relationship with the practical needs of society. One way to accomplish this is through research. (p. 267)

They also pointed out that "Research studies in the area of measurement and the metric system are few" (p. 270).

The implementation of metrics in America should follow sound educational research. Since studies dealing with this new area are scarce, it becomes increasingly apparent that investigative research providing data on system approaches and instructional strategies must be given serious attention by scholars.

Statement of Hypotheses

Four factors were included in this study: the systems approaches for presenting metric concepts; the sensory-based instructional methods for presenting metric content; alternative test sequences; and the two Test Trials.

1. Research hypothesis

It was hypothesized that there would not be a significant difference in the posttest scores among students studying metrics through the direct approach, and those studying metrics through a conversion approach.

Statistical hypothesis

$$H_0: \mu_D = \mu_C = \mu_T$$

$$H_A: \mu_D \neq \mu_C \neq \mu_T$$

Level of significance 0.05

μ_D = the mean of posttest scores of the direct approach group.

μ_C = the mean of posttest scores of the conversion method group.

μ_T = the mean of posttest scores of the control group.

2. Research hypothesis

It was hypothesized that there would not be a significant difference in the posttest scores among the students encountering metrics via the visual learning PAC and the audile learning PAC.

Statistical hypothesis

$$H_0: \mu_V = \mu_A$$

$$H_A: \mu_V \neq \mu_A$$

Level of significance 0.05

μ_V = the mean of scores of the visual learning PAC group.

μ_A = the mean of scores of the audile learning PAC instruction group.

Grade level, age, major, option, high school rank, high school size, ACT test score, and interaction between four experimental factors were variables to be observed and introduced

into the statistical model if any effects were evident.

Statement of Assumptions

The following assumptions were made in designing the format of this study:

1. The samples drawn in this study were representative of the students taking courses in the Department of Industrial Education at Iowa State University.
2. The posttest which was conducted was a valid measure of the metric content comprehension ability for the population under study.
3. The contents of the metric concepts presented were the same for the samples under study.
4. There was no test by treatment interaction.
5. Extraneous variables were considered by the researcher. Internal invalidity such as history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, or selection — maturation interaction — to effect the experiment would have minimal, if any, influence.
6. The Hawthorne effect, if existent, was equally distributed among all the samples.
7. The implications of this study would be generalized to college students and high school students.

Limitations of the Study

The study was conducted in view of the following limitations:

1. Only students taking courses in the Department of Industrial Education at Iowa State University were included in the population under study.
2. Only basic concepts and content of the metric measurement system were introduced to the subjects in this study.

3. The source for drawing random samples was limited to the students enrolled in:
 - a. Industrial Education 124, Introduction to Graphic Communications;
 - b. Industrial Education 130X, Introduction to Materials and Processes;
 - c. Industrial Education 224, Technical Graphics;
 - d. Industrial Education 253B, Electricity II;
 - e. Industrial Education 323, Reprographics;
 - f. Industrial Education 324, Architectural Drafting and Design for Industrial Education Teachers;
 - g. Industrial Education 357, Electronics I; and
 - h. Industrial Education 490D, Independent Study in Industrial Education, during the Winter Quarter, 1976.
4. Test Form A was generated by Dr. Evan E. McFee. The validity and the reliability of the test have been examined.
5. Test Form B was generated by the researcher himself with carefully matching of similar concepts by item from Test Form A.
6. All the treatments were conducted with the sample groups outside the regular class period. The work for those samples was considered part of their course requirement.
7. Due to varied reading speeds, the time of treatment for visual and audile methods could not be specified.

Procedure of the Study

This study utilized a four-dimensional factorial design involving the systems approaches, instructional methods for presenting metric content, alternative test sequences, and two test trials. The population of the study was comprised of

students taking courses in the Department of Industrial Education of the College of Education at Iowa State University.

Since every student enrolled in the industrial education curriculum must take I.Ed. 124, I.Ed. 130X, I.Ed. 224, I.Ed. 253, I.Ed. 323, and I.Ed. 357 as required courses for his or her B.S. degree, students in these courses were selected as a representative population of industrial education students. In addition, two elective courses I.Ed. 324, and I.Ed. 490D were also involved in the study. The simple random sampling method with a table of random numbers was used during the Winter Quarter of 1976 for drawing 120 individuals from among the students enrolled in those courses listed above. Because of the practical difficulty, the actual sampling was made by the following arrangement: (1) 80 students enrolled in I.Ed. 130X, I.Ed. 224, I.Ed. 323, and I.Ed. 357 were randomly drawn and assigned in 8 experiment cells; and (2) 40 students enrolled in I.Ed. 124, I.Ed. 253, I.Ed. 323, and I.Ed. 490D were randomly drawn and assigned in 4 control cells. Due to the problem of student drop-out from those classes, further arrangements were made in order to form equally sized cells. Eight observations were finally randomly picked from each cell originally containing 10 sampling students. The eight treatment-cells and the four control-cells used in this study were characterized as follows:

1. direct approach, visual learning PAC, Form A - B group.
2. direct approach, visual learning PAC, Form B - A group.
3. direct approach, audile learning PAC, Form A - B group.
4. direct approach, audile learning PAC, Form B - A group.
5. conversion approach, visual learning PAC, Form A - B group.
6. conversion approach, visual learning PAC, Form B - A group.
7. conversion approach, audile learning PAC, Form A - B group.
8. conversion approach, audile learning PAC, Form B - A group.
9. control, first, Form A - B group.
10. control, first, Form B - A group.
11. control, second, Form A - B group.
12. control, second, Form B - A group.

Table 1 presents the three factor model design of the study. Upon adding the fourth factor -- test trial -- the four-dimensional model was then developed for testing the major hypotheses. The sixteen treatment-cells and eight control-cells used in this study were characterized as follows:

1. direct approach, visual learning PAC, Form A - B group, pretest.
2. direct approach, visual learning PAC, Form A - B group, posttest.
3. direct approach, visual learning PAC, Form B - A group, pretest.

Table 1. The design of the study, three-factor model

	Direct approach				Conversion approach	
	A - B group		B - A group		A - B group	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
	Test Form A	Test Form B	Test Form B	Test Form A	Test Form A	Test Form B
Visual learning PAC	8		8		8	
Audile learning PAC	8		8		8	
Total	16		16		16	

Table 2. The design of the study, four-factor model

	Direct approach				Conversion approach	
	A - B group		B - A group		A - B group	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
	Test Form A	Test Form B	Test Form B	Test Form A	Test Form A	Test Form B
Visual learning PAC	8	8	8	8	8	8
Audile learning PAC	8	8	8	8	8	8
Total	16	16	16	16	16	16

Conversion approach		Control group				Total
B - A group		A - B group		B - A group		
Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	
Test Form B	Test Form A	Test Form A	Test Form B	Test Form B	Test Form A	
8		8		8		48
8		8		8		48
16		16		16		96

Conversion approach		Control group				Total
B - A group		A - B group		B - A group		
Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	
Test Form B	Test Form A	Test Form A	Test Form B	Test Form B	Test Form A	
8	8	8	8	8	8	
8	8	8	8	8	8	
16	16	16	16	16	16	

4. direct approach, visual learning PAC, Form B - A group, posttest.
5. direct approach, audile learning PAC, Form A - B group, pretest.
6. direct approach, audile learning PAC, Form A - B group, posttest.
7. direct approach, audile learning PAC, Form B - A group, pretest.
8. direct approach, audile learning PAC, Form B - A group, posttest.
9. conversion approach, visual learning PAC, Form A - B group, pretest.
10. conversion approach, visual learning PAC, Form A - B group, posttest.
11. conversion approach, visual learning PAC, Form B - A group, pretest.
12. conversion approach, visual learning PAC, Form B - A group, posttest.
13. conversion approach, audile learning PAC, Form A - B group, pretest.
14. conversion approach, audile learning PAC, Form A - B group, posttest.
15. conversion approach, audile learning PAC, Form B - A group, pretest.
16. conversion approach, audile learning PAC, Form B - A group, posttest.
17. control, first, Form A - B group, pretest.
18. control, first, Form A - B group, posttest.
19. control, first, Form B - A group, pretest.
20. control, first, Form B - A group, posttest.
21. control, second, Form A - B group, pretest.
22. control, second, Form A - B group, posttest.

23. control, second, Form B - A group, pretest.

24. control, second, Form B - A group, posttest.

Table 2 presents the four factor model design of the study.

On the first day of the study, in the third week of Winter Quarter, all subjects were given a pretest of either Form A or Form B which included both metric content comprehension and metric problem-solving items. Then the subjects in the eight treatment cells received four designated treatments, respectively, according to the random grouping. The four control groups did not receive any form of treatment. Two metric units, including length, mass, volume, temperature, work, power and other quantities, were presented through two different instructional methods and two different systems of approach. After the Christmas holidays, in the sixth week of the quarter, students, except for those in the control groups, were given the necessary instruction to familiarize them with the learning environment. The two units were conducted in the seventh and eighth weeks through listening to prepared tapes, and viewing of slides, with each of the two different systems of approach. In the tenth week, all students were given a posttest which measured metric content comprehension and problem-solving ability and were asked to fill out a Personal Data sheet. In the thirteenth week of the quarter, students were given a

Nelson-Denny reading ability test which provided the researcher with their preferred learning style.

To insure that the pretest and posttest did not threaten the interval validity of the study, two test forms A and B were designed, validated and administered as equivalent forms of the test. Table 1 indicates how the subjects of the experimental and control groups were then randomly assigned to two different groups within the treatments. Students in one group, or group A - B, were given a pretest of Form A and a posttest of Form B; the other group, or group B - A, were given a pretest of Form B and a posttest of Form A.

The scores on the pretest were analyzed to ascertain whether or not there was any initial difference among the twelve cells. If there was a difference, the analysis of covariance for adjusted means was used. Scores on the posttest were then analyzed to test the appropriate hypothesis. Findings were shown through the statistical analysis of variance. Based on these findings, the final conclusions of the study were drawn.

Definitions of Terms

Terms used in this study are defined as follows:

SI Metric System The international system of measuring units, called SI for its basic name — Systeme International d'Unites — is a modernized version of the metric system established in 1960 (Metric Center, Western Michigan University).

Direct Approach A system of presenting the metric concepts in which only the metric system is introduced without using any other measuring system.

Conversion Method A system used for presenting metric concepts. Under this method, both the metric system and the English system are used for comparison and learning purposes.

Basic Concepts In this study, the basic concepts of metric measurement include units of length, mass/weight, time, temperature, volume, and speed; the decimal system of numeration; and metric prefixes and symbols.

Audile Learning PAC A learning packet of self-instructional materials, which may be recorded on open-reel tape, audio cassettes, etc. to be used by the individual learner as he/she seeks knowledge or develops skills through the sense of hearing.

Visual Learning PAC A learning packet of self-instructional materials which contains still projection such as slides, to be used by the student through the sense of sight at his/her own pace.

CHAPTER II. REVIEW OF LITERATURE

A review of the literature was conducted to trace the background of measurement identified for the study. Since there are three major subjects within this study, the review was written in the following sections: (1) the metric system, including an historical background of this measuring system, the system itself, the metric system and America, the advantages of the system, and the SI metric system itself; (2) the teaching of the metric system, its present status and possible systems approaches; and (3) sensory-based individualized instructional methods (the audile learning PAC and the visual learning PAC) were reviewed briefly.

The Metric System

Prior to 3000 B.C., ancient Babylon and Egypt had developed primitive systems of weights and measures, marking the beginning of man's use of uniform systems of measurement. The Greeks and Romans then contributed to those systems, and after the decline of the Roman empire, England and France became leaders and further improved measurement systems. Since much confusion and many inconveniences existed, both of these countries tried to single-handedly solve the problems, and in so doing, went in two different directions. France discarded entirely the existing measurement systems and substituted a new one, while England, on the other hand, gradually improved

the existing system. As a result, the two major measuring systems used in the world today were established. Because of its simplicity, scientific and logical nature, the so-called French system grew very fast and was widely adopted throughout the world during the 20th century. Today (1976), the metric measurement system which evolved from the French system is the basis for the vast majority of commercial dealings and industries.

Historical background of the metric measurement system

The metric measurement system begun in France is a system created by man with concern for scientific accuracy. In the U.S. Metric Study Tenth Interim Report: A History of the Metric System Controversy in the United States, the nature of the metric system is described:

The metric system presents an entirely different case from that of the customary system. As already noted, it did not evolve from ancient measures and practices to assume its ultimate configuration — it was created whole and put into use under unusual conditions and to serve very specific purposes. Furthermore it is based on what were, at the time of its creation, the most advanced scientific principles known. . . .

(Treat, 1971, p. 16)

The primitive concept of the metric system was created by Gabriel Mouton, its founder, in 1670. In the following one

hundred and twenty-five years (1795) this system was gradually improved upon, to be officially adopted in France. In 1798, nine additional nations adopted the metric system. Seventeen nations, primarily South American and European countries, joined the metric world in 1880, and through 1900, eighteen more countries officially accepted the metric measurement system. Today (1976), fewer than ten nations remain under the English system, since the rest of the world has adopted the metric system as a standard measurement system.

In A Metric Handbook for Teachers, Higgins (1974) listed historical steps leading toward metrication. These were adapted from materials published and copyrighted by the Agency for Instructional Television:

- 1670 Gabriel Mouton proposed a decimal system of weights and measures, defining its basic unit of length as a fraction of the length of a great circle of the earth.
- 1740 Preliminary calculations were made with a provisional form of a meter.
- 1790 A metric system of measurement was developed by the French Academy.
- 1795 France officially adopted a decimal system of measurement.
- 1798 A meeting was held in Paris to disseminate information about the metric system.

- 1799 The provisional meter and kilogram were replaced by newly established standards.
- 1840 France made use of the metric system compulsory.
- 1875 The "Treaty of Meter," setting up well-defined metric standards for length and mass, was signed in Paris by seventeen nations.
- 1880 Most of Europe and South America had gone metric.
- 1960 The meter was redefined in terms of a wavelength of light. The modernized metric system, the International System of Units (SI units) was established.
- 1965 Great Britain announced its intention to convert to the metric system. (p. 26-27)

In 1975, ten years after Great Britain successfully converted to the metric system, the remaining United Kingdom nations also began the process of converting to the metric system.

The metric system and America

The metric system actually is not new to the American people. Early in 1790, the U.S. Congress discussed the need for a uniform system of weights and measures. Then, in 1821, John Quincy Adams issued a document listing the advantages and disadvantages of both the English and metric systems. In the year 1866, legislation made the metric system lawful in the United States — "lawful throughout the U.S. to employ the

weights and measures of the metric system." Parker, Chalupsky and Crawford pointed out the historical relation between metrics and America to show that the term metric is not new in this country. Parker (1973) stated:

Use of the metric system has been legal in the United States since 1866. Even our customary measures are defined in terms of metric ones. An inch is no longer the length of three round, dry barleycorns, laid end to end (as an English king decreed in 1324 A.D.). An inch is exactly 25.4 millimeters. (p. 35)

Similarly, Chalupsky and Crawford (1975) wrote:

The U.S. Congress enacted a law in 1866 which made use of the metric system legal but not mandatory; in 1893 the Secretary of the Treasury issued an order to establish the international meter and kilogram as "fundamental" standards of length and mass for the U.S. (p. 262)

Although the metric system has not been adopted exclusively in this country, the metric movement has gained much backing and encouragement. In 1875 the United States was one of seventeen countries which participated in the "Treaty of the Meter" in Paris to establish the International Bureau of Weights and Measures with headquarters near Paris. In 1893 the units of meter and kilogram were declared as the national fundamental standards of length and mass. The units of the

English system were then based on fractions of the metric system. Afterwards, the adoption of the metric system in this country was argued, discussed, and studied with little or no advancement over a period of seventy-five years (Hallerberg, 1973, p. 250-252).

Treat (1971) in his U.S. Metric Study Tenth Interim Report summarized the historical movement of the metric system in the United States in five major periods: 1. the period of consolidation (1786-1866); 2. the educational movement (1886-1889); 3. the movement to introduce the metric system through government adoption (1890-1914); 4. the propaganda period (1914-1933); and 5. the comprehensive study phase (1934-1968) (p. 255-262).

The last ten years of the fifth period were the most significant for worldwide metric development. The United States also participated in this movement and increased the use of metric measurement in science, medicine, industry, education, etc. Hallerberg (1973) listed the major activities of recent metric development in the United States between the years of 1957 and 1968.

1. 1957 After the launching of the Soviet Union's first Sputnik, the scientists of the United States started to seriously consider the advantages of metric system in scientific research.

2. 1958 A standing Committee on Science and Astronautics which was given jurisdiction over standardization of weights and measures and the metric system was created by the U.S. House of Representatives.
3. 1959 The English standards were officially defined according to the metric units.
4. 1960 The United States participated in the Eleventh General Conference on Weights and Measures to redefine the meter and to set the Systeme International d'Unite's (SI) metric official system.
5. 1968 After Great Britain started her ten-year metrification plan in 1965, the U.S. Congress authorized the Secretary of Commerce to conduct a three-year U.S. Metric Study to determine the feasibility of converting to metrics in this country and to study the alternatives for national policy. (p. 253)

As a result of the three-year U.S. metric Study, the U.S. Senate passed the "Metric Conversion Act of 1972" (S. 2483) in August, 1972. This action resulted in the country's achieving a big step towards the metrification of America. Although the bill was defeated by the House of Representatives, all sectors of society were made aware that it was time for

Americans to think metric and to go metric. Due to the nationwide recognition of the importance of metric conversion, in December, 1975, Congress finally passed the "Metric Conversion Act of 1975" and the President signed the bill into law. Although the bill is relatively weak, relying solely on a voluntary conversion to the metric system, it is a good starting point for encouraging people in each sector of the society to begin to work and plan for conversion in the near future.

John L. Feirer (1976), Director of the Center for Metric Education, has pointed out future steps for the metric movement:

Since Congress has now given its blessing to "going metric" and the President has signed into law the Metric Conversion Act of 1975, the logical question to ask is, "Now that we have the act, when will we see the action?" (p. 13)

After a nearly two-hundred-year-battle, metric conversion is now a law.

The advantages of the metric system

One of the most sound reasons for changing to metric measurement is the many advantages of the metric system. In an article entitled It's Simple, Frances J. Parker clearly points out the complication and tediousness of the English system. She used the consumer as an example:

It is not easy to be an American consumer today.

Consider the ambiguity in sizes. One may mean a

size 7 shoe, a size 10 sock, a size 34 shirt, and a size tall suit — only some of which are related to measurement. We buy a 46-ounce can of vegetable juice, a 17-ounce can of vegetables, and 1 1/4-pound package of frozen vegetables. . . . In our present system there are 80 separate standards. Of course, we are all comfortable with our system and we all know how many square feet in an acre, how many acres make a square mile, and the number of quarts in a barrel — don't we? (Parker, 1973, p. 35)

On the other hand, much evidence indicates the positive results of adopting metric measurement, such as scientific development, industrial growth, world trade increase, etc. Armagnac states that western scientists have even credited the success of the first Russian satellite to orbit the earth as a result of the utilization of the metric system (Armagnac, 1969, p. 56).

The worldwide adoption of metric system is another point which indicates the better functioning of this measuring system. Since 1965, when the British announced their move to metrics, Australia, Canada and other commonwealth countries started a conversion plan. Ninety percent of all nations in the world are already either using or converting to the metric system. The whole world has been moving more and more towards the metric system, and no single nation has ever abandoned the

metric system after adopting it.

All the facts show the metric system to be a better system for measurement. Why is it better? The nature of the metric system reveals its superiority. The advantages of the metric system may be identified as follows:

1. The metric system is a logical, simple system of measurement with most of the standards based on natural phenomena. The conversion between units requires only the adjustment of the decimal point (Negus, 1973, p. iii).
2. The metric system was developed by man to fit the ten-base counting system (Ballew, 1973, p. 177).
3. There are very close relationships among all base units and derived units which make easy coordination for the entire system (Johnson et al., 1948, p. 12).
4. Since the prefixes used in the metric system give uniformity to names of all types of measures, it avoids the problem of memorizing many different names within a unit (Hallerberg, 1973, p. 255).
5. Since the metric system is a universal system, its adoption would enhance the country's position in science, industry, world trade, and improve the international communication (United States Senate, 1973, p. 4).

6. From an educational point of view, the metric system will simplify the teaching and learning of the measuring system by its very nature. The student will save time in calculations and gain a better understanding of the measurement concept (Robinson, 1971, p. 9).

These are but a few advantages of the metric system. Exclusive adoption would not only improve international communication but also reduce the barriers among different sectors of our own society. It seems that the success of using the metric system will make a better life possible for people in this country.

The SI metric system

The SI (Système International d'Unités) metric system was established by the General Conference on Weights and Measures in 1960. It was accepted by the International Organization for Standardization (ISO) (Chiswell and Grigg, 1971, p. 6).

There are three classes of SI metric units: 1. base units, 2. derived units, and 3. supplementary units. The base units were determined by their practical, independent and unique characteristics. Seven base units (the meter, the kilogram, the second, the ampere, the kelvin, the mole, and the candela) represent the most practical measurements of seven major physical quantities. The large or small measurements of

any physical quantity would be obtained through the prefix system. Both prefixes and base units have their own symbols. When different prefixes are combined with certain units, they form a new measurement given certain physical quantities. The seven base units and their definitions are listed in Table 3.

The derived units are units other than the seven base units and two supplementary units. They were derived from the base units and may either be given a special name or may be expressed in base units. Table 4 lists the most common derived units and their symbols.

The two supplementary units are radian, the unit of plane angle, and steradian, the unit of solid angle. Because these units have not been classified as either base units or derived units, they are assigned to the third class called supplementary units. Similar to base units, supplementary units can be used to form derived units. Table 5 gives the two supplementary units, their symbols and definitions.

The prefix approach is a unique characteristic of the metric system. The 11th General Conference in 1960 adopted names and symbols of prefixes for use in naming decimal multiples and submultiples of either basic or derived SI units, a scientific notation system based on powers of ten (LeMaraic & Ciaramella, 1973, p. 12). Generally, six prefixes for multiples and eight prefixes for the submultiples of base units are used, each of which has its own symbol to be used with any

Table 3. SI metric base units (LeMaraic & Ciaramella, 1973, p. 3-6)

Physical quantity	Base unit	Symbol	Definition
Length	Meter	m	The meter is the length equal to 1,650,763.73 wavelengths in vacuum of radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the Krypton ⁻⁸⁶ atom.
Mass	Kilogram	kg	The kilogram is the unit of mass equal to the mass of the international prototype of the kilogram. This is the only base unit with a prefix.
Time	Second	s	The second is the duration of 9,192,631,770 period of radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.
Electric current	Ampere	A	The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.

Table 3. Continued

Physical quantity	Base unit	Symbol	Definition
Thermodynamic temperature	Kelvin	k	The kelvin is the fraction $1/273.16$ of the thermodynamic temperature of the triple point of water.
Amount of substance	Mole	mol	The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.
Luminous intensity	Candela	cd	The candela is the luminous intensity, in the perpendicular direction, of a surface of $1/600,000$ square meter of a black body at the temperature of freezing platinum under a pressure of 101,325 newtons per square meter.

Table 4. SI metric derived units (LeMaraic & Ciaramella, 1973, p. 45)

Physical quantity	Derived unit	Symbol
Area	Square meter	m ²
Volume	Cubic meter	m ³
Frequency	Hertz	Hz (s ⁻¹)
Density	Kilogram per cubic meter	kg/m ³
Velocity	Meter per second	m/s
Angular velocity	Radian per second	rad/s
Acceleration	Meter per second squared	m/s ²
Angular acceleration	Radian per second squared	rad/s ²
Force	Newton	N (kg.m/s ²)
Pressure	Newton per square meter	N/m ²
Kinematic viscosity	Square meter per second	m ² /s
Dynamic viscosity	Newton-second per square meter	N.s/m ²
Work, energy, quantity of heat	Joule	J (N.m)
Power	Watt	W (J/s)
Electric charge	Coulomb	C (A.s)

Table 4. Continued

Physical quantity	Derived unit	Symbol
Voltage, potential difference, electromotive force	Volt	V (W/A)
Electric field strength	Volt per meter	V/m
Electric resistance	Ohm	Ω (V/A)
Electric capacitance	Farad	F (A.s/V)
Magnetic flux	Weber	Wb (V.S)
Inductance	Henry	H (V.s/A)
Magnetic flux density	Tesla	T (Wb/m ²)
Magnetic field strength	Ampere per meter	A/m
Magnetomotive force	Ampere	A
Luminous flux	Lumen	lm (cd.sr)
Illumination	Lux	lx (lm/m ²)
Wave number	1 per meter	m ⁻¹
Entropy	Joule per kelvin	J/K
Specific heat	Joule per kilogram kelvin	Jkg ⁻¹ K ⁻¹
Thermal conductivity	Watt per meter kelvin	Wm ⁻¹ K ⁻¹

Table 4. Continued

Physical quantity	Derived unit	Symbol
Radiant intensity	Watt per steradian	W/sr
Activity (of a radioactive source)	1 per second	s ⁻¹

Table 5. SI metric supplementary units (LeMaraic & Ciaramella, 1973, p. 11)

Physical quantity	Supplementary unit	Symbol	Definition
Plane angle	Radian	rad	The radian is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.
Solid angle	Steradian	sr	The steradian is the solid angle which, having its vertex in the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

symbol of the base unit to form a new measuring unit. Table 6 lists the multiple and submultiple prefixes used in SI metric system.

Table 6. SI prefixes (Randall, 1974, p. 69)

Prefix	Symbol	Value	Power of 10
tera	T	1,000,000,000,000 units	10^{12}
giga	G	1,000,000,000 units	10^9
mega	M	1,000,000 units	10^6
kilo	k	1,000 units	10^3
hecto	h	100 units	10^2
deka	da	10 units	10^1
	base unit	1 unit	10^0
deci	d	0.1 unit	10^{-1}
centi	c	0.01 unit	10^{-2}
milli	m	0.001 unit	10^{-3}
micro	μ	0.000001 unit	10^{-6}
nano	n	0.000000001 unit	10^{-9}
pico	p	0.000000000001 unit	10^{-12}
femto	f	0.000000000000001 unit	10^{-15}
atto	a	0.000000000000000001 unit	10^{-18}

Rules and regulations do exist for proper use of the SI metric system. However, the base units, derived units, supplementary units, symbols and prefixes supply the basic information for anyone who wishes to learn the SI metric system.

The Teaching of the Metric System

Although the metric system was not adopted as a major measuring unit in this country, metric measures have been taught in the mathematics and science curriculum for several decades. However, the concept and utilization of the metric system were not enough to build the competence of the student to become familiar with the international standards. Murphy and Polzin (1969) reviewed the research studies concurred with the teaching of metrics and found that:

1. Students in selected high schools in 1929 possessed an inadequate knowledge of the metric system and of the relationship between the metric and English units.
2. Thirty-four percent of the problems in three selected high school chemistry textbooks in 1930 were in metric units.
3. There is evidence of the metric controversy in many of the studies on teaching the metric system.
4. Recent research suggests that the metric system should be taught in the private and public schools at the grade-school level, and in so doing

de-emphasize the English system.

5. Elementary pupils and teachers, high school pupils, and college juniors selected for study have difficulty in appraising quantitative value.
6. Modern school mathematics instruction is often superior to traditional instruction in the area of measurement for selected seventh-grade pupils.
7. Research studies in the area of measurement and the metric system are few. All studies that the writers could find are reviewed in this article.

(p. 270)

Since successful metric education fully depends on the proper approach and method of teaching, it is very important to thoroughly study the most effective way to present metric concepts and content at all levels of instruction for students and adults, as pointed out in McFee's study. In summary, the review of literature revealed that education in metric principles is imperative and that present methods of instruction are inadequate. Therefore, a real need exists for investigation into the most efficient and effective methods for teaching metric concepts (McFee, 1967, p. 26).

The Preliminary Report of Metric Education also stated:

The motivational task is a large one. People must appreciate the need for change if they are to accept it. This requires a general effective change that

will not come automatically. That is the task of education, which also must provide the requisite cognitive knowledge and skill. (Snydam et al., 1974, p. 6)

After the U.S. Congress directed the Secretary of Commerce to make a three-year metric study in 1968, all sectors of the society started increasingly to plan or use the metric system of measurement. Because of the unique and important role that education must assume in this metric conversion process, the government, Congress, and educators have been aware that early starting and thorough planning were essential. The U.S. Commissioner of Education has been authorized to use \$10 million for each of the fiscal years prior to July 1, 1978, for grants and contracts to support metric education through educational agencies to prepare students and the public to learn the SI metric system (Chalupsky & Crawford, 1975, p. 263).

The involvement of education at the beginning of the changeover is very important, based on observations of the experiences of other countries. Evans (1974) stated:

[it] . . . suggests that the involvement of education after-the-fact of metrication is a mistake. Metrication which is introduced without education leads to opposition based on misunderstanding, precipitates learning by trial and error (some of the errors can be enormously expensive), and slows the introduction

of metric technology, because neither the work force nor consumers can use it effectively. (p. 90)

Through federal grants, many metric education programs have been developed, such as the Center for Metric Education and Studies at Western Michigan University, The Toll Gate Metrication Project at Warwick, Rhode Island, The Five-State Consortium on Metric Education, etc.

At the state level, metric education is also rapidly progressing. Most states have established some type of metric education program and in-service teacher training plans.

Chalupsky and Crawford (1975) report:

Metric progress is even more evident at the state level. According to a survey by Jeffrey Odom, Director of the Metric Information Office of National Bureau of Standards, 49 states had some type of formal metric education under way by mid-1974. Six states had enacted laws directing action in metric education, while 13 state boards of education had adopted "go metric" resolutions. (p. 263)

In the Preliminary Report of Metric Education, Snyder also pointed out that "In many states across the country, state departments of education and local educational agencies are already involved in metrication process" (Snyder, 1974, p. 53).

At the local level, many school districts have begun

preparations to teach the metric system and have planned various metric oriented activities. There are many new programs involving local schools in metric education. At Northwood Elementary School in Ames, Iowa, children are introduced to metric measurement in the second grade. By the sixth grade students are expected to be familiar with the basic concepts of the system. The junior high and high schools in Ames also emphasize the metric measurement in their mathematics and science courses. Other subject areas such as home economics introduce metric measurement with the dual markings of the metric recipes in class (Howard, 1975, p. 10).

The policy of continuously planning and developing a sound metric education program through the whole nation has been emphasized especially after the Metric Conversion Act became a law. John L. Feirer, Director of the Center for Metric Education, pointed out the educational aspect of the act:

For education, the act states ". . . that it is the policy of the United States to assist in the development of a broad educational program to be carried out in the nation's elementary and secondary schools and institutions of higher learning as well as with the public at large designed to enable all Americans to become familiar with the meaning and application of metric terms in daily life." (Feirer, 1976, p. 13)

Since education plays a vital role in the entire metric conversion process, educators should be aware of the major elements of education programs. Dieffenderfer (1974), in his *Metric Conversion as a Planning Problem*, clearly stated the following:

Carrying out United States conversion to the SI metric system will present a variety of unique training and educational problems for the public and private sectors of the economy as well as for individual citizens. In the field of education, these problems might include (1) how to develop appropriate curriculum materials, (2) the need for in-service and preservice teacher education to prepare teachers to teach SI metric related content, and (3) the development and organization of metric education programs for workers and trainees. (p. 84)

Vervoort (1973) agreed with this point of view, claiming "In preparation for that time, there is an immediate need for greater emphasis on teaching the metric system and consequent need for retaining teachers and revising the textbooks" (p. 276).

Feirer (1976) also stated the importance of teacher training and adequate instructional material development:

There must be an adequate and solid program of both pre- and in-service education to prepare teachers to

use the metric system There must be adequate instructional material written to proper standards. All forms of instructional materials including texts, films, filmstrips and other learning devices must be available and also must include an adequate amount of metric instruction. (p. 13)

Teacher training is one of the most important aspects of promoting a smooth changeover process. Both preservice and in-service teacher metric education depend upon the opportunities provided by teacher education institutions. The Interstate Consortium on Metric Education (ICME) Recommendation 13 urges:

. . . that state educational agencies encourage teacher-education institutions to begin immediately to include opportunities for students to develop competencies in using and teaching the metric system.

(Tradif, Hoffmann, & Lorenzen, 1975, p. 8)

Since the metric system is a relatively new concept and content for most people in this country, it is quite different when compared with other subject areas. In order to teach metric measurement efficiently, effectively, and successfully, the proper approach for conducting metric technology is the first thing that should be considered.

Although many educators have proposed approaches to teaching the metric system, all of them can be summarized into the

following two categories:

- (1) Direct approach - A system for presenting metric concepts, in which only the metric system is introduced, without using any other measuring system.
- (2) Conversion approach - A system for presenting metric concepts, in which both the metric system and the English system are used for comparison and learning purposes.

Most of the suggestions and judgments are based upon intuition and experience; very few were a result of scientific research. However, those ideas and opinions serve as preliminary references for the investigator of this study. Because of the lack of research evidence, Chalupsky and Crawford recommend that the future projects should seriously consider studying effective teaching strategies.

To date, experienced participants have judged the effectiveness of metric teaching strategies. Their judgments are based on consensus and are plausible. However, we need experimentally validated evidence that fulfills the canons of behavioral science.

(Chalupsky & Crawford, 1975, p. 264-5)

The majority of educators suggested the direct method as the most viable teaching approach, while others thought the conversion approach was needed. Odom (1972) strongly objects to conversion techniques while the system is being learned.

It is best if both students and teachers learn to use metric units by measuring familiar things in metric units only. I would warn against a general attempt to teach metric equivalents and conversion factors from customary to metric and vice versa. (p. 19)

Higgins concurs with Odom on the direct approach, suggesting "Teach the metric system by itself so that teachers and pupils learn to think in this language of measure." He also stated:

Do not try to learn or teach the metric system through conversion problems, and do not try to learn conversion factors. Learn the metric system by itself. Think metric. (1974, p. 70)

In testimony before the House Committee on Science Astronautics, Macek stated his belief that conversion as an approach to teach metric system would not be effective. He felt that learning through conversion would be only little more than a waste of time (U.S. House Committee on Science and Astronautics, 1966, p. 64). Pray also strongly objects to conversion from the metric to the English system, believing conversion should be entirely eliminated (1961, p. 180). Furthermore, Izzi feels conversion might cause the learner to lose interest in the metric system (1973, p. 27), while Bright and Jones point out the approach most often used was the conversion method, which promoted confusion and dislike by the learners

(Bright & Jones, 1973, p. 16).

In Chalupsky and Crawford's (1974) opinion of the conversion approach:

Dissatisfaction with training emphasizing conversion between English and metric measures is generally reported. Most instructors feel that teaching conversion equivalences between English and metric measures presents unnecessary difficulties. (p. 53)

Chalupsky and Crawford base their opinions on the results of experiments conducted in Western Australia, thus proving the direct approach to be the superior teaching method of the metric system (p. 53).

A similar opinion is held by Baillargeon, who through his study of other metric-converting countries' experiences pointed out conversion was a waste of time. From his viewpoint, it was much better to learn the metric system directly (Baillargeon, 1974, 83).

Moreover, Connelly and Smith believe the conversion between two systems would destroy the simplicity of the metric system. The metric system should be approached as a separate and distinct system of measurement. They used learning a new language as an example pointing out that translating effects progress (Connelly & Smith, 1975, p. 491). Freeman agrees with the direct approach as the best way to learn metric system, also using language learning as his example:

To use a language with facility a person must think in that language. An English-speaking person can use French with facility only if he thinks in French; he is less fluent if he thinks in English and has to translate. In the same way, to use metric easily one must think metric. (Freeman, 1975, p. 378)

Hawkins (1973) clearly states two important points in teaching metrics:

1. The metric system should be taught as a primary language.
2. Conversion manipulation should not be used at all. (p. 393)

In the final report of Interstate Consortium on Metric Education (ICME) it was recommended that the conversion process between metric and English systems should be avoided (Tradif, Hoffmann, & Lorenzen, 1975, p. 7).

In Canada, the findings of an experimental study at the University of Alberta by Reese and Cathcart concluded:

The most efficient way for us to help our students to "think metric" is to immerse them in the metric system and avoid, in as far as possible, any reference to the British system of measurement. This experiment indicates that when people are faced with both systems they concentrate on the one they are familiar with and ignore the other. Conversely, when

forced to measure themselves in the metric system only, they think in terms of the metric units. (1974, p. 31)

On the other hand, some experts believe that the proper conversion approach would facilitate learning, especially for the learner who has already lived and worked under the English system. In the yearbook of the National Council of Teachers of Mathematics, it was suggested that approximate conversions can be made for those people who already know both the metric and English systems (Johnson, 1948, p. 368).

As opposed to the views of Connelly, Smith, Freeman and others, Bright (1973) believes that metric and English systems should be like two languages for people, so that every one should be familiar with both measuring systems. For him, rule-of-thumb conversions would be the proper approach:

Merely being able to solve problems in one or the other of the systems is not enough to develop bilingualism. The metric and English systems should be related to each other. The proper approach to this is through rule-of-thumb conversions; exact conversions should be avoided. (p. 398)

Baillargeon agreed with the proper conversion approach, which means the use of both metric and English systems for comparison and learning purposes but not arithmetic conversion from one to the other. He said "It is logical to make comparisons between the old and the new, but the process of converting

arithmatically will not lead to facility with metric" (1975, p. 48).

Before the entire nation goes to metric, it would be good to teach students the metric system with some English measuring references. From the observation of a part of the Toll Gate Education Complex experiment, a teacher of 11 fourth-year students at Drum Rock School thought "My initial emphasis is on teaching the fundamental metric units by stressing comparison rather than conversion." She also noted:

Instead of making children memorize conversion tables, I explain that a meter is a little longer than a yard and that a centimeter is about the width of a paper clip. ("Students learn to live," 1974, p. 25)

Catlett stated that proper conversion references would help people in this stage, in which the English system is still regularly used by the society. He used the dual-dimensioning approach drawing in present industry as an example.

To aid in conversion, some industries are producing drawings in metric, with a list of customary equivalents boxed somewhere on the drawing. This encourages use of metric terms without eliminating a point of reference. Until full conversion occurs, people are going to need this point of reference, or they might get lost. (Catlett, 1974, p. 92)

Research into the teaching of the metric system to 7th grade science students was the subject of Evan McFee's doctoral dissertation. The two methodologies he tested were metric plus conversion and metric only. He found that:

The teaching of conversion techniques does not inhibit the ability of students to perform tasks in metric measures. Students instructed in metric measures plus conversion and students instructed in metric measures without conversion demonstrated the same improvement in ability to perform tasks in the metric system.

(McFee, 1967, p. 78)

In the area of metric education, research concerned with teaching approaches is very limited. Although most metric educators favor the direct approach as a result of their experiences and deductions, it is essential to back experience and deduction with research evidence.

Sensory-based Individualized Instructional Methods

Although the Metric Conversion Act of 1975 has been signed into law, the bill only provides a voluntary base for this nation to convert to metrics. Feirer (1976) explains, This is a relatively weak bill in that it contains no mandate to convert to metrics, and no timetable (not the ten-year period most metric proponents would like to have). While there will be a United States

Metric Board, it will have no power to require any group or sector of the economy to convert to metrics.

(p. 13)

In the near future, it will not be easy to establish any formal metric program in teacher education institutions. Coupled with the relatively weak metric conversion bill, the lack of metric educators, standardized instructional materials, general recognition by higher administrations, etc., cause further difficulty in establishing metrics as an integral part of the educational program. Evans clearly pointed out this problem, and predicts:

- a. Some of these institutions will require at least a generation to establish metrics as an integral part of their educational program, and
- b. Metrication will be seen by historians as just one of a long series of technological changes which have affected schools. (1974, p. 100)

As a result of these circumstances, instructional methods which would fit smoothly into the existing curriculum need to be developed. Individualized instruction is one alternative to infuse metric content without interfering with existing programs for both preservice and in-service teacher training. By the nature of metric technology, individualized instruction is also the best method for the various levels and different backgrounds of individuals to learn metrics.

Mason pointed out that individual differences would have a big effect on learning metrics:

Many surveys showed that acceptance of metric measures decreased with age, lack of education, and lower social status. Women were markedly more antagonistic to metric measures than the men surveyed. (1975, p. 7)

Individualized instruction can solve previous difficulties because, through the individualized learning PAC, (1) all learning will take place with the learner, (2) each person learns at a different rate and pursues his/her own interests, and (3) the sequential nature of the metric system can be learned more effectively.

White's (1972) views of individualized instruction follows:

Individualized instruction means that the student has been matched to an instructional system such that he is working at his own speed, learning style, and ability level on appropriate materials in keeping with his goals, supported by adequate assistance in a suitable learning environment. (p. 394)

Many types of individualized instruction approaches have been developed, including programmed instruction, visual learning PAC, audile learning PAC, computer assisted instruction, etc. For economic and practical purposes, visual learning PAC through slides and audile learning PAC through cassette tape

are preferable methods. Many teachers indicated either slides or cassette tape offered endless opportunities for learning.

Brown, Lewis, & Harcleroad (1973) stated the advantages of using slides as a learning medium:

The flexibility of arrangement of 2-by-2-inch slides is a principal teaching advantage. You may tailor (and update) slide sets simply by adding a slide here or dropping one there. (p. 165)

They also pointed out the convenience of using slides. Since the portable viewer has been made available, slides can be shown almost anywhere and in any limited space (Brown et al., 1973, p. 165). Lewis (1976) agreed with these observations on the advantages of slides:

Slides offer great flexibility in use. The order can be changed, new slides added, and others removed with very little trouble The variety of easy ways to produce slides makes them a creative and effective communications medium. (p. 27)

The use of audio-tape as a learning medium has much evidence to show its success. Milne (1973) reported the findings of the Dial Access Retrieval System (DARS) project, "In all cases, audio learning was deemed as an essential ingredient in increasing student learning" (p. 11). Nordland and others found in their research that students in the audio-tutorial instruction method achieved higher means than did

those in group classroom instruction (1975, p. 283).

Since learning is communication, and the sense of seeing and the sense of hearing are two major functions of communication, the use of slides or tapes can provide suitable and convenient learning environments for effectively carrying out the learning experience.

CHAPTER III. METHODS OF PROCEDURE

One of the purposes of this study was to provide research information to teacher educators regarding systems approaches and methods for introducing metric concepts and content.

Two systems approaches for presenting metric concepts, the direct approach and the conversion approach, were utilized. Two sensory-based instructional methods were introduced to the student for presenting metric content, the visual learning PAC and the audile learning PAC.

This chapter presents the instrumentation and procedure used in the study. The chapter is divided into seven sections: (1) the subjects, (2) the design of the experiment, (3) the experimental treatments, (4) the preparation of materials for the experimental groups, (5) the instruments, (6) the data collection procedure, and (7) the method of statistical analysis.

Subjects

Students participating in this study were selected from those individuals enrolled in undergraduate courses during the winter quarter 1976. The population for the study consisted of the students who were taking the following courses offered in the Department of Industrial Education: (a) I.Ed. 124, Introduction to Graphic Communications; (b) I.Ed. 130X, Introduction to Materials and Processes; (c) I.Ed. 224, Technical Graphics;

(d) I.Ed. 253B, Electricity II; (e) I.Ed. 323, Reprographics; (f) I.Ed. 324, Architectural Drafting and Design for Industrial Education Teachers; (g) I.Ed. 357, Electronics I; and (h) I.Ed. 490D, Independent Study in Industrial Education. Ten percent of the total course grade was based upon the completion and performance of the exercises in this study. This simply meant that the metric study would be a part of the course requirement. By the limitation of the real situation, selection of subjects was first begun in clustering the above courses into two groups. Group I, which included I.Ed. 130X, I.Ed. 224, I.Ed. 323, and I.Ed. 357, served as the source of experimental subjects, whereas Group II, which included I.Ed. 124, I.Ed. 253B, I.Ed. 324, and I.Ed. 490D, was used as the source of the control group. In order to equate the two groups, the investigator tried to arrange the same level courses into both groups. At the outset, 80 students were randomly selected and assigned to eight experimental cells with 10 subjects in each cell (see Table 1) from Group I, and 40 students were randomly selected and assigned to 4 control cells from Group II (see Table 1). As a result of students dropping these courses during the study, further randomization was conducted in order to have equal-sized sample cells. Eight participants were finally randomly selected from each cell. A total of 96 subjects were used for this study.

The study sample consisted of 91 (94.79%) industrial education majors and 5 (5.21%) from other fields (see Table 7 and Fig. 1). Within the 91 industrial education majors, 55 were in the teaching option, and 34 were in the industrial option. The two remaining individuals were undeclared (see Table 8 and Fig. 2).

The ages of those participating varied from 18 to 30, with a mean age of 21.63 (see Table 9 and Fig. 3). The classification of the sample contained 11 (11.49%) freshmen, 19 (19.79%) sophomores, 37 (38.54%) juniors, 28 (29.17%) seniors, and 1 (1.04%) graduate (see Table 10 and Fig. 4).

The high schools from which the sample graduated varied in size from 250 students or less to more than 2,000 students. The Personal Data sheet (see Appendix I) which students completed during the study disclosed that 26 students (27.08%) graduated from a high school with 250 students or less; 18 (18.75%) graduated from a high school with 251 to 500 students; 14 (14.58%) from a high school with 501-750 students; 5 (5.21%) from a high school with 751-1,000 students; 14 (14.58%) from a high school with 1,001-1,500 students; 11 (11.46%) from a high school with 1,501-2,000 students; and 8 (8.33%) graduated from a high school with more than 2,000 students (see Table 11 and Fig. 5).

The academic background of the sample could be described by individual high school ranks and ACT test scores provided

Table 7. Description of sample by curriculum major

Curriculum major	Frequency (n)	Percent (%)
Industrial education	91	94.792
Others	5	5.208
Total	96	100.000

Table 8. Description of sample by option of concentration

Option of concentration	Frequency (n)	Percent (%)
Teaching option	55	57.292
Industrial option	34	35.417
Others ^a	7	7.292
Total	96	100.000

^aFive of seven students in this category were not Industrial Education majors. The other two were undeclared.

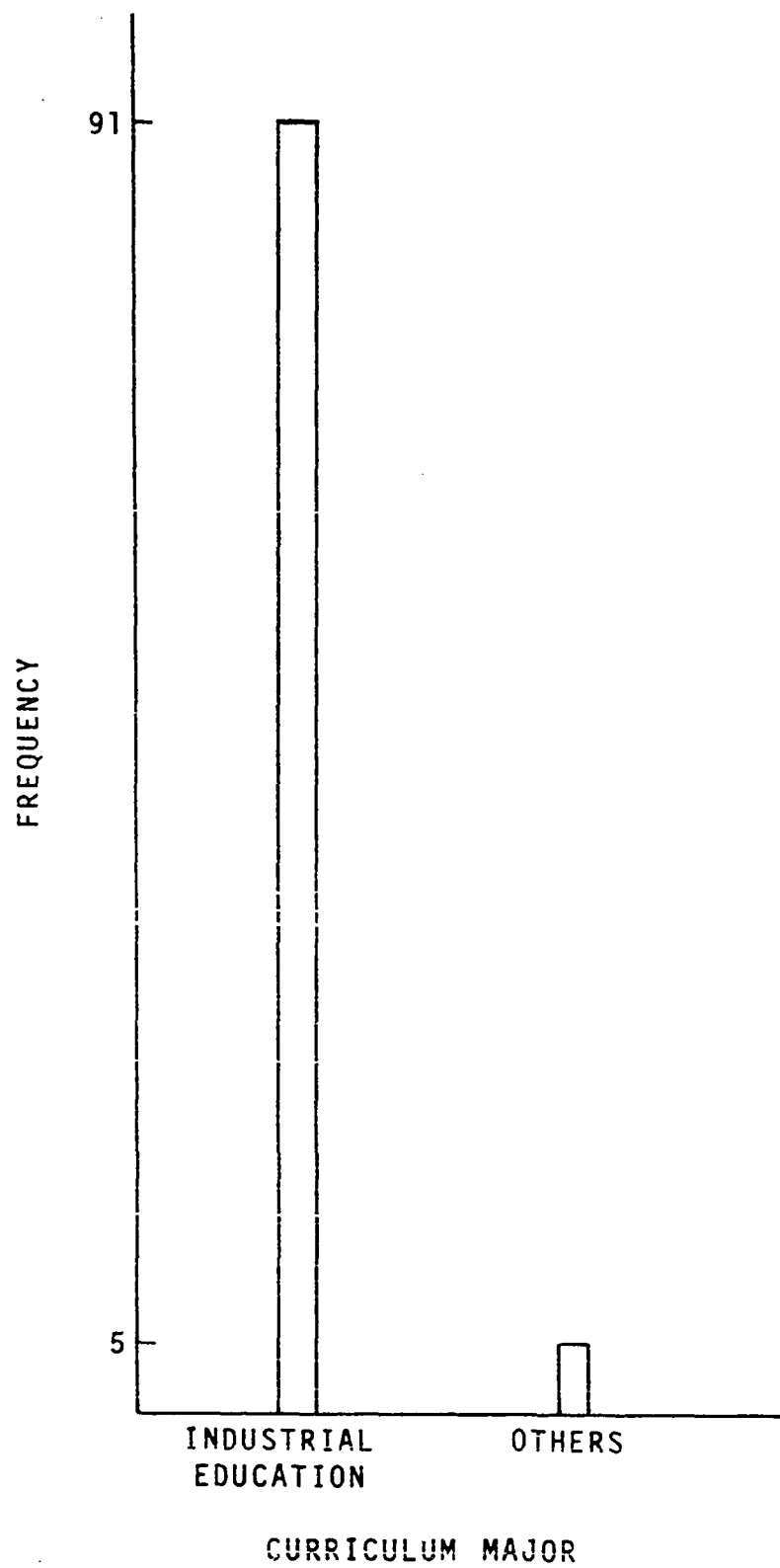


Figure 1. Distribution of sample by curriculum major

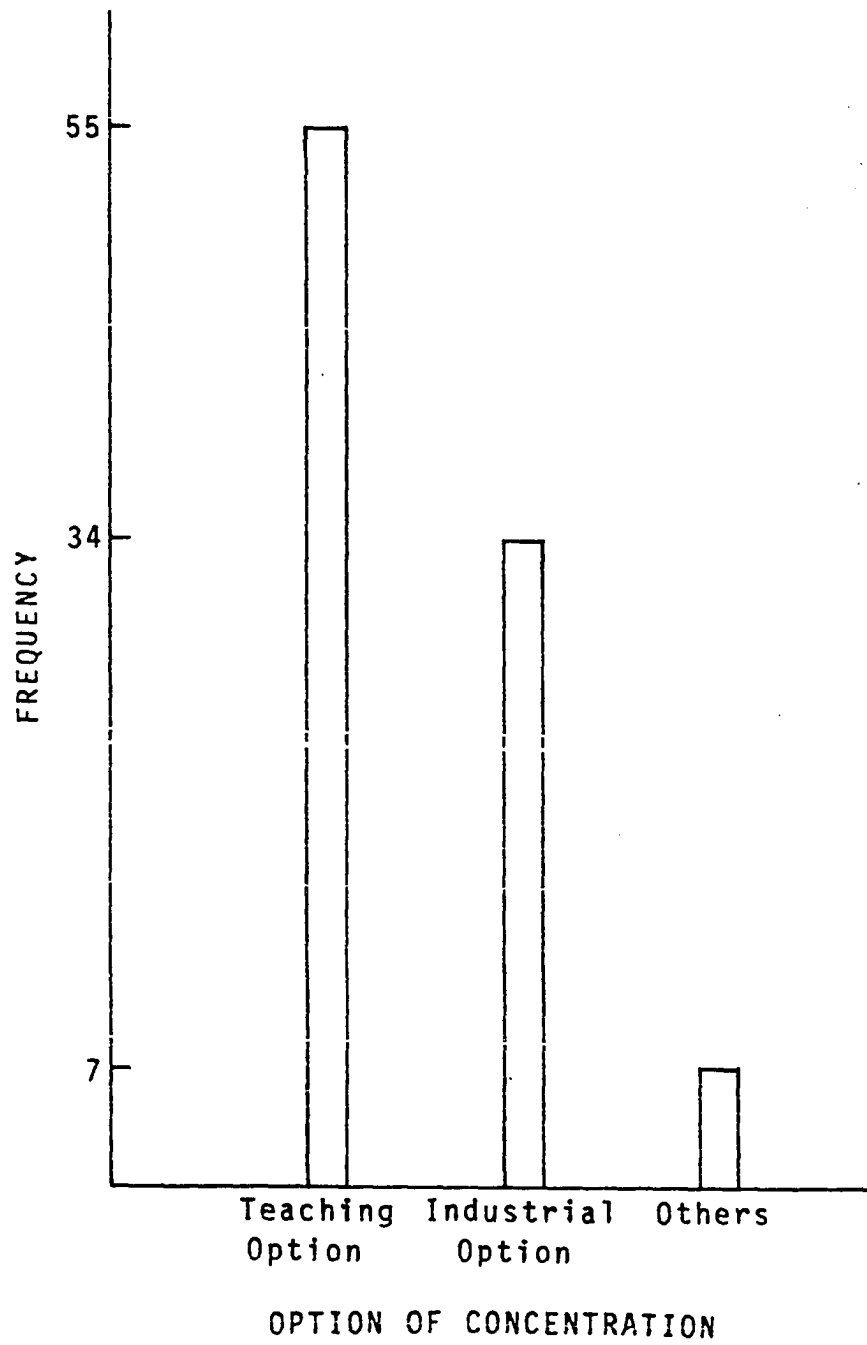


Figure 2. Distribution of sample by option of concentration

Table 9. Description of sample by age

Age	Frequency (n)	Percent (%)
18	1	1.042
19	15	15.625
20	17	17.708
21	27	28.125
22	12	12.500
23	8	8.333
24	4	4.167
25	3	3.125
26	3	3.125
27	2	2.083
28	2	2.083
29	1	1.042
30	1	1.042
Total	96	100.000

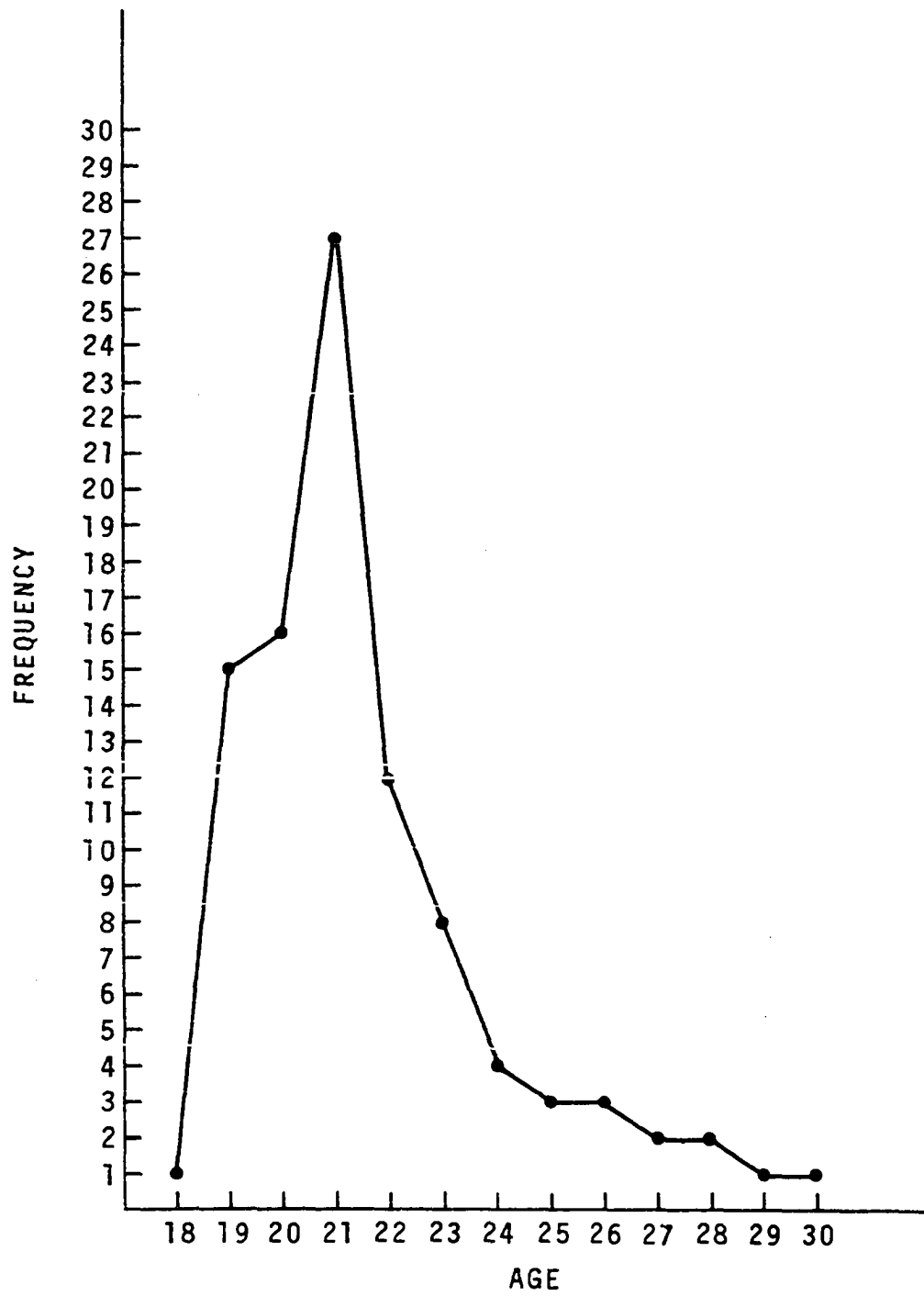


Figure 3. Distribution of sample by age

Table 10. Description of sample by academic classification
(grade level)

Academic classification (grade level)	Frequency (n)	Percent (%)
Freshman	11	11.458
Sophomore	19	19.792
Junior	37	38.542
Senior	28	29.167
Graduate	1	1.042
Total	96	100.000

Table 11. Description of sample by size of high school

High school size (number of students)	Frequency (n)	Percent (%)
250 or less	26	27.083
251 - 500	18	18.750
501 - 750	14	14.583
751 - 1,000	5	5.208
1,001 - 1,500	14	14.583
1,501 - 2,000	11	11.458
2,001 or more	8	8.333
Total	96	100.000

Figure 4. Distribution of sample by academic classification
(grade level)

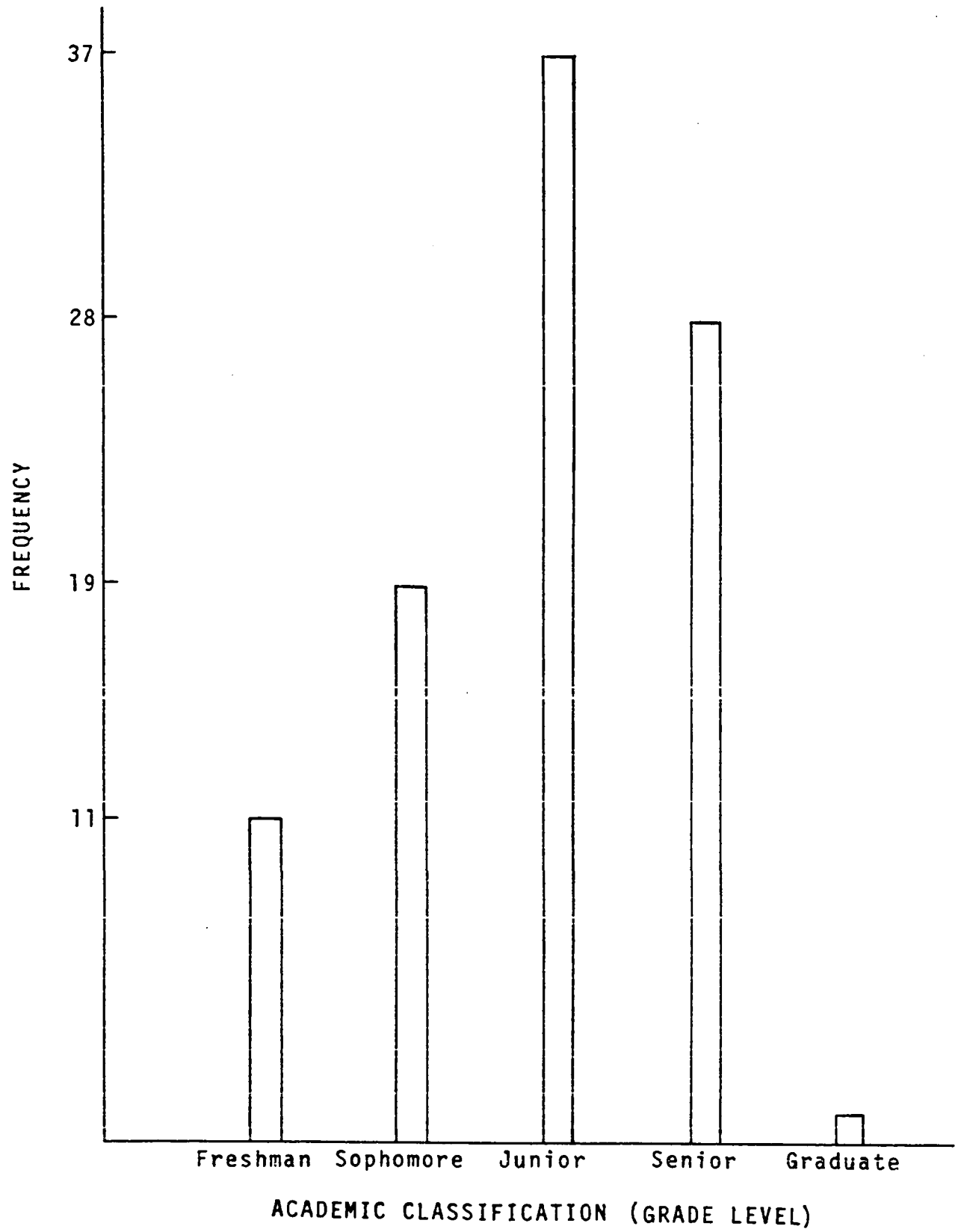
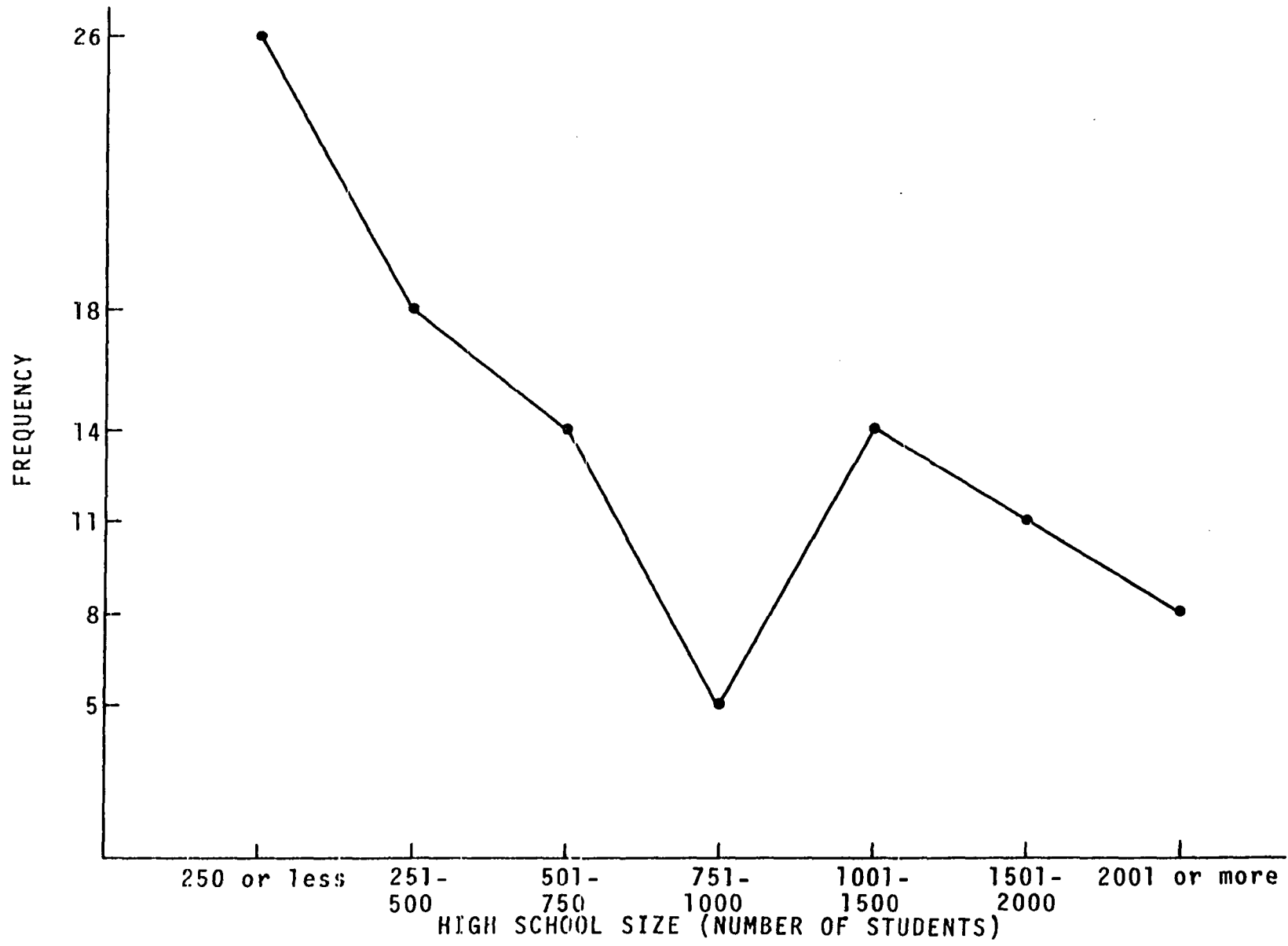


Figure 5. Distribution of sample by size of high school



by the Registrar's Office at I.S.U. Unfortunately, four people had no record of their high school rank and 25 had no record of their ACT test score. (The 4 students without a record of their high school rank also had no record of their ACT test score.) The subjects' high school ranks varied from a high of 2 percentile to a low of 96 percentile. The mean percentile of the sample was 39.27 (see Table 12 and Fig. 6). The range of the ACT test scores of those 71 students whose test information was recorded was from a low of 11 to a high of 31. The mean score of the ACT test was 23.10 with a standard deviation of 4.28 (see Table 13 and Fig. 7).

The Design of the Experiment

This study utilized a pretest/posttest control - group factorial design with random assignment (Borg and Gall, 1971, p. 379). Both three dimensional (see Table 1) and four dimensional (see Table 2) factorial statistical analyses were employed in the experiment. The investigator was interested in four main aspects: (1) systems approaches, (2) instructional methods, (3) test sequences, and (4) test trials. Interaction patterns among the main effects were also observed.

Students enrolled in eight courses offered in the Department of Industrial Education during the winter quarter, 1976, were used as the source of the target population. The study was conducted as follows:

Table 12. Description of sample by high school rank

High school rank (percentile) (1% top)	Frequency (n)	Percent (%)
2	1	1.042
3	2	2.083
4	1	1.042
5	3	3.125
7	1	1.042
8	2	2.083
9	1	1.042
10	1	1.042
12	1	1.042
13	1	1.042
14	1	1.042
15	1	1.042
16	1	1.042
18	5	5.208
20	1	1.042
21	2	2.083
23	2	2.083
24	2	2.083
25	1	1.042
27	1	1.042
28	2	2.083
29	2	2.083

Table 12. Continued

High school rank (percentile) (1% top)	Frequency (n)	Percent (%)
30	3	3.125
33	3	3.125
34	1	1.042
35	4	4.167
36	2	2.083
38	2	2.083
39	2	2.083
40	2	2.083
41	1	1.042
42	1	1.042
44	1	1.042
45	1	1.042
48	1	1.042
50	2	2.083
51	1	1.042
52	1	1.042
54	3	3.125
55	1	1.042
57	2	2.083
58	4	4.167
60	2	2.083
61	1	1.042

Table 12. Continued

High school rank (percentile) (1% top)	Frequency (n)	Percent (%)
62	1	1.042
65	1	1.042
68	3	3.125
69	1	1.042
70	2	2.083
73	1	1.042
78	1	1.042
84	1	1.042
86	2	2.083
89	1	1.042
94	1	1.042
96	1	1.042
Missing data	4	4.167
Total	96	100.000

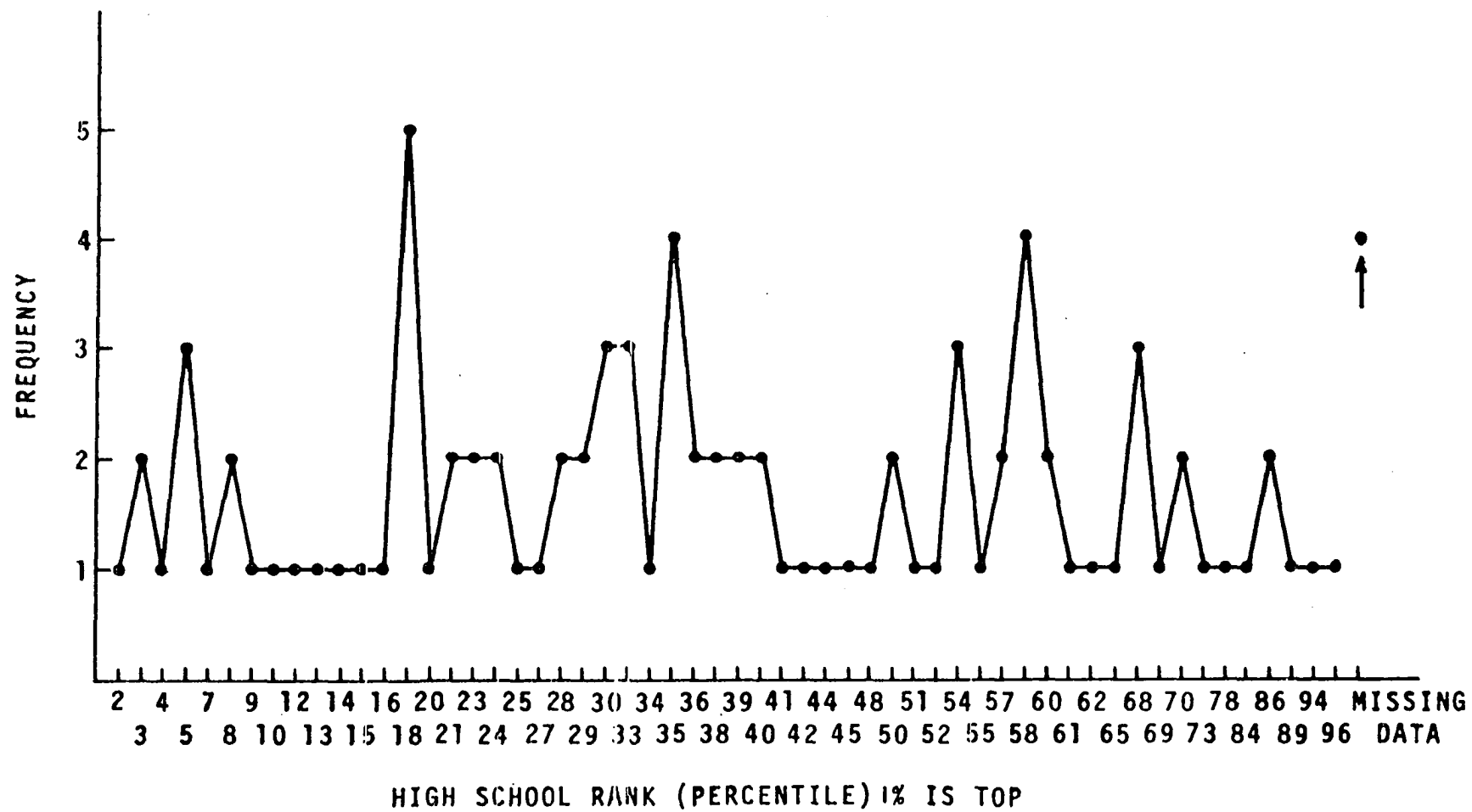
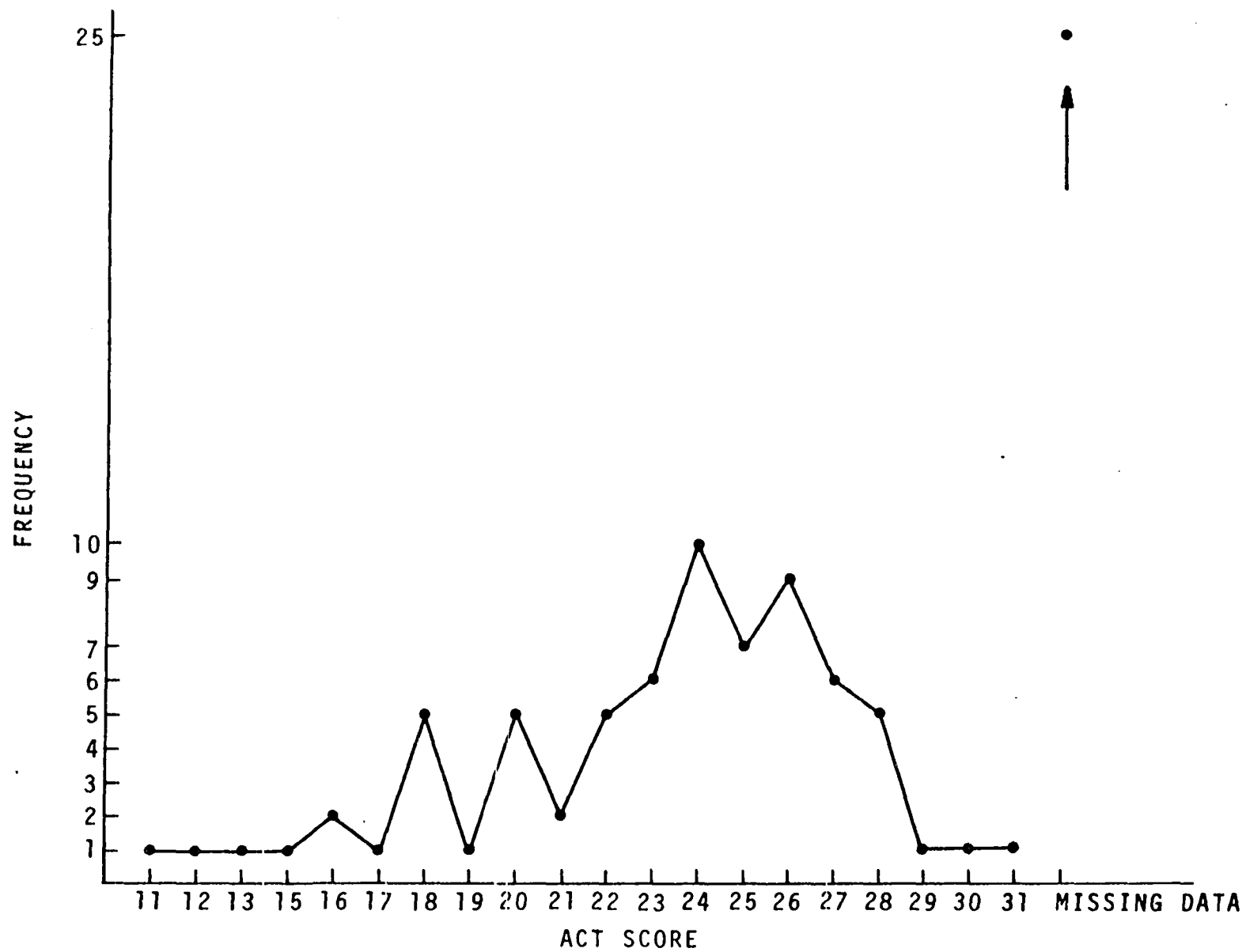


Figure 6. Distribution of sample by high school rank

Table 13. Description of sample by American College Test score

ACT score	Frequency (n)	Percent (%)
11	1	1.042
12	1	1.042
13	1	1.042
15	1	1.042
16	2	2.083
17	1	1.042
18	5	5.208
19	1	1.042
20	5	5.208
21	2	2.083
22	5	5.208
23	6	6.250
24	10	10.417
25	7	7.292
26	9	9.375
27	6	6.250
28	5	5.208
29	1	1.042
30	1	1.042
31	1	1.042
Missing data	25	26.042
Total	96	100.000

Figure 7. Distribution of sample by American College Test score



	<u>Classes and section</u>	<u>Design</u>
Experimental groups	I.Ed. 130X(A)	$O_{pre}T_1T_2O_{post}$
	I.Ed. 224(A)	$O_{pre}T_1T_2O_{post}$
	I.Ed. 323(A)	$O_{pre}T_1T_2O_{post}$
	I.Ed. 357(A)	$O_{pre}T_1T_2O_{post}$
Control groups	I.Ed. 124(A)	$O_{pre} \quad O_{post}$
	I.Ed. 253(B)	$O_{pre} \quad O_{post}$
	I.Ed. 324(A)	$O_{pre} \quad O_{post}$
	I.Ed. 490(D)	$O_{pre} \quad O_{post}$

O_{pre} = Pretest, either Form A or Form B according to assignment.

O_{post} = Posttest, either Form A or Form B, different from the form of the pretest.

T_1 = Lesson 1 of the metric study, 4 different types of instruction.

T_2 = Lesson 2 of the metric study, 4 different types of instruction.

The eight combinations of experimental conditions and four control groups (employing only two different conditions) were given instruction and monitored during the winter quarter 1976.

The entire process of this study was directly conducted by the instructors of their respective classes in order to eliminate or reduce the psychological effect of experimental

treatment. Since all the instructions were individualized material, there should not be any effect of different instructors administering the process. Students in the courses of I.Ed. 130X, I.Ed. 224, I.Ed. 323, I.Ed. 357, I.Ed. 124, I.Ed. 324, I.Ed. 357, and I.Ed. 490D were told they would take a unit of study covering the metric system at the beginning of the quarter. The whole unit included 3 tests and 2 individualized lessons. Upon completion of the work, they would be evaluated based upon (1) their attendance and attitude toward the study, and (2) the test score, with each part weighing 5% of the course grade. Those students in the control groups were told that they would have two tests first and then receive two lessons. During the last contact hour of the third week of the quarter, each instructor of the above courses administered the pretest which contained Form A and Form B. Every student received a designated form of the test, randomly pre-assigned to the student by the investigator. A name label was affixed to each test with an instruction sheet (see Appendix J). Test scores of the sample were used for the study; however all scores were utilized by the participating instructors for course evaluation. At the same time, every student was asked to sign a schedule (see Appendix K) for one hour a week during the two study weeks. The schedule included the sixth and seventh weeks for experimental groups and the tenth and eleventh weeks for the control groups. The fourth and

fifth weeks were the university's Christmas holidays, after which the students who were in the selected experimental groups were given a written information sheet (see Appendix L) which stated the time of his or her lesson, the place, the specific type of instruction he or she should get, etc. The same information was provided by the investigator on the sign-up sheet after each student's name, and this sheet was placed in the area where the student received his or her instruction. The investigator checked the attendance sheet every day and tried to locate students who missed their lessons. These were usually made up the following day; since several copies of the same type of instruction were prepared, there were no problems encountered with the make-up lessons. The same procedure was repeated in the seventh week for the second lesson. In this period of time, the students in the control groups received no lessons. At the last contact hour of the ninth week, all students in both the experimental group courses and in the control group courses received the posttest. The posttest was also administered in two forms, Form A and Form B, with the appropriate instruction sheet. Students who took Form A for the pretest received Form B as the posttest, and vice versa. The test scores of the designated subjects were then tabulated for further analysis. During this time the Personal Data sheets were completed. The tenth and eleventh weeks were scheduled for those students in the control group classes to

take the instruction. The same procedures were implemented with the students in the control group as the experimental group. Finally, during the 12th and 13th weeks, the Nelson-Denny Reading Ability Test was given to all students for research analysis purposes.

The entire process of this study was designed to be conducted under as normal a situation as possible in order to reduce the experimental effect. Because of the problem of student drop-outs from the classes, two step randomization was used to achieve equal-number subject cells, and fortunately the final sample size was not reduced too much.

Experimental Treatments

In the three-factor model, three treatments were applied to the experimental groups: (1) systems approaches, (2) sensory-based instructional methods, and (3) test sequences. Eight different combinations of those treatments formed eight experimental cells. The control group was divided into four cells; however, they experienced only two different conditions. According to the different treatment combinations, the whole experiment was classified into the following groups:

1. Experimental groups

- a. Direct, visual, A - B (D.V.a.): The students in this group took Test Form A (see Appendix C) as the pretest, then receiving two one-hour slide metric lessons prepared utilizing the direct

approach, and finally took Test Form B as the posttest (see Appendix D).

- b. Direct, audile, A - B (D.A.a.): The students in this group took Test Form A as the pretest, then receiving two one-hour cassette tape metric lessons prepared utilizing the direct approach, and finally took Test Form B as the posttest.
- c. Direct, visual, B - A (D.V.b.): The students in this group took Test Form B as the pretest, next receiving two one-hour slide metric lessons prepared with the direct approach, and then took Test Form A as the posttest.
- d. Direct, audile, B - A (D.A.b.): The students in this group took Test Form B as the pretest, received two one-hour cassette tape metric lessons which were prepared utilizing the direct approach, and finally took Test Form A as the posttest.
- e. Conversion, visual, A - B (C.V.a.): The students in this group took Test Form A as the pretest. They then received two one-hour slide metric lessons which used the conversion approach, and finally took Test Form B as the posttest.
- f. Conversion, audile, A - B (C.A.a.): The students in this group took Test Form B as the pretest, before receiving two cassette tape metric lessons

prepared utilizing the conversion approach, and concluded with Test Form B as the posttest.

- g. Conversion, visual, B - A (C.V.b.): The students in this group took Test Form B as the pretest, then they received two slide metric lessons using the conversion approach, finally taking Test Form A as the posttest.
- h. Conversion, audile, B - A (C.A.b.): The students in this group took Test Form B as the pretest. They then received two cassette tape metric lessons which were developed using the conversion approach and finally took Test Form A as the posttest.

2. Control group

- a. Control, visual, A - B (T.V.a.): The students in this group took Test Form A as the pretest, then took Test Form B as the posttest. No treatment was administered to this group between the two tests.
- b. Control, audile, A - B (T.A.a.): The students in this group took Test Form A as the pretest, then took Test Form B as the posttest. No treatment was administered to this group between the two tests. Actually, this group was treated in exactly the same manner as the control, visual, A - B

(T.V.a.) group.

- c. Control, visual, B - A (T.V.b.): The students in this group took Test Form B as the pretest, then took Test Form A as the posttest. No treatment was administered to this group between the two tests.
- d. Control, audile, B - A (T.A.b.): The students in this group took Test Form B as the pretest, then took Test Form A as the posttest. Again, no treatment was administered to this group between the two tests. Actually, this group was treated in exactly the same manner as the control, visual, B - A (T.V.b.) group. This arrangement of two separate groups was employed for the convenience of statistical analysis.

A total of one hundred students enrolled in I.Ed. 130X, I.Ed. 224, I.Ed. 323, and I.Ed. 357 served as the population for the experimental groups. Simple random selection was first applied to assign ten students to each of eight experimental groups. Then, after the experiment, eight subjects were randomly selected from each group to be used for final statistical analysis. Therefore, sixty-four subjects were used in the experimental groups. Forty-two students, who were taking I.Ed. 124, I.Ed. 253, I.Ed. 324, and I.Ed. 490D, served as the population for the control groups, and the same procedures were

employed to select thirty-two subjects for the control groups. Twelve different combination groups and ninety-six subjects were used in this study.

When the four-factor model was applied, the fourth treatment — test trial — was added into the previous model. Therefore both pretest scores and posttest scores were used as the criteria. The whole experiment then was classified into sixteen experimental groups and eight control groups (see Table 2) with eight subjects in each cell.

Preparation of Instructional Materials

Four different types of instructional materials were applied to the experimental groups. Since the purpose of this study was to provide teacher educators with directions regarding systems approaches and instructional methods for instructing metric concepts and content, two systems approaches and two sensory-based instructional methods were used as bases for producing the instructional materials. The two systems approaches utilized were the direct approach and the conversion approach. The two sensory-based instructional methods were the visual learning PAC and the audile learning PAC.

1. The direct approach, visual learning PAC (obtainable from the researcher): Two slide presentation sets composed the two metric lessons. The first set consisted of 80 single slides and the second set of 66 slides. The direct approach was utilized to present the metric measurement system concept

in these slide lessons. In other words, students learned the metric system exclusively without any English system conversion information.

2. The conversion approach, visual learning PAC (obtainable from the researcher): Two metric lessons were presented, incorporating two sets of slides. The first lesson consisted of 79 single slides, while the second lesson had 66 single slides. The conversion approach was used to introduce the metric measurement system concept in these two slide lessons. The students learned the metric system with related English system conversion information.

3. The direct approach, audile learning PAC (see Appendix A): Two metric lessons were presented through two one-hour cassette tapes. The first tape lasted approximately fifty-five minutes, and the second about fifty minutes. All the instructions began and ended with a short accompanying period of "easy listening" music. In these two tapes, the direct approach was exclusively used for introducing the concept of the metric measurement system.

4. The conversion approach, audile learning PAC (see Appendix B): Two one-hour cassette tapes were utilized for these metric lessons, the first tape running approximately fifty-five minutes, and the second one containing instruction lasting about fifty minutes. A short period of "easy listening" music was recorded at the beginning and end of each

lesson. The conversion approach was used, meaning that related English system information was provided concurrently with the metric system concepts.

The major sources utilized for information concerning instruction were: (1) Thinking Metric, by Thomas F. Gilbert and Marilyn B. Gilbert, published by John Wiley & Sons, Inc. (1973); (2) Metric in Career Education, by Dr. John R. Lindbeck, published by Chas. A. Bennett Co., Inc. (1975); (3) Going Metric, materials developed by the Center for Metric Education at Western Michigan University; and (4) Think Metric! Instructor's Guide for Metric System Transparencies, published by DCA Educational Products, Inc. (1974). The investigator utilized his own knowledge and experience combined with the above mentioned materials to develop the four experimental metric instructional packages.

During the experiment, the eight different metric lessons were coded to: (1.a) Slide Lesson 1, copy 2; (1.b) Slide Lesson 2, copy 2; (2.a) Slide Lesson 1, copy 1; (2.b) Slide Lesson 2, copy 1; (3.a) Tape Lesson 1, copy 2; (3.b) Tape Lesson 2, copy 2; (4.a) Tape Lesson 1, copy 1; (4.b) Tape Lesson 2, copy 1. The students were not told the difference between copy 1 and copy 2 in order to minimize the experimental effect. The instructional content of both the direct approach and the conversion approach was developed as similarly as possible. The main difference was that the conversion approach

provided related English system information along with metric system information. The materials involved in the slide sets were developed after the tape sets were completed. The section-by-section matching was closely examined to insure equal content in both sensory-based instructional methods. All instructional materials were evaluated by Dr. William Wolansky, the Chairman of the Metric Committee, Department of Industrial Education, Iowa State University, and corrections and minor changes were made as a result of his evaluation.

The Instruments

Data for this study were collected using student records, three instruments, and one questionnaire.

1. Student records: Both student ACT (American College Test) scores and high school ranks were obtained from the registrar's office of Iowa State University. This information was used for examining the differences among all experimental and control group subjects.

2. Metric Test Form A (see Appendix C) consists of fifty multiple choice items with four alternatives. Test Form A was administered to half of the sample as a pretest, and to half of the sample as a posttest. The test was divided into two parts, a General Proficiency Section containing twenty items, and an Intuition Section consisting of thirty items. Metric content comprehension and problem-solving ability were measured by this test. The Form A test was copied from instruments

used in two doctoral dissertations: (1) The Relative Merits of Two Methodologies of Teaching the Metric System to Seventh Grade Science Students, by Dr. Evan E. McFee (1967), and (2) Evaluation of a Metric Booklet as a Supplement to Teach the Metric System to Undergraduate Non-Science Majors, by Dr. Kenith Gene Exum (1973). This instrument was developed by Dr. Evan McFee. The validity and reliability of the test had been examined carefully. This information can be located in Appendix H. The instrument and the information concerning the validity and reliability of the test were released for use by the author (see Appendix H). The last ten items were added by the investigator to evaluate the additional content of instruction. Test Form A was machine scored and an item analysis was done by the Iowa State University Testing Service. The results gave the KR-20 estimate of reliabilities as follow:

- a. When the test was administered as a pretest:
 - (1) Experimental groups (n = 32): 85%
 - (2) Control groups (n = 16): 90%
- b. When the test was administered to the other half of the sample as a posttest:
 - (1) Experimental groups (n = 32): 83%
 - (2) Control groups (n = 16): 86%

Further information concerning the results of this test is found in Appendix F.

3. Metric Test Form B (see Appendix D) is made up of fifty multiple-choice items with 4 alternative choices. Test

Form B was administered to one half of the sample as a pretest, and to the other half as a posttest. The test was also divided into two parts, a General Proficiency Section which consisted of twenty items, and an Intuition Section which consisted of thirty items. This test measured metric content comprehension and problem-solving ability and was developed by the investigator. It was generated by carefully matching concepts item by item from Test Form A. Test Form B was machine scored and an item analysis was done by the Iowa State University Testing Service. The results gave the KR-20 estimate reliabilities as follow:

a. When the test was administered as a pretest:

(1) Experimental groups (n = 32): 88%

(2) Control groups (n = 16): 92%

b. When the test was administered to the other half of the sample as a posttest:

(1) Experimental groups (n = 32): 88%

(2) Control groups (n = 16): 91%

Further information concerning the results of this test is located in Appendix G.

Both Test Form A and Test Form B were reviewed by Dr. William D. Wolansky, Chairman of the Metric Committee, Department of Industrial Education at Iowa State University. Test Form B was examined extensively and revised where necessary.

4. The Nelson-Denny Reading Ability Test, Form B, was developed by M. J. Nelson and E. C. Denny originally and

revised by J. I. Brown, Professor of Rhetoric, University of Minnesota. The test contained a 100-item vocabulary section and a 36-item reading comprehension section. The reliability of the test ranged from .92 to .93 (Buros, 1965, p. 1078). Raw scores for the test were calculated by adding the number of correct items in the vocabulary section and twice the number of correct items in the reading comprehension section.

The reading test was administered so as to examine any difference in reading ability among all the groups. More specifically, the reading test scores were examined to detect any discrepancies between those individuals assigned to the visual learning PAC and the audile learning PAC.

The Nelson-Denny Reading Test is a well-constructed standardized test suitable for testing college students and provided useful information for the individual learning capacity. The evaluation of the test by David B. Orr, Senior Research Scientist, American Institute for Research; and Director of School and Survey Research, University of Pittsburgh Project Talent Office, indicates "In general the format is clear and workable, and, with a few exceptions, the items seem well constructed and unambiguous" (Buros, 1965, p. 1077).

In summary, in spite of certain defects, this test is one of the better of its kind and represents a useful improvement of an already useful test. . . .

In general the test may be expected to provide useful information at a reasonable cost and will doubtlessly continue to find a place in the test user's repertoire. (Buros, 1965, p. 1078)

Agatha Townsend, Consultant, Educational Records Bureau, also reviewed the Nelson-Denny Reading Test: "It is not a test which will adequately differentiate among the reading skills of college students, but it has its place for screening" (Buros, 1965, p. 1080).

5. Personal Information for Metric Study is a questionnaire sheet, designed for supplying information, age, academic classification, curriculum major, option of concentration, location, and the size of the high school from which the student graduated. A copy of this questionnaire can be found in Appendix I. This instrument was designed for obtaining related information of all participants in order to describe the characteristics of the sample and to analyze the differences among all groups.

The Method of Collecting Data

Data were collected from the students' cumulative files, three tests, and the Personal Data sheet. The procedures for conducting and collecting the data were as follow:

1. Experimental groups

a. First session

(1) Introduction to the Metric Research Study:

Instructors of the selected classes described the requirements for the work and the evaluation procedure to be used. The students were asked to fill out a one-hour period study schedule sheet for two hours in a two-week period (see Appendix K).

(2) Administration of the pretest: One of two forms, Form A or Form B, was administered to all students in the classes by a preassigned test form arrangement. The instructions for taking the test were read aloud carefully before students started the test (see Appendix J). Computer marking answer sheets were used for machine scoring and analyzing purposes.

b. Second session

(1) Introduction to the procedure of taking the first metric lesson: All students in the classes received a detailed, written procedure sheet. Four different types of sheets were distributed to the students, according to the four combinations of the experimental instruction arrangements. The sheet provided the information of "when," "where," "how," and the exact procedures of taking the metric lesson. A copy of the procedure sheet is found in Appendix L.

(2) Receiving the first metric lesson: Every student was asked to follow the procedure sheet at his or her

scheduled time and to go to the arranged location for the assigned instruction -- Introduction to the Metric, Lesson 1. An attendance sheet (see Appendix N) was provided in all four learning areas. The student was told to sign his or her name after completing the lesson.

c. Third session

(1) Introduction to the procedure of taking the second metric lesson: All students in the classes received a detailed, written procedure sheet for lesson 2 from his or her instructor at the beginning of the first contact hour of the class in that week.

(2) Receiving the second metric lesson: The student was asked to follow the procedure sheet to take the second lesson -- Introduction to the Metric, Lesson 2. The student's signature was again required to indicate attendance.

d. Fourth session

(1) Administration of the posttest: Either Form A or Form B was administered to all students as a posttest. Each student received a test with his or her name on the booklet. The student who took Form A as a pretest would take Form B as a posttest, and vice versa.

(2) Administration of the Personal Information Data for Metric Study Sheet: Each student was asked to complete the personal information data sheet and return it along with the test booklet and answer sheet.

e. Fifth session

(1) Administration of the Nelson-Denny Reading Test:

This time-limited test was conducted by the instructors of all selected classes. The purpose of the test was explained to the class before the test was administered. Ten minutes were allowed for the vocabulary section and twenty minutes for the reading comprehension part. Special answer sheets ordered through the publisher of the test were used.

The first session was conducted during the week prior to the two-week university holidays. The second and third sessions were conducted during the two consecutive weeks following the holidays. Between the third and fourth sessions, there was a week long break. The fifth session was conducted two weeks after the fourth session.

2. Control groups

a. First session

(1) Introduction to the Metric Research Study:

Instructors of the selected classes reviewed the requirements for the work and the evaluation procedure for the study.

(2) Administration of the pretest: Two forms, Form A and Form B, were administered to students in the class by a preassigned test form arrangement. The same test procedures and materials as administered to the experimental groups were also used with the control groups.

A five-week time lapse occurred between sessions one and two.

b. Second session

(1) Administration of the posttest: Two forms were administered to the students, with each student receiving the preassigned test form booklet, either A or B, bearing his or her name. The same procedures and materials used with the experimental groups were used with the control groups.

(2) Administration of the Personal Information for Metric Study Sheet: Each student was asked to complete the personal information sheet.

A two-week period occurred between sessions two and three.

c. Third session

(1) Administration of the Nelson-Denny Reading Test: Every student in the selected control group participated in this test. Classes were asked to take the reading test following an explanation of its purpose. The same procedures and materials were used with the control groups as with the experimental groups.

The scores from the pretest, posttest and the Nelson-Denny Reading Test, and the information from student cumulative files and personal information sheets were recorded for those randomly selected by the investigator. The second step of randomization was processed, and the data for all ninety-six

subjects were coded to computer data form and key punched for statistical analysis.

The Method of Statistical Analysis

The entire statistical data process and analysis involved use of the computer program of the Statistical Analysis System (SAS) (Barr and Goodnight, 1972). There were six major statistical analyses used in this study:

1. Initial status analysis (learner variable analysis)
2. Background examinations
3. Test sensitization examination
4. Learning achievement analysis
5. Posttest analysis
6. Four-factor model analysis.

Analysis of variance and analysis of covariance were applied for analyzing the data in this study.

Initial status analysis (learner variable analysis)

According to the major characteristic information, initial differences were examined. Three-way factorial analysis of variance was applied to each of the seven major learner characteristics. The objectives of this analysis were to examine the homogeneity of all random assigned groups under the three factors and to find the possible covariates, if any.

Background examinations

Two dependent variables, the pretest score and the Nelson-Denny Reading Test score, were analyzed to examine prior knowledge of the metric system and the reading ability of learning. These two were the important variables affecting the result of the study. Three-way factorial analysis of variance was used to examine the difference of all groups for both of the variables.

Test sensitization examination

Data from eight experimental groups were analyzed. The differences between the pretest scores and the posttest scores were examined through a four-way factorial analysis of variance. In addition, data from four control groups were also analyzed by the same process. The four factors used were approach, instructional method, test sequence, and test trial.

Learning achievement analysis

Posttest scores of all subjects were used to determine if there was any learning achievement resulting from the differently prepared types of instruction. An analysis of covariance was applied using the pretest scores as the covariate. Borg and Gall (1971) suggested in Educational Research: "The best statistical method to use is analysis of covariance, in which the posttest means are compared using the pretest means as the covariate" (p. 383).

John D. Williams also stated in Regression Analysis in Educational Research:

In many situations, a pretest can be given before an experiment takes place, and a posttest occurs at the conclusion of the experiment. Here, the pretest can serve as the covariate; also, the pretest - posttest situation can be viewed as a measure of change.

(Williams, 1938, p. 103)

The objective of this analysis was to determine if any achievement occurred with those subjects in the treatment groups.

Posttest analysis

The posttest scores of all subjects were used to test the main hypotheses, stated earlier in Chapter I, the differences among the groups, under three factors. Three-way factorial analysis of covariance was applied in this statistical process. The three covariates were age, academic classification, and high school rank.

Four-factor model analysis

Four factors — approach, instructional method, test sequence, and test trial were used in this analysis. This was a composite analysis to test the main hypotheses. Four-way factorial analysis of variance method was applied. All the main factor effects and all levels of interaction were analyzed for the final conclusion.

The design of the statistical analysis tried to provide sufficient evidence to support the value of the research study. Also, the variables which may have affected the results were subjected to control to the extent possible.

CHAPTER IV. FINDINGS, DISCUSSION

This chapter contains results of statistical tests performed on data collected for the study. The findings of the study are explained primarily through the use of tables and figures of analysis of variance, analysis of covariance, and tabulated means, along with a discussion of the findings. The results have been organized as follows:

1. Test of learner variables and an examination of possible covariates

Those variables selected as criteria were curriculum major, option of concentration, student age, academic classification, the American College Test score, high school rank, and high school size.

2. Test of previous metric system knowledge and reading ability

Pretest scores and the Nelson-Denny Reading Test scores were the data which the investigator considered.

3. Test sensitization

Pretest and posttest scores were compared and analyzed separately in the experimental and control groups.

4. Test of achievement

Posttest scores were analyzed using pretest scores as covariates.

5. Test of instructional effects (posttest analysis)

The posttest scores were analyzed to test the chief hypotheses which were stated in Chapter I for this study.

6. Test of the four-factor model

The effects of the systems approaches, sensory-based instructional methods, test sequences, test trials, and interaction of these variables were analyzed based upon pretest and posttest scores.

Based on these six group tests, the investigator tried to determine differences among the randomly assigned groups according to the following:

- 1-1. The learner variable of curriculum major.
- 1-2. The learner variable of option of concentration.
- 1-3. The learner variable of student age.
- 1-4. The learner variable of academic classification.
- 1-5. The learner variable of American College Test performance.
- 1-6. The learner variable of high school rank.
- 1-7. The learner variable of high school size.
- 2-1. The background of metric system knowledge based upon pretest performance.
- 2-2. Reading ability based upon Nelson-Denny Reading Test performance.

Other questions to be answered from the findings asked whether

- 3-1. The experimental group exhibited any signs of test sensitization as a result of the pretest.
- 3-2. The control groups exhibited any signs of test sensitization as a result of the pretest.
- 4-1. Significant achievement occurred because of the instructions students received.
- 5-1. There were any instructional effects among the three main factors and their interactions.

- 6-1. There were any differences among the treatment groups of systems approaches.
- 6-2. There were any differences among the groups resulting from two test sequences.
- 6-3. There were any differences between the groups resulting from two sensory-based instructional methods.
- 6-4. There were any differences between the groups resulting from two test trials.
- 6-5. There were any interaction effects among the factors.

Questions 1-1 through 1-7 were tested using a 3x2x2 factorial analysis of variance. All seven learner variables were the criteria respectively in each test. An F-test was applied.

Questions 2-1 and 2-2 were tested using a 3x2x2 factorial analysis of variance. Pretest scores and reading test scores were the criteria, respectively, in each test. An F-test was applied here also.

Question 3-1 was tested using a 2x2x2x2 factorial analysis of variance, with both pretest scores and posttest scores the criteria in this test. An F-test was applied.

Question 3-2 was tested using a 2x2x2 factorial analysis of variance, with both pretest scores and posttest scores the criteria in this test. An F-test was applied.

Question 4-1 was tested using a 3x2x2 factorial analysis of covariance. Posttest scores were the criterion, and pretest scores were the covariate, with an F-test applied.

Question 5-1 was tested using a 3x2x2 factorial analysis of covariance. Posttest scores were again the criterion. Age, academic classification, and high school rank were the three covariates used.

Questions 6-1 through 6-5 were tested using a 3x2x2x2 factorial analysis of variance. Both pretest scores and post-test scores were the criteria. An F-test was applied.

Testing of Hypotheses Group 1

Group 1. Test of learner variables and examination of possible covariates

The variables selected as criteria were (1) curriculum major, (2) option of concentration, (3) student age, (4) academic classification, (5) the American College Test score, (6) high school rank, and (7) high school size.

The three-factor model was applied to analyze these variables. The three factors were (1) systems approach (approach), (2) test sequence (sequence), and (3) sensory-based instructional method (method).

The 3x2x2 factorial analysis of variance was used. All hypotheses of this group tested statistically by the analysis of variance were accepted at the F-ratio .05 level of significance. If the results were significant at the .01 level, they were reported as such.

1-1. Curriculum major as the criterion of the learner variable :

Table 14. Analysis of variance of the student curriculum major

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	0.08	0.04	0.8
B (sequence)	1	0.01	0.01	0.2
C (method)	1	0.01	0.01	0.2
A x B	2	0.08	0.04	0.8
A x C	2	0.08	0.04	0.8
B x C	1	0.01	0.01	0.2
A x B x C	2	0.08	0.04	0.8
Residual	84	4.38	0.05	
Total (corrected)	95	4.74		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

Hypothesis 1-1a: No significant difference occurred at the .05 level among the direct approach, conversion approach, and control groups on the basis of student curriculum majors as the criterion.

From an analysis of variance (Table 14), when 2 and 84 degrees of freedom were used, a value of .8 was not significant

at the .05 level. Therefore, student curriculum majors were distributed throughout the direct approach, conversion approach, and control groups without any significant difference. Hypothesis 1-1a was not rejected.

Hypothesis 1-1b: No significant difference occurred at the .05 level between the test sequences, A - B group and B - A group, on the basis of student curriculum majors as the criterion.

From an analysis of variance (Table 14), when 1 and 84 degrees of freedom were used, a value of .2 was not significant at the .05 level. Therefore, student curriculum majors were distributed in the sequence A - B group and the sequence B - A group without any significant difference. Hypothesis 1-1b was not rejected.

Hypothesis 1-1c: No significant difference occurred at the .05 level between the visual learning PAC method and the audile learning PAC method groups on the basis of student curriculum major as the criterion.

From an analysis of variance (Table 14), when 1 and 84 degrees of freedom were used, a value of .2 was not significant at the .05 level, thus indicating that student curriculum majors were distributed in the visual learning PAC method and the audile learning PAC method groups without any significant difference. Hypothesis 1-1c was not rejected.

Hypothesis 1-1d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student curriculum major as the criterion.

From an analysis of variance (Table 14), no F-value of interaction terms exceeded the table value of F-ratio. No significant difference occurred at the .05 level in any interaction effects. Therefore, student curriculum majors were distributed throughout all classifications without any significant difference. Hypothesis 1-1d was not rejected.

1-2. Option of concentration as the criterion of the learner variable

Table 15. Analysis of variance of the student option of concentration (teaching option vs. nonteaching option)

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	0.65	0.32	1.33
B (sequence)	1	0.26	0.26	1.07
C (method)	1	0.51	0.51	2.10
A x B	2	0.27	0.14	0.56
A x C	2	1.02	0.51	2.10
B x C	1	0.26	0.26	1.07
A x B x C	2	0.15	0.07	0.30
Residual	84	20.38	0.24	
Total (corrected)	95	23.49		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

Hypothesis 1-2-1a: No significant difference occurred at the .05 level among the direct approach, conversion approach, and control groups on the basis of student option of concentration (teaching option vs. nonteaching option) as the criterion.

From an analysis of variance (Table 15), when 2 and 84 degrees of freedom were used, a value of 1.33 was not significant at the .05 level. Therefore, student options of concentration (teaching option vs. nonteaching option) were distributed throughout the direct approach, conversion approach, and control groups without any significant difference. Hypothesis 1-2-1a was not rejected.

Hypothesis 1-2-1b: There was no significant difference at the .05 level between the test sequences, A - B group and B - A group, on the basis of student option of concentration (teaching option vs. nonteaching option) as the criterion.

From an analysis of variance (Table 15), when 1 and 84 degrees of freedom were used, a value of 1.07 was not significant at the .05 level; hence, student options of concentration (teaching option vs. nonteaching option) were distributed in the sequence A - B group and the sequence B - A group without any significant difference. Hypothesis 1-2-1b was not rejected.

Hypothesis 1-2-1c: No significant differences occurred at the .05 level between the visual learning PAC method

and the audile learning PAC method groups on the basis of student option of concentration (teaching option vs. non-teaching option) as the criterion.

From an analysis of variance (Table 15), when 1 and 84 degrees of freedom were used, a value of 2.10 was not significant at the .05 level; thus, student options of concentration (teaching option vs. nonteaching option) were distributed in the visual learning PAC method and the audile learning PAC method groups without any significant difference. Hypothesis 1-2-1c was not rejected.

Hypothesis 1-2-1d: There was no significant difference at the .05 level for all possible combined interaction effects on the basis of student option of concentration (teaching option vs. nonteaching option) as the criterion.

From the analysis of variance (Table 15), no F-value of interaction terms exceeded the table value of F-ratio. No significant difference occurred at the .05 level in any interaction effects. Therefore, student options of concentration (teaching option vs. nonteaching option) were distributed throughout all classifications without any significant difference. Hypothesis 1-2-1d was not rejected.

Table 16. Analysis of variance of the student option of concentration (industrial option vs. nonindustrial option)

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	0.27	0.14	0.60
B (sequence)	1	0.04	0.04	0.18
C (method)	1	0.38	0.38	1.66
A x B	2	0.94	0.45	1.98
A x C	2	0.81	0.40	1.80
B x C	1	0.38	0.38	1.66
A x B x C	2	0.19	0.09	0.41
Residual	84	19.00	0.23	
Total (corrected)	95	21.96		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom is 3.10.

Hypothesis 1-2-2a: Among the direct approach, conversion approach, and control groups, no significant difference occurred at the .05 level on the basis of student option of concentration (industrial option vs. nonindustrial option) as the criterion.

From an analysis of variance (Table 16), when 2 and 84 degrees of freedom were used, a value of 0.60 was not significant at the .05 level. Because of this, student options of

concentration (industrial option vs. nonindustrial option) were distributed throughout the direct approach, conversion approach, and control groups without any significant difference. Hypothesis 1-2-2a was not rejected.

Hypothesis 1-2-2b: No significant difference occurred at the .05 level between the test sequences, A - B group and B - A group, on the basis of student option of concentration (industrial option vs. nonindustrial option) as the criterion.

From an analysis of variance (Table 16), when 1 and 84 degrees of freedom were used, a value of 0.18 was not significant at the .05 level. Therefore, student options of concentration (industrial option vs. nonindustrial option) were distributed in the sequence A - B group and the sequence B - A group without any significant difference. Hypothesis 1-2-2b was not rejected.

Hypothesis 1-2-2c: There was no significant difference at the .05 level between the visual learning PAC method and the audile learning PAC method groups on the basis of student option of concentration (industrial option vs. nonindustrial option) as the criterion.

From an analysis of variance (Table 16), when 1 and 84 degrees of freedom were used, a value of 1.66 was not significant at the .05 level. Therefore, student options of concentration (industrial option vs. nonindustrial option) were

distributed in the visual learning PAC method and the audile learning PAC method groups without any significant difference. Hypothesis 1-2-2c was not rejected.

Hypothesis 1-2-2d: At the .05 level no significant difference occurred for all possible combined interaction effects on the basis of student option of concentration (industrial option vs. nonindustrial option) as the criterion.

From an analysis of variance (Table 16), no F-value of interaction terms exceeded the table value of F-ratio. No significant difference occurred at the .05 level in any interaction effects. Therefore, student options of concentration (industrial option vs. nonindustrial option) were distributed throughout all classifications without any significant difference. Hypothesis 1-2-2d was not rejected.

1-3. Student age as the criterion of the learner variable

Hypothesis 1-3a: No significant difference occurred at the .05 level among direct approach, conversion approach, and control groups on the basis of student age as the criterion.

From an analysis of variance (Table 17), when 2 and 84 degrees of freedom were used, a value of .61 was not significant at the .05 level. Thus student ages were distributed throughout the direct approach, conversion approach, and control groups without any significant difference. Hypothesis 1-3a was not rejected.

Table 17. Analysis of variance of student age

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	6.94	3.47	0.61
B (sequence)	1	1.50	1.50	0.26
C (method)	1	2.04	2.04	0.36
A x B	2	21.94	10.97	1.92
A x C	2	9.65	4.83	0.84
B x C	1	5.04	5.04	0.88
A x B x C	2	38.40	19.20	3.25*
Residual	84	481.00	5.73	
Total (corrected)	95	566.50		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

*F is significant at the .05 level.

Hypothesis 1-3b: No significant difference occurred at the .05 level between the test sequences, A - B group and B - A group, on the basis of student age as the criterion.

From an analysis of variance (Table 17), when 1 and 84 degrees of freedom were used, a value of .26 was not significant at the .05 level. Consequently, student ages were distributed in the sequence A - B group and the sequence B - A group without any significant difference. Hypothesis 1-3b was

not rejected.

Hypothesis 1-3c: On the basis of student ages as the criterion, no significant difference occurred at the .05 level between the visual learning PAC method and the audile learning PAC method groups.

From an analysis of variance (Table 17), when 1 and 84 degrees of freedom were used, a value of .36 was not significant at the .05 level. Therefore, student ages were distributed into the visual learning PAC method and the audile learning PAC method groups with no significant difference. Hypothesis 1-3c was not rejected.

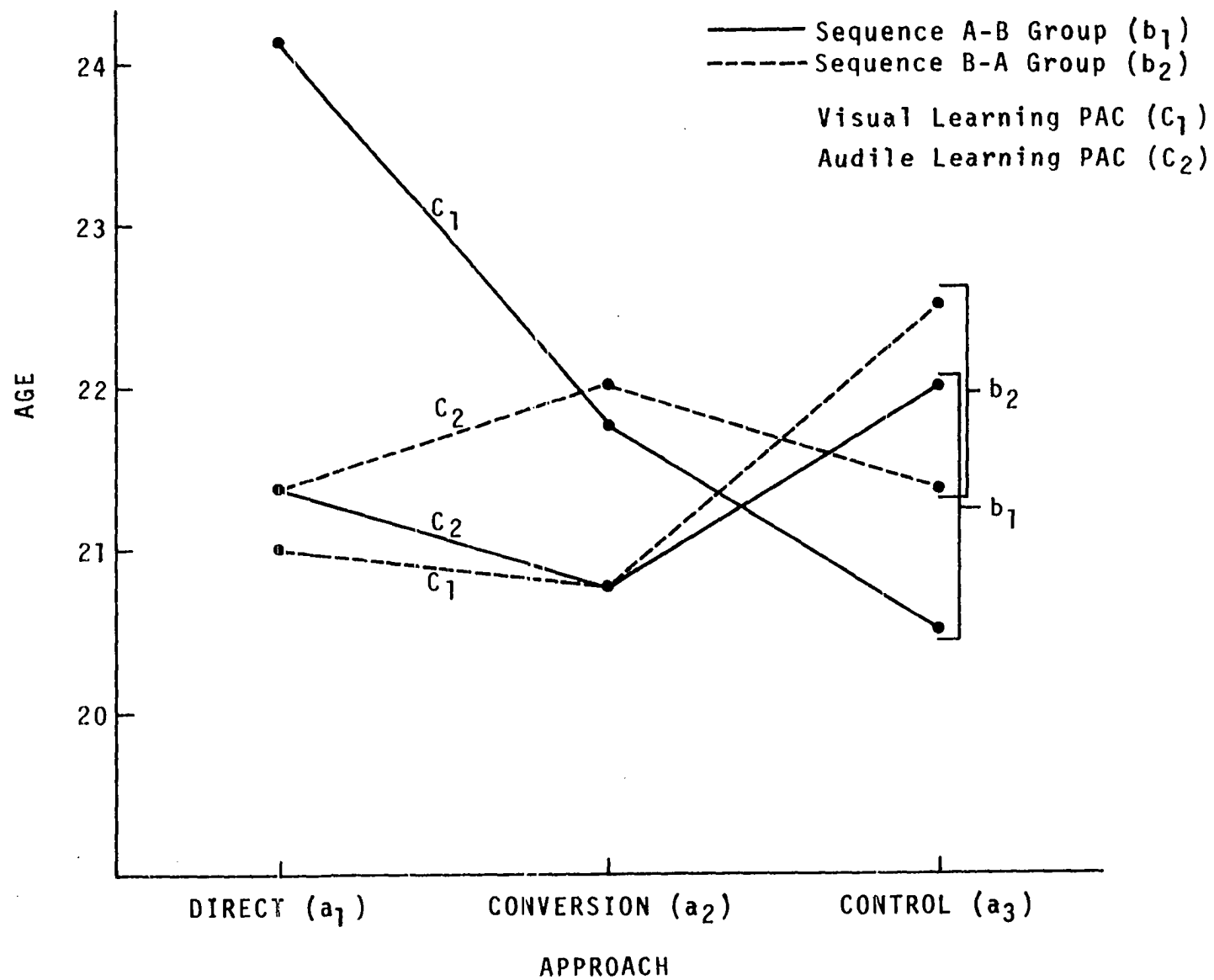
Hypothesis 1-3d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student age as the criterion.

From the analysis of variance (Table 17), no F-value of those three two-factor interaction terms exceeded the table value of F-ratio. However, the three-factor interaction term (approach x sequence x method) indicated the value of 3.35 exceeded the table value of F-ratio at .05 level. Therefore, student ages were distributed equally throughout these three two-factor classifications without any significant difference, but in the three-factor classification the student ages were distributed with significant difference. Three sub-hypotheses of the hypothesis 1-3d were not rejected. (The sub-hypothesis that the three-factor interaction effect has no significant

Table 18. Means of ages with three-factor classification

(A) approach	(B) sequence	(C) method	N	Mean of ages
(A ₁) direct	(B ₁) A - B group	(C ₁) visual PAC	8	24.13
(A ₁) direct	(B ₁) A - B group	(C ₂) audile PAC	8	21.38
(A ₁) direct	(B ₂) B - A group	(C ₁) visual PAC	8	21.00
(A ₁) direct	(B ₂) B - A group	(C ₂) audile PAC	8	21.38
(A ₂) conversion	(B ₁) A - B group	(C ₁) visual PAC	8	21.75
(A ₂) conversion	(B ₁) A - B group	(C ₂) visual PAC	8	20.75
(A ₂) conversion	(B ₂) B - A group	(C ₁) visual PAC	8	20.75
(A ₂) conversion	(B ₂) B - A group	(C ₂) audile PAC	8	22.00
(A ₃) control	(B ₁) A - B group	(C ₁) first	8	20.50
(A ₃) control	(B ₁) A - B group	(C ₂) second	8	22.00
(A ₃) control	(B ₂) B - A group	(C ₁) first	8	22.50
(A ₃) control	(B ₂) B - A group	(C ₂) second	8	21.38

Figure 8. The interaction of factors A x B x C for student ages



difference was rejected at .05 level.)

Table 18 and Figure 8 provide further analysis and discussion.

In the level of lower B (sequence A - B group), the main effect A (approach), C_1 (visual learning PAC) is negative, C_2 (audile learning PAC) is first negative and then positive.

In the level of higher B (sequence B - A group), the main effect A (approach), C_1 (visual learning PAC) is negative then positive, while C_2 (audile learning PAC) is positive and then negative.

The figure showed that in the classified group of direct approach, A - B group, visual learning PAC method, the mean of ages was higher than that in all other classified groups. Therefore, the analysis showed that student ages were not distributed evenly among each classified group. Due to this evidence, student age was considered as a covariate when applied to the subsequent analysis of covariance.

1-4. Academic classification (grade level) as the criterion of the learner variable

Hypothesis 1-4a: No significant difference occurred at the .05 level among direct approach, conversion approach, and control groups on the basis of student academic classification (grade level) as the criterion.

From an analysis of variance (Table 19), when 2 and 84 degrees of freedom were used, a value of 4.21 was significant

Table 19. Analysis of variance of the academic classification (grade level)

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	8.08	4.04	4.21 [*]
B (sequence)	1	0.26	0.26	0.27
C (method)	1	0.51	0.51	0.53
A x B	2	0.58	0.29	0.30
A x C	2	1.08	0.54	0.56
B x C	1	0.26	0.26	0.27
A x B x C	2	2.33	1.17	1.22
Residual	84	80.63	0.96	
Total (corrected)	95	93.74		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

^{*}F is significant at the .05 level.

at the .05 level. Therefore, student academic classifications were not distributed evenly in the direct approach, the conversion approach, and the control groups. Hypothesis 1-4a was rejected.

Orthogonal comparisons were made to break the main effect (approach) into portions, each with a single degree of freedom in order to test the difference between the combined

experimental group (direct approach and conversion approach) and the control group, as well as to test the difference between the two experimental groups (direct approach group and conversion approach group). Two sub-hypotheses were then tested by applying further analysis.

In his Methods for Data Analysis about the use of the group comparisons, Cox (1972) stated:

The simple analysis of variance provided a way of examining the evidence for the presence of group differences. Such an examination is only the first step in most analysis. A significant F-test based on $(a-1)$ and $(n-1)$ degrees of freedom indicates some differences among group means. More specific information on the nature of the group differences is almost always desired. The objective should be to subdivide the sum of squares for groups into portions each with a single degree of freedom, that that represent meaningful comparisons among the means. (p. 6-1)

Table 20. Further analysis of variance of the academic classification (grade level)

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	8.08	4.04	4.21 [*]
(1) experiment vs. control	(1)	7.57	7.57	7.89 ^{**}
(2) direct vs. conversion	(1)	0.64	0.64	0.67
Residual	84	80.63	0.96	

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

^{*}F is significant at the .05 level.

^{**}F is significant at the .01 level.

The sums of the squares of the comparisons are calculated below:

$$\begin{array}{llllll} \Sigma \lambda_1 = 0 & C_1 \text{ experiment vs. control} & 1 & 2 & 3 & \Sigma \lambda^2 \\ & & 1 & 1 & -2 & \Sigma \lambda_1^2 = 6 \\ \Sigma \lambda_2 = 0 & C_2 \text{ direct vs. conversion} & 1 & -1 & 0 & \Sigma \lambda_2^2 = 2 \end{array}$$

$$C_1^2 = (\bar{y}_{1.} + \bar{y}_{2.} - 2\bar{y}_{3.})^2 = (2.78 + 2.59 - 2 \times 3.28)^2 = 1.42$$

$$C_2^2 = (\bar{y}_{1.} - \bar{y}_{2.})^2 = (2.78 - 2.59)^2 = 0.04$$

$$SS_1 = \frac{nC_1}{\Sigma \lambda_1^2} = \frac{32 \times 1.42}{6} = \frac{45.44}{6} = 7.57$$

$$SS_2 = \frac{nC_2^2}{\Sigma \lambda_2^2} = \frac{32 \times 0.04}{2} = 0.64$$

Sub-hypothesis 1-4a-1: With student academic classification as the criterion, no significant difference occurred at the .05 level between the combined experimental group (direct approach group and conversion approach group) and the control group.

From further analysis of variance (Table 20), when 1 and 84 degrees of freedom were used, a value of 7.89 was significant at both .05 and .01 levels. Consequently, student academic classifications were distributed differently in the combined experimental group and the control group. Sub-hypothesis 1-4a-1 was rejected.

Sub-hypothesis 1-4a-2: No significant difference occurred at the .05 level between the direct approach group and the conversion approach group on the basis of student academic classification as the criterion.

From further analysis of variance (Table 20), when 1 and 84 degrees of freedom were used, a value of .67 was not significant at the .05 level. Therefore, student academic classifications were distributed in the direct approach group and the conversion approach group without any significant difference. Sub-hypothesis 1-4a-2 was not rejected.

Table 21. Means of academic classifications with direct approach, conversion approach, and control groups

Groups	N	Means of academic classifications
Direct approach	32	2.78
Conversion approach	32	2.59
Control	32	3.28

Since sub-hypothesis 1-4a-1 was rejected but sub-hypothesis 1-4a-2 was not rejected, the evidence showed that the distribution of academic classifications was not equal between the combined experimental group and the control group, but was equal between the two experimental groups. From the table of group means (Table 21), it can be seen that the mean of control group was higher than that of the other two groups. Thus, the subjects in the control group were, on the average, higher grade level students. The equality of two experimental groups provided an equal base for testing the treatment effect between the direct approach group and the conversion approach group. On the other hand, the difference between the control group and the combined experimental group led the experimenter to use the learner variable of academic classification as a covariate for the analysis of covariance.

Hypothesis 1-4b: No significant difference occurred at the .05 level between the test sequences, A - B group and

B - A group, on the basis of student academic classification as the criterion.

From an analysis of variance (Table 19), when 1 and 84 degrees of freedom were used, a value of .27 was not significant at the .05 level. Therefore, student academic classifications were distributed throughout the sequence A - B group and the sequence B - A group without any significant difference, and hypothesis 1-4b was not rejected.

Hypothesis 1-4c: There was no significant difference at the .05 level between the visual learning PAC method and audile learning PAC method groups on the basis of student academic classification as the criterion.

From an analysis of variance (Table 19), when 1 and 84 degrees of freedom were used, a value of .53 was not significant at the .05 level. Therefore, student academic classifications were distributed throughout the visual learning PAC method group and the audile learning PAC method group without any significant difference.

Hypothesis 1-4d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student academic classification as the criterion.

From an analysis of variance (Table 19), no F-value of interaction terms exceeded the table value of F-ratio. No significant difference occurred at the .05 level with any

interaction effects. Hence, student academic classifications were distributed throughout all effect classifications without any significant difference. Hypothesis 1-4d was not rejected.

1-5. ACT (American College Test) score as the criterion of the learner variable

Table 22. Analysis of variance of the ACT score

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	83.57	41.79	2.28
B (sequence)	1	1.11	1.11	0.06
C (method)	1	6.47	6.47	0.35
A x B	2	55.08	27.54	1.51
A x C	2	17.90	8.95	0.49
B x C	1	10.15	10.15	0.56
A x B x C	2	6.85	3.43	0.19
Residual	59 ^a	1079.00	18.29	
Total (corrected)	70 ^a	1250.31		

Table value of F-ratio at .05 level with 1 and 59 degrees of freedom used is 4.00.

Table value of F-ratio at .05 level with 2 and 59 degrees of freedom used is 3.15.

^aThe reduced number of degrees of freedom of residual and corrected total due to 25 missing data.

Because of the lack of 25 ACT scores, the analysis of variance was obtained by using the procedure of regression of the SAS program.

Hypothesis 1-5a: Among direct approach, conversion approach, and control groups on the basis of student ACT scores as the criterion, no significant difference occurred at the .05 level.

From an analysis of variance (Table 22), when 2 and 59 degrees of freedom were used, a value of 2.28 was not significant at the .05 level. Student ACT scores were distributed throughout the direct approach, conversion approach, and control groups without any significant difference, thus hypothesis 1-5a was not rejected.

Hypothesis 1-5b: No significant difference occurred at the .05 level between the test sequences, A - B group and B - A group, on the basis of student ACT scores as the criterion.

From an analysis of variance (Table 22), when 1 and 59 degrees of freedom were used, a value of .06 was not significant at the .05 level. Therefore, student ACT scores were distributed in the sequence A - B group and the sequence B - A group without any significant difference. Hypothesis 1-5b was not rejected.

Hypothesis 1-5c: No significant difference occurred at the .05 level between the visual learning PAC method and

the audile learning PAC method groups on the basis of student ACT scores as the criterion.

From an analysis of variance (Table 22), when 1 and 59 degrees of freedom were used, a value of .35 was not significant at the .05 level. Therefore, there was no significant difference in distribution of student ACT scores in the visual learning PAC method and the audile learning PAC method groups. Hypothesis 1-5c was not rejected.

Hypothesis 1-5d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student ACT scores as the criterion.

From an analysis of variance (Table 22), no F-value of interaction variables exceeded the table value of F-ratio. No significant difference occurred at the .05 level in any interaction effects. Therefore, student ACT scores were distributed throughout all classifications without any significant difference. Hypothesis 1-5d was not rejected.

Since the missing data in student ACT scores represented 26 percent of the total ACT scores, the value of this statistical result would be only considered as partially supporting information.

1-6. Student high school rank as the criterion of the learner variable

Table 23. Analysis of variance of the high school rank

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	6007.65	3003.83	5.61**
B (sequence)	1	25.86	25.86	0.05
C (method)	1	0.50	0.50	0.00
A x B	2	348.59	174.30	0.33
A x C	2	188.93	94.47	0.18
B x C	1	767.39	767.39	1.43
A x B x C	2	115.12	557.76	1.04
Residual	80 ^a	42861.07	535.76	
Total (corrected)	91 ^a	51432.21		

Table value of F-ratio at .05 level with 1 and 80 degrees of freedom used is 3.96.

Table value of F-ratio at .05 level with 2 and 80 degrees of freedom used is 3.11.

^aThe reduced number of degrees of freedom of residual and corrected total is due to 4 missing bits of data.

** F is significant at the .01 level.

Because of the lack of 4 high school percentile ranks, the analysis of variance was obtained by using the procedure of regression of the SAS program.

Hypothesis 1-6a: No significant difference occurred at the .05 level among direct approach, conversion approach, and control groups on the basis of student high school percentile rank as the criterion.

From an analysis of variance (Table 23), when 2 and 80 degrees of freedom were used, a value of 5.61 was significant at both .05 and .01 level. Therefore, student high school percentile ranks were not distributed evenly in the direct approach, conversion approach, and control groups. Hypothesis 1-6a was rejected.

Due to the 4 missing data, orthogonal comparisons were not desirable to be used for the further analysis. However, the group means were tabulated as follows for further discussion.

Table 24. Means of high school percentile ranks with direct approach, conversion approach, and control groups

Groups	N	Means of high school rank
Direct approach	32	50.25
Conversion approach	31	32.10
Control	29	34.83

From Table 24, it can be noted that the mean of the direct approach group was much higher than that of the other groups, and the mean of the control group was slightly higher than that of the conversion approach group. This means that students in the conversion approach group had better high school records than did students in the control and direct approach groups. Students in the direct approach group had, on the average, much lower high school records.

Because this significant difference among groups existed, the analysis of covariance was considered to be used for the major hypothesis tests with high school rank as a covariate.

Hypothesis 1-6b: At the .05 level between the test sequences, A - B group and B - A group, no significant difference occurred on the basis of student high school rank as the criterion.

From an analysis of variance (Table 23), when 1 and 80 degrees of freedom were used, a value of .05 was not significant at the .05 level; thus, student high school ranks were distributed throughout the sequence A - B group and the sequence B - A group with no significant difference. Hypothesis 1-6b was not rejected.

Hypothesis 1-6c: No significant difference occurred at the .05 level between the visual learning PAC method and audile learning PAC method groups on the basis of student high school rank as the criterion.

From an analysis of variance (Table 23), when 1 and 80 degrees of freedom were used, a value of .00 was not significant at the .05 level. Therefore, student high school ranks were distributed throughout the visual learning PAC method group and the audile learning PAC method group without any significant difference, and hypothesis 1-6c was not rejected.

Hypothesis 1-6d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student high school rank as the criterion.

From an analysis of variance (Table 23), no F-value of interaction terms exceeded the table value of F-ratio, and no significant difference occurred at the .05 level in any interaction effects. Student high school ranks were therefore distributed throughout all effect classifications without any significant difference. Hypothesis 1-6d was not rejected.

1-7. High school size as the criterion of the learner variable

Hypothesis 1-7a: No significant difference occurred at the .05 level among the direct approach, conversion approach, and control groups on the basis of students' high school size as the criterion.

From an analysis of variance (Table 25), when 2 and 84 degrees of freedom were used, a value of 1.67 was not significant at the .05 level. Therefore, student high school sizes were distributed throughout the direct approach, the conversion

Table 25. Analysis of variance of high school size

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	12.90	6.45	1.67
B (sequence)	1	15.04	15.04	3.90
C (method)	1	6.00	6.00	1.55
A x B	2	21.40	10.70	2.77
A x C	2	9.44	4.72	1.22
B x C	1	12.04	12.04	3.12
A x B x C	2	0.77	0.39	0.09
Residual	84	324.25	3.86	
Total (corrected)	95	401.83		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

approach, and the control groups without any significant difference. Hypothesis 1-7a was not rejected.

Hypothesis 1-7b: No significant difference occurred at the .05 level between the test sequences, A - B group and B - A group, on the basis of students' high school size as the criterion.

From an analysis of variance (Table 25), when 1 and 84 degrees of freedom were used, a value of 3.90 was not significant at the .05 level. Therefore, student high school sizes

were distributed in the sequence A - B group and the sequence B - A group without any significant difference. Hypothesis 1-7b was not rejected.

Hypothesis 1-7c: At the .05 level, no significant difference occurred between the visual learning PAC method and audile learning PAC method groups on the basis of student high school size as the criterion.

From an analysis of variance (Table 25), with 1 and 84 degrees of freedom used, a value of 1.55 was not significant at the .05 level; hence, student high school sizes were distributed in the visual learning PAC method and the audile learning PAC method groups without any significant difference. Hypothesis 1-7c was not rejected.

Hypothesis 1-7d: No significant differences occurred at the .05 level for all possible combined interaction effects on the basis of student high school size as the criterion.

From an analysis of variance (Table 25), no F-value of interaction terms exceeded the table value of F-ratio. No significant differences occurred at the .05 level in any interaction effects. Since student high school sizes were distributed throughout all classifications without any significant difference, hypothesis 1-7d was not rejected.

The findings of the previous tests of seven learner variables indicated that the distributions of the learner variables of curriculum major, option of concentration, ACT score

and high school size were not significantly different in the three main factors and all possible interaction combinations.

The learner variable of student age was significantly different at the .05 level concerning the three-way main factor effect. Therefore, student age will be used as a covariate for the two final analyses.

Both learner variables of academic classification and high school rank were found to be significantly different with the classification of the main factor, systems approach, at the .05 level. Consequently, the academic classification and high school rank will be used as covariates for the two final analyses.

The seven learner variables tested were considered as possible factors which might effect the learning of metric system. Sheila Mason has indicated that "Many surveys showed that acceptance of metric measures decreased with age, lack of education, and lower social status" (1975, p. 7). McFee also pointed out that learning factors such as I.Q., social and cultural background, critical thinking ability and age level needed to be considered for effective teaching metric measures (1967, p. 81).

Three of seven learner variables which were identified by the researcher showed uneven distribution in the random assignment. In order to better control the results of this study,

these three variables will be used as covariates for the final analyses.

Testing of Hypotheses Group 2

Group 2. Test of previous metric system knowledge and reading ability

Pretest scores and the Nelson-Denny Reading Test scores were the two criteria for testing these two hypotheses.

The three-factor model was applied to analyze these two variables. The three factors were (1) approach, (2) sequence, and (3) method. The 3x2x2 factorial analysis of variance was used. All hypotheses of this group tested statistically by the analysis of variance were accepted at the F-ratio .05 level of significance. If the results were significant at the .01 level, it was reported as such.

2-1. Pretest score as the criterion of the previous metric system knowledge

Hypothesis 2-1a: No significant differences occurred at the .05 level among the direct approach, conversion approach, and control groups on the basis of student metric pretest score as the criterion.

From an analysis of variance (Table 26), using 2 and 84 degrees of freedom, a value of 1.36 was not significant at the .05 level; thus, the students' previous knowledge of the metric system in the direct approach, conversion approach, and

Table 26. Analysis of variance of the metric pretest scores

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	213.40	106.70	1.36
B (sequence)	1	243.84	243.84	3.11
C (method)	1	3.76	3.76	0.05
A x B	2	60.44	30.22	0.39
A x C	2	26.65	13.32	0.17
B x C	1	10.01	10.01	0.13
A x B x C	2	27.02	13.51	0.17
Residual	84	6590.88		
Total (corrected)	95	7175.99		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

control groups was not significantly different. Thus hypothesis 2-1a was not rejected.

A table of group means was provided (Table 27) for further interpretation.

From Table 27, the mean of the control group was higher than the other groups, while the mean of the conversion group was slightly lower than the control group but higher than that of the direct approach group. This indicates that students in the control group had a better background of metric system

Table 27. Means of metric pretest scores with direct approach, conversion approach, and control groups

Groups	N	Means of metric pretest scores
Direct approach	32	29.09
Conversion approach	32	31.94
Control	32	32.50

than did those students in the conversion and direct approach groups. Although the analysis of variance indicated there was no significant difference among the three groups, the evidence of the different sample means did provide useful information.

Hypothesis 2-1b: Between the test sequence, A - B group and B - A group, no significant difference occurred at the .05 level on the basis of the students' metric pretest scores as the criterion.

From an analysis of variance (Table 26), when 1 and 84 degrees of freedom were used, a value 3.11 was not significant at the .05 level. Therefore, test forms did not produce any significant difference. This finding could be utilized to show the evidence of equal tests between the Form A test and the Form B test. Hypothesis 2-1b was not rejected.

Since the F-value of 3.11 was close to the table value of F-ratio of 3.95, it is necessary to check the means of the two groups. Table 28 identifies the mean of Form B test as higher

Table 28. Means of metric pretest scores with Form A test and Form B test

Groups	N	Means of metric pretest scores
Form A (A - B group)	48	29.58
Form B (B - A group)	48	32.77

than the mean of Form A test. It is possible that the Form B test was slightly easier than the Form A test. However, this difference is not statistically significant.

Hypothesis 2-1c: On the basis of student metric pretest scores as the criterion, no significant difference occurred at the .05 level between the visual learning PAC method and the audile learning PAC method groups.

An analysis of variance (Table 26), when 1 and 84 degrees of freedom were used, show a value .05 was not significant at the .05 level. Therefore the students' previous knowledge of the metric system was equally distributed throughout the visual learning PAC method group and the audile learning PAC method group. Hypothesis 2-1c was not rejected.

The means of these two groups were very close (see Table 29).

Table 29. Means of metric pretest scores with visual learning PAC method group and audile learning PAC method group

Groups	N	Means of metric pretest scores
Visual learning PAC method	48	30.98
Audile learning PAC method	48	31.38

Hypothesis 2-1d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student metric pretest score as the criterion.

From an analysis of variance (Table 26), no F-value of interaction effects exceeded the table value of F-ratio. No significant difference occurred at the .05 level between any interaction effects. Therefore, students' previous knowledge of metric system was distributed throughout all classifications without any significant difference. Hypothesis 1-3d was not rejected.

The findings of the previous four hypotheses indicate that the previous knowledge of metric system of all experiment classifications was evenly distributed. Therefore, no initial differences existed. This evidence provides sound support for the main findings of the study.

2-2. The Nelson-Denny Reading Test score as the criterion of the preferable learning ability

Table 30. Analysis of variance of the Nelson-Denny Reading Test scores

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	103.27	51.64	0.11
B (sequence)	1	42.67	42.67	0.09
C (method)	1	0.00	0.00	0.00
A x B	2	7.27	3.64	0.01
A x C	2	982.31	491.16	1.09
B x C	1	60.17	60.17	0.13
A x B x C	2	1278.40	639.20	1.41
Residual	84	37977.75	452.12	
Total (corrected)	95	40451.83		

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

Hypothesis 2-2a: No significant difference occurred at the .05 level among the direct approach, conversion approach, and control groups on the basis of student Nelson-Denny Reading Test score as the criterion.

From an analysis of variance (Table 30), when 2 and 84 degrees of freedom were used, a value of .11 was not

significant at the .05 level. Therefore, student reading ability was distributed throughout the direct approach, the conversion approach, and the control groups without any significant difference. The reading ability of the subjects in each of these three groups was statistically equal. Reading ability, consequently, did not contribute any influence to the analysis under the main effect regarding the approach used. Hypothesis 2-2a was not rejected.

Hypothesis 2-2b: No significant difference occurred at the .05 level between the test sequences, A - B group and B - A group, with student Nelson-Denny Reading Test score as the criterion.

An analysis of variance (Table 30), using 1 and 84 degrees of freedom, indicates a value of .09 not to be significant at the .05 level. Therefore, student reading ability was distributed throughout the sequence A - B group and the sequence B - A group without any significant difference. The subjects who took Form A test as a pretest had the same reading ability as did those who took Form B test as a pretest. Hypothesis 2-2b was not rejected.

Hypothesis 2-2c: No significant difference occurred at the .05 level between the visual learning PAC method and audile learning PAC method groups on the basis of student Nelson-Denny Reading Test score as the criterion.

From an analysis of variance (Table 30), when 1 and 84 degrees of freedom were used, a value of .00 was not significant at the .05 level. Therefore, student reading ability was distributed throughout the visual learning PAC method and the audile learning PAC method groups without any significant difference. The subjects who were assigned to visual learning PAC method group had the same reading ability as did those who were assigned to audile learning PAC method group. Reading ability did not contribute any influence to the analysis under the main effect regarding method. Hypothesis 2-2c was not rejected.

Hypothesis 2-2d: No significant difference occurred at the .05 level for all possible combined interaction effects on the basis of student Nelson-Denny Reading Test score as the criterion.

From an analysis of variance (Table 30), no F-value of interaction effects exceeded the table value of F-ratio, and no significant difference occurred at the .05 level in any interaction effects. Therefore, the Nelson-Denny Reading Test scores of the subjects were distributed throughout all classifications without any significant difference. The subjects under any combined experiment classification had equal reading ability. Hypothesis 2-2d was not rejected.

The facts identified from the previous four hypotheses testings provided information regarding the equal reading

ability in all experiment classifications of the three main effects and their interaction effects. Reading ability did not contribute any effect through the experiment. In other words, any differences occurring in the analysis were not due to reading ability.

Testing of Hypotheses Group 3

Group 3. Test of the test sensitization

Pretest and posttest scores were compared and analyzed separately in the experimental and control groups.

Three factors — sequence, method, and test trial — were considered in analyzing the difference between the pretest and posttest scores of the control group. The four-factor model was applied to analyze the difference of pretest and posttest scores between the two experimental groups and used as factors (1) approach, (2) sequence, (3) method, and (4) test trial. All hypotheses tested statistically by the analysis of variance were accepted at the F-ratio .05 level of significance. If the results were significant at the .01 level, they were reported as such.

3-1. Pretest and posttest scores as the criteria of the test sensitization of the control group

Hypothesis 3-1a: No significant difference occurred at the .05 level between the pretest scores and posttest scores in the control group.

Table 31. Analysis of variance of the pretest and posttest scores of the control group

Source of variation	d.f.	S.S.	M.S.	F
B (sequence)	1	34.52	34.52	0.24
C (method)	1	135.14	135.14	0.94
B x C	1	102.52	102.52	0.72
Error B	28	4011.18	143.26	
D (test trial) ^a	1	70.14	70.14	3.15
B x D ^a	1	26.27	26.27	1.18
C x D	1	17.02	17.02	0.76
B x C x D	1	2.64	2.64	0.12
Error W	28	624.44	22.30	
Total (corrected)	63	5023.86		

Table value of F-ratio at .05 level with 1 and 28 degrees of freedom used is 4.20.

^aThe sources will be discussed.

From an analysis of variance (Table 31), when 1 and 28 degrees of freedom were used, a value of 3.15 was not significant at the .05 level. Therefore, pretest scores and posttest scores of students in the control group were not significantly different. The analysis revealed no significant score gain in the posttest after the pretest, meaning there was no test sensitization happening through the test process in the control group. Hypothesis 3-1a was not rejected.

Hypothesis 3-1b: At the .05 level of interaction effect, no significant difference occurred between the test sequence and test trial on the basis of the pretest and posttest scores as the criteria.

With analysis of variance (Table 31), using 1 and 28 degrees of freedom, a value of 1.18 was not significant at the .05 level. Therefore, there was no significant difference of interaction effect between the test sequence and test trial. Neither the subjects taking Form A as pretest and Form B as posttest, nor subjects in the reverse sequence exhibited differences between pretest scores and posttest scores. Hypothesis 3-1b was not rejected.

The results of the previous two hypotheses testings indicated that the control group in which the subjects received no instructional treatment had no significant difference between pretest scores and posttest scores. Subjects in the control group did not gain any test experience from the pretest.

3-2. Pretest and posttest scores as the criteria of the test sensitization of the two experimental groups

Hypothesis 3-2a: No significant difference occurred at the .05 level between the pretest scores and posttest scores in either of the two experimental groups.

From an analysis of variance (Table 32), taking 1 and 56 degrees of freedom, a value of 125.68 was significant at both

Table 32. Analysis of variance of the pretest and posttest scores of experimental groups

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	1	175.78	175.78	1.67
B (sequence)	1	144.50	144.50	1.38
C (method)	1	0.13	0.13	0.00
A x B	1	13.78	13.78	0.13
A x C	1	0.03	0.03	0.00
B x C	1	3.13	3.13	0.03
A x B x C	1	0.03	0.03	0.00
Error B	56	5881.14	105.02	
D (test trial) ^a	1	2096.28	2096.28	125.68 ^{**}
A x D	1	8.00	8.00	0.48
B x D	1	52.53	52.53	3.15
C x D	1	2.53	2.53	0.15
A x B x D	1	50.00	50.00	3.00
A x C x D	1	1.13	1.13	0.07
B x C x D	1	5.28	5.28	0.32
A x B x C x D	1	1.13	1.13	0.07
Error W	56	934.13	16.68	
Total (corrected)	127	9369.50		

Table value of F-ratio at .05 level with 1 and 56 degrees of freedom used is 4.01.

^aThe source will be discussed.

^{**}F is significant at the .01 level.

the .05 and .01 levels. Therefore, student pretest scores and posttest scores in the experimental groups were significantly different, and hypothesis 3-2a was rejected.

It might be interpreted that the instructional treatment resulted in significant gain as reflected in the posttest scores. Table 33 provides the high difference between the mean scores of pretest and posttest.

Table 33. Means of pretest and posttest scores in the experimental group

Groups	N	Means of scores
Pretest	64	30.52
Posttest	64	38.61

From the results of hypotheses 3-1a and 3-2a, it can be concluded that no test experience occurred through the pretest-posttest process in the experimental groups. Thus, differing pretest and posttest scores were due to instructional treatment.

The evaluation of this test-retest learning for the experimental and the control group separately was complementary to the combined four-factor model test identified in hypotheses group 6.

Testing of Hypotheses Group 4

Group 4. Test of achievement

Students metric posttest scores were the criterion to be used for identifying any learning achievement resulting from variously prepared types of instruction. The three-factor model was applied to analyze the posttest scores. Metric pretest scores were the covariate in the analysis of covariance. The three factors employed were (1) approach, (2) sequence, and (3) method. All hypotheses of this group tested statistically by the analysis of covariance were accepted at the F-ratio .05 level of significance. If the results were significant at the .01 level, this was reported as such.

4-1. Metric posttest score as the criterion of testing the learning achievement

Hypothesis 4-1a: No significant difference occurred at the .05 level in the achievement of the direct approach, conversion approach, and control groups on the basis of student posttest score as the criterion and student pretest score as the covariate.

From an analysis of covariance (Table 34), when 2 and 83 degrees of freedom were used, a value of 10.92 was significant at both the .05 and .01 levels. Therefore, learning achievement among the direct approach, conversion approach, and control groups was significantly different, and hypothesis 4-1a

Table 34. Analysis of covariance of the student metric post-test score using student metric pretest score as the covariate

Source of variation	d.f.	S.S.	M.S.	F
A (approach) ^a	2	585.38	292.69	10.92 ^{**}
B (sequence)	1	44.73	44.73	1.67
C (method)	1	35.01	35.01	1.31
A x B	2	51.65	25.83	0.96
A x C	2	30.11	15.06	0.56
B x C	1	26.42	26.42	0.99
A x B x C	2	4.93	2.47	0.09
E (pretest) ^b	1	2634.38	2634.38	98.24 ^{**}
Residual	83	2225.62	26.81	
Total (corrected)	95	5478.96		

Table value of F-ratio at .05 level with 1 and 83 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 83 degrees of freedom used is 3.10.

^aThe sources were discussed.

^bCovariate.

^{**}F is significant at the .01 level.

was rejected.

Orthogonal comparisons were made in order to break the main effect-approach into portions each with a single degree of freedom so as to test the difference between the combined

experimental group (direct approach and conversion approach) and the control group, and the difference between the two experimental groups — direct approach group and conversion approach group. Two sub-hypotheses were then tested with further analysis.

Table 35. Further analysis of variance of the student metric posttest score (covariate: pretest score)

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	585.38	292.69	10.92**
(1) experiment vs. control	(1)	591.36	591.36	22.06**
(2) direct vs. conversion	(1)	0.04	0.04	0.00
Residual	83	2225.62	26.81	

Table value of F-ratio at .05 level with 1 and 83 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 83 degrees of freedom used is 3.10.

** F is significant at the .01 level.

The sums of the squares of the comparisons were calculated as follow:

$$\begin{array}{llllll}
 \Sigma \lambda_1 = 0 & C_1 \text{ experiment vs. control} & 1 & 2 & 3 & \Sigma \lambda^2 \\
 & & 1 & 1 & -2 & \Sigma \lambda_1^2 = 6 \\
 \Sigma \lambda_2 = 0 & C_2 \text{ direct vs. conversion} & 1 & -1 & 0 & \Sigma \lambda_2^2 = 2
 \end{array}$$

$$C_1^2 = (\bar{y}_1. + \bar{y}_2. - 2\bar{y}_3.)^2 = (39 + 39.05 - 2 \times 33.76)^2 = 110.88$$

$$C_1^2 = (\bar{y}_1. + \bar{y}_2.)^2 = (39 - 39.05)^2 = 0.0025$$

$$SS_1 = \frac{nC_1^2}{\Sigma\lambda_1^2} = \frac{32 \times 110.88}{6} = \frac{3548.16}{6} = 591.36$$

$$SS_2 = \frac{nC_2^2}{\Sigma\lambda_2^2} = \frac{32 \times 0.0025}{2} = \frac{0.08}{2} = 0.04$$

Sub-hypothesis 4-1a-1: No significant difference occurred at the .05 level between the combined experimental group and the control group on the basis of student posttest score as the criterion, and student pretest score as the covariate.

After further analysis of variance (Table 35), with 1 and 83 degrees of freedom, a value of 22.06 was significant at both the .05 and .01 levels. Thus, the student posttest scores of the combined experimental group were significantly different from the student posttest scores of the control group. Sub-hypothesis 4-1a-1 was rejected.

Sub-hypothesis 4-1a-2: At the .05 level between the direct approach group and the conversion group on the basis of student posttest score as the criterion, and student pretest score as the covariate, no significant difference occurred.

Furthermore, from additional analysis of variance (Table 35), when 1 and 83 degrees of freedom were used, a value of .00 was not significant at the .05 level. Student posttest scores of the direct approach group, therefore, were not significantly different from those posttest scores of the conversion approach group. Sub-hypothesis 4-1a-2 was not rejected.

Table 36. Adjusted means of student metric posttest scores with direct approach, conversion approach, and control groups

Groups	N	Adjusted means of posttest scores
Direct approach	32	39.00
Conversion approach	32	39.05
Control	32	33.76

Table 36 indicates that the mean of the posttest score of the control group was lower than were the posttest scores of both the direct approach and the conversion approach groups. However, the mean posttest scores of the direct approach group and the conversion approach group were very close. From the results of sub-hypothesis 4-1a-1 and sub-hypothesis 4-1a-2 testings and the evidence of the adjusted mean table, it can be ascertained that the different types of metric instruction resulted in significant learning achievement.

Testing of Hypotheses Group 5

Group 5. Test of instructional effects

The students' metric posttest scores were the criterion to be used for testing whether differences occurred due to different approaches, methods and test sequences. The three-factor model — using approach, sequence, and method — was applied to analyze the posttest scores, with student age, academic classification, and high school rank as covariates for the analysis of covariance. All hypotheses of this group tested statistically by the analysis of covariance were accepted at the F-ratio .05 level of significance. Results significant at the .01 level were reported as such.

5-1. Metric posttest score as the criterion of testing the instructional effects

Hypothesis 5-1a: No significant difference occurred at the .05 level among the instructional effects of the direct approach, conversion approach, and control groups on the basis of student metric posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

After an analysis of covariance (Table 37), using 2 and 81 degrees of freedom, a value of 5.58 was significant at both the .05 and .01 levels. Thus, instructional effects among the direct approach, conversion approach, and control groups were

Table 37. Analysis of covariance of the student metric post-test score with student age, academic classification, and high school rank as the covariates

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	581.18	290.59	5.58**
B (sequence)	1	0.56	0.56	0.01
C (method)	1	79.69	79.69	1.53
A x B	2	7.53	3.77	0.07
A x C	2	62.78	31.39	0.60
B x C	1	77.25	77.25	1.48
A x B x C	2	16.20	8.10	0.16
F (age) ^a	1	7.55	7.55	0.14
G (academic classification) ^a	1	151.89	151.89	2.92
H (high school rank) ^a	1	318.36	318.36	6.11*
Residual	81	4219.85	52.10	
Total (corrected)	95	5478.96		

Table value of F-ratio at the .05 level with 1 and 81 degrees of freedom used is 3.96.

Table value of F-ratio at the .05 level with 2 and 81 degrees of freedom used is 3.11.

^aCovariate.

* F is significant at the .05 level.

** F is significant at the .01 level.

significantly different, and hypothesis 5-1a was rejected.

Orthogonal comparisons were made to break the main effect-approach into portions each with a single degree of freedom so the difference between the combined experimental group (direct approach and conversion approach) and the control group and the difference between the two experimental groups (direct approach group and conversion approach group) might be tested. Two sub-hypotheses were then tested by further analysis.

Table 38. Further analysis of variance of the student metric posttest scores (covariates: age, academic classification, high school rank)

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	581.18	290.59	5.58**
(1) experiment vs. control	(1)	653.55	653.55	12.54**
(2) direct vs. conversion	(1)	3.20	3.20	0.06
Residual	81	4219.85	52.10	

Table value of F-ratio at the .05 level with 1 and 81 degrees of freedom used is 3.96.

Table value of F-ratio at the .05 level with 2 and 81 degrees of freedom used is 3.11.

** F is significant at the .01 level.

The sums of squares of the comparisons were calculated as follow:

$$\begin{array}{llllll} \Sigma\lambda_1 = 0 & C_1 \text{ experiment vs. control} & 1 & 2 & 3 & \Sigma\lambda^2 \\ & & 1 & 1 & -2 & \Sigma\lambda_1^2 = 6 \\ \Sigma\lambda_2 = 0 & C_2 \text{ direct vs. conversion} & 1 & -1 & 0 & \Sigma\lambda_2^2 = 2 \end{array}$$

$$C_1^2 = (\bar{y}_{1.} + \bar{y}_{2.} - 2\bar{y}_{3.})^2 = (38.89 + 39.34 - 2 \times 33.58)^2 = 122.54$$

$$C_2^2 = (\bar{y}_{1.} - \bar{y}_{2.})^2 = (38.89 - 39.34)^2 = 0.20$$

$$SS_1 = \frac{nC_1}{\Sigma\lambda_1^2} = \frac{32 \times 122.54}{6} = \frac{3921.28}{6} = 653.55$$

$$SS_2 = \frac{nC_2}{\Sigma\lambda_2^2} = \frac{32 \times 0.20}{2} = \frac{6.4}{2} = 3.2$$

Sub-hypothesis 5-1a-1: No significant difference occurred at the .05 level between the combined experimental group and the control group on the basis of student posttest score as the criterion, and student age, academic classification, and high school rank as the covariates.

Upon further analysis of variance (Table 38), with 1 and 81 degrees of freedom, a value of 12.54 was significant at both the .05 and .01 levels. Student posttest scores of the combined experimental group were consequently significantly different than were student posttest scores of the control group; sub-hypothesis 5-1a-1 was rejected.

Sub-hypothesis 5-1a-2: There was no significant difference at the .05 level between the direct approach group and the conversion group on the basis of student posttest score as the criterion, and student age, academic classification, and high school rank as the covariates.

Upon further analysis of variance (Table 38), when 1 and 81 degrees of freedom were used, a value of .06 had no significance at the .05 level. Therefore, student posttest scores of the direct approach group were not significantly different from those posttest scores of the conversion approach group, and sub-hypothesis 5-1a-2 was not rejected.

Table 39. Adjusted means of student posttest scores of the direct approach and conversion approach with student age, academic classification, and high school rank as the covariates

Groups	N	Adjusted means
Direct approach	32	38.89
Conversion approach	32	39.34

The adjusted mean table (Table 39) showed that subjects studying conversion approach received a slightly higher posttest score than did those following the direct approach. However, this difference was not significant enough to determine if one approach was superior to the other.

Student age, academic classification, and high school rank were found to be unevenly distributed within the experiment classifications (see hypotheses 1-3d, 1-4a, 1-6a). In order to control the fact of initial differences of subjects, the analysis of covariance was utilized. The results revealed significant differences in three hypotheses testings between the subjects who received the metric instruction via the direct approach or the conversion approach and those subjects who were not exposed to the treatment. However, no differences occurred in the scores of the subjects who received the metric instruction utilizing either the direct approach or the conversion approach.

Hypothesis 5-1b: There was no significant difference at the .05 level between the test sequence A - B group and sequence B - A group on the basis of student posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

From an analysis of covariance (Table 37), using 1 and 81 degrees of freedom, a value of .01 was not significant at the .05 level, and therefore, posttest scores of students in test sequence A - B group were no different than posttest scores of students in test sequence B - A group. Hypothesis 5-1b was not rejected.

The results of test of hypothesis 5-1b showed that students who took Form A test as the pretest, followed by Form B

test as the posttest, did not make any significantly different score than did those who took Form B test as the pretest with Form A as the posttest. It can also be observed that whatever the sequence of taking these tests, the order would not effect the result of the study.

Hypothesis 5-1c: No significant difference occurred at the .05 level between the visual learning PAC method and the audile learning PAC method groups on the basis of student posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

An analysis of covariance (Table 37), when 1 and 81 degrees of freedom were used, a value of 1.53 had no significance at the .05 level. Therefore, posttest scores of students who received metric instruction under the visual learning PAC method were not different from the scores of those who received metric instruction under the audile learning PAC method. Hypothesis 5-1c was not rejected.

The adjusted means of these two method groups (see Table 40) indicate that students utilizing the audile learning PAC method did better work in the posttest than did those following the visual learning PAC method. However, this slight difference was not significant enough to conclude that one method was better than the other.

Table 40. Adjusted means of student posttest scores of the visual learning PAC method and the audile learning PAC method using student age, academic classification, and high school rank as the covariates

Groups	N	Adjusted means
Visual learning PAC method	48	36.36
Audile learning PAC method	48	38.19

Hypothesis 5-1d: No significant difference occurred at the .05 level between the interaction effect of approach and sequence, on the basis of student posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

With an analysis of covariance (Table 37), using 2 and 81 degrees of freedom, a value of .07 was not significant at the .05 level. Therefore, there was no interaction effect between the approach factor and sequence factor. Hypothesis 5-1d was not rejected.

Hypothesis 5-1e: At the .05 level, no significant difference occurred between the interaction effect of approach and method, on the basis of student posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

From an analysis of covariance (Table 37), when 2 and 81 degrees of freedom were used, a value of .60 was not

significant at the .05 level, and there was no interaction effect between the approach factor and the method factor. Thus, hypothesis 5-le was not rejected.

Hypothesis 5-lf: No significant difference occurred at the .05 level between the interaction effect of sequence and method, on the basis of student posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

An analysis of covariance (Table 37), when 1 and 81 degrees of freedom were used, indicates a value of 1.48 not to be significant at the .05 level. Therefore, there was no interaction effect between the method factor and the sequence factor. Hypothesis 5-lf was not rejected.

Hypothesis 5-lg: There was no significant difference at the .05 level among the interaction effect of approach, sequence, and method, on the basis of student posttest score as the criterion and student age, academic classification, and high school rank as the covariates.

From an analysis of covariance (Table 37), using 2 and 81 degrees of freedom, a value of .16 was not significant at the .05 level. Consequently, there was no interaction effect among the approach factor, sequence factor, and the method factor. Hypothesis 5-lg was not rejected.

The three treatment factors — approach, test sequence, and method — did not effect each other on any of two-factor

combinations, nor did they effect one another. Therefore, the results of the tests of the three main effects were dependable.

Testing of Hypotheses Group 6

Group 6. Test of the four-factor model

In order to minimize the possible variable effects during the experiment and control, the initial differences, four main factors were considered in the hypothesis testing model: (1) systems approaches, (2) sensory-based instructional methods, (3) test sequences, and (4) test trials as factors. All hypotheses were tested statistically through the process of analysis of variance with the 3x2x2x2 factorial model. Both pretest scores and posttest scores were used as the criteria. All hypotheses would be accepted at the F-ratio .05 level of significance. Results significant at the .01 level were reported as such.

6-1. Pretest score and posttest score as the criteria of testing the instructional effects

Hypothesis 6-1a: No significant difference occurred at the .05 level among the instructional effects of the direct approach, conversion approach, and control groups on the basis of student metric pretest scores and posttest scores as the criteria.

An analysis of variance (Table 41), when 2 and 84 degrees of freedom were used, indicates a value of 0.93 to be not

Table 41. Analysis of variance of the student metric pretest and posttest scores

Source of variation	d.f.	S.S.	M.S.	F
A (approach)	2	219.79	109.90	0.93
B (sequence)	1	174.42	174.42	1.48
C (method)	1	41.26	41.26	0.35
A x B	2	18.38	9.19	0.08
A x C	2	94.04	47.02	0.40
B x C	1	53.13	53.13	0.45
A x B x C	2	52.54	26.27	0.22
Error B	84	9892.31	117.77	
D (test trial)	1	1782.42	1782.42	96.09**
A x D	2	392.00	196.00	10.57**
B x D	1	78.80	78.80	4.25*
C x D	1	13.55	13.55	0.73
A x B x D	2	50.00	25.00	1.35
A x C x D	2	7.13	3.56	0.19
B x C x D	1	7.92	7.92	0.43
A x B x C x D	2	1.13	0.56	0.03
Error W	84	1558.56	18.55	
Total (corrected)	191			

Table value of F-ratio at .05 level with 1 and 84 degrees of freedom used is 3.95.

Table value of F-ratio at .05 level with 2 and 84 degrees of freedom used is 3.10.

* F is significant at the .05 level.

** F is significant at the .01 level.

significantly different at the .05 level. Therefore, there was no significant difference among the direct approach group, the conversion group, and the control group on the basis of student metric pretest and posttest scores as the criteria. Hypothesis 5-1a was not rejected.

Because the pretest mean score of the control group was higher than both the pretest mean scores of the direct approach and the conversion approach groups (see Table 27), the F-value of a main effect-approach was reduced after adding pretest scores into the model serving as part of the criterion, as well as the posttest scores.

Hypothesis 6-1b: No significant difference occurred at the .05 level between the test sequence A - B group and the sequence B - A group on the basis of student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), when 1 and 84 degrees of freedom were used, a value of 1.48 had no significance at the .05 level. Therefore, there was no significant difference between the test sequence A - B group and the sequence B - A group on the basis of student metric pretest and posttest scores as the criteria. Hypothesis 6-1b was not rejected.

Table 42. Means of student pretest and posttest scores of the test sequence A - B group and sequence B - A group of the four-factor model

Groups	N	Means
Sequence A - B group	96	33.27
Sequence B - A group	96	35.17

The mean of the sequence B - A group was slightly higher than the mean of the sequence A - B group. However, no statistical significance occurred. Using both pretest and posttest scores as the criteria, the result of the analysis of variance indicates that students who took Form A as pretest and Form B as posttest showed no significant difference from those who took Form B as pretest and Form A as a posttest, on the basis of the pretest scores and the posttest scores combined model. Therefore, the two test forms were very close. This evidence supports the confidence of the final findings.

Hypothesis 6-1c: At the .05 level, no significant difference occurred between the instructional effects of the visual learning PAC method and the audile learning PAC method groups on the basis of student metric pretest scores and posttest scores as the criteria.

An analysis of variance (Table 41), using 1 and 84 degrees of freedom, shows a value of 0.35 to have no significance at the .05 level. Therefore, learning achievement between the

visual learning PAC and the audile learning PAC method was not significantly different. Hypothesis 6-1c was not rejected.

When the means of these two method groups were compared with the sample of this study, students who received metric instruction through the audile learning PAC method had slightly higher mean scores than did those who received metric instruction through the visual learning PAC method. However, this slight difference did not result in a statistical significance (see Table 43).

Table 43. Means of student pretest and posttest scores of the visual learning PAC method and the audile learning PAC method of the four-factor model

Groups	N	Means
Visual learning PAC method	96	33.76
Audile learning PAC method	96	34.68

Using two sensory-based instructional methods — visual learning PAC method and audile learning PAC method — to conduct the metric instruction made no significant difference on the student learning achievement of the basic metric system knowledge.

Hypothesis 6-1d: No significant difference occurred at the .05 level between the pretest scores and the posttest

scores on the basis of student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), when 1 and 84 degrees of freedom were used, a value of 96.09 was significant both at the .05 and .01 levels. Therefore, student pretest scores were highly significantly different from student posttest scores, and hypothesis 6-1d was rejected.

A mean table (Table 44) shows that the mean scores of the posttest were much higher than were the mean scores of the pretest.

Table 44. Means of student pretest scores and posttest scores of the four-factor model

Groups	N	Means
Pretest	96	31.18
Posttest	96	37.27

Student posttest scores were significantly different from student pretest scores. This finding indicates that students made significant gains in basic metric system knowledge through the learning process.

Hypothesis 6-1e: There was no significant difference at the .05 level of interaction effect between the factors of systems approach and test sequence on the basis of the

student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), using 2 and 84 degrees of freedom, a value of 0.08 was not significant at the .05 level. Therefore, no interaction effect existed significantly between the factors of the systems approach and the test sequence. Hypothesis 6-1e was not rejected.

Hypothesis 6-1f: Between the factors of systems approach and instructional method on the basis of the student metric pretest scores and posttest scores as the criteria, no significant difference occurred at the .05 level of interaction effect.

From an analysis of variance (Table 41), with 2 and 84 degrees of freedom used, a value of 0.40 showed no significance at the .05 level; therefore, no interaction effect significantly existed between the factors of systems approach and instructional method. Hypothesis 6-1f was not rejected.

Hypothesis 6-1g: No significant difference occurred at the .05 level of interaction effect between the factors of the systems approach and the test trial, on the basis of student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), when 2 and 84 degrees of freedom were used, a value of 10.57 was significant at both the .05 level and the .01 level. A significant

interaction effect existed between two factors of system approach and test trial, and hypothesis 6-1g was rejected.

Figure 9 shows the interaction effect between two factors of system approach and test trial. Figure 10 shows the difference between the pretest and posttest scores under the above two factors-interaction.

Hypothesis 6-1h: No significant difference occurred at the .05 level of interaction effect between the factors of test sequence and instructional method, on the basis of the student metric pretest scores and posttest scores as the criteria.

After an analysis of variance (Table 41), working with 1 and 84 degrees of freedom, a value of 0.45 was not significant at the .05 level. Thus, no interaction effect existed significantly between the factors of the test sequence and the instructional method. Hypothesis 6-1h was not rejected.

Hypothesis 6-1i: There was no significant difference at the .05 level of interaction effect between the factors of test sequence and test trial on the basis of student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), when 1 and 84 degrees of freedom were used, a value of 4.25 was significant at the .05 level. A interaction effect existed significantly, therefore, between the factors of the test sequence and the test trial. Hypothesis 6-1i was rejected.

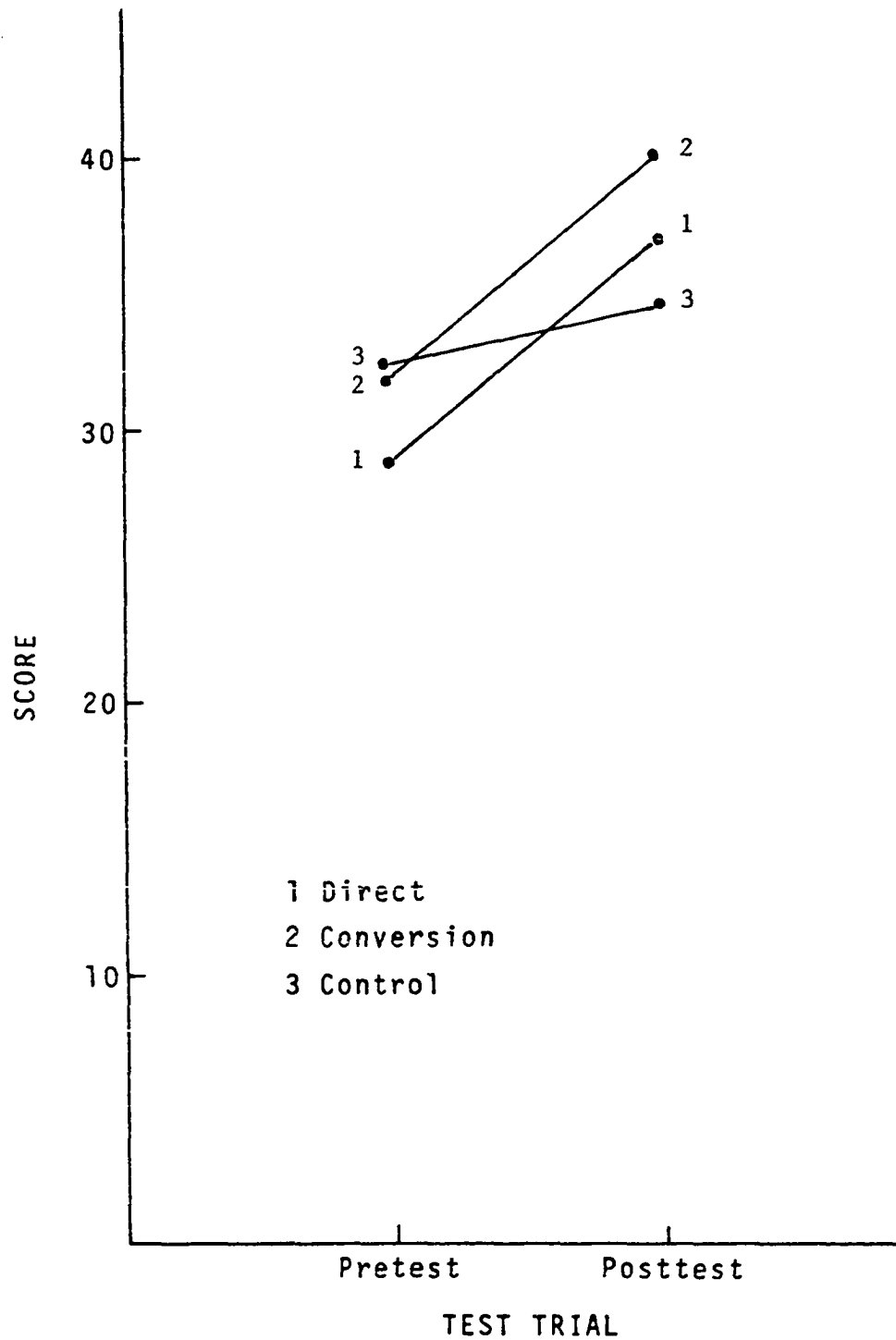


Figure 9. The interaction of factors A x D for student pretest and posttest scores (test trials)

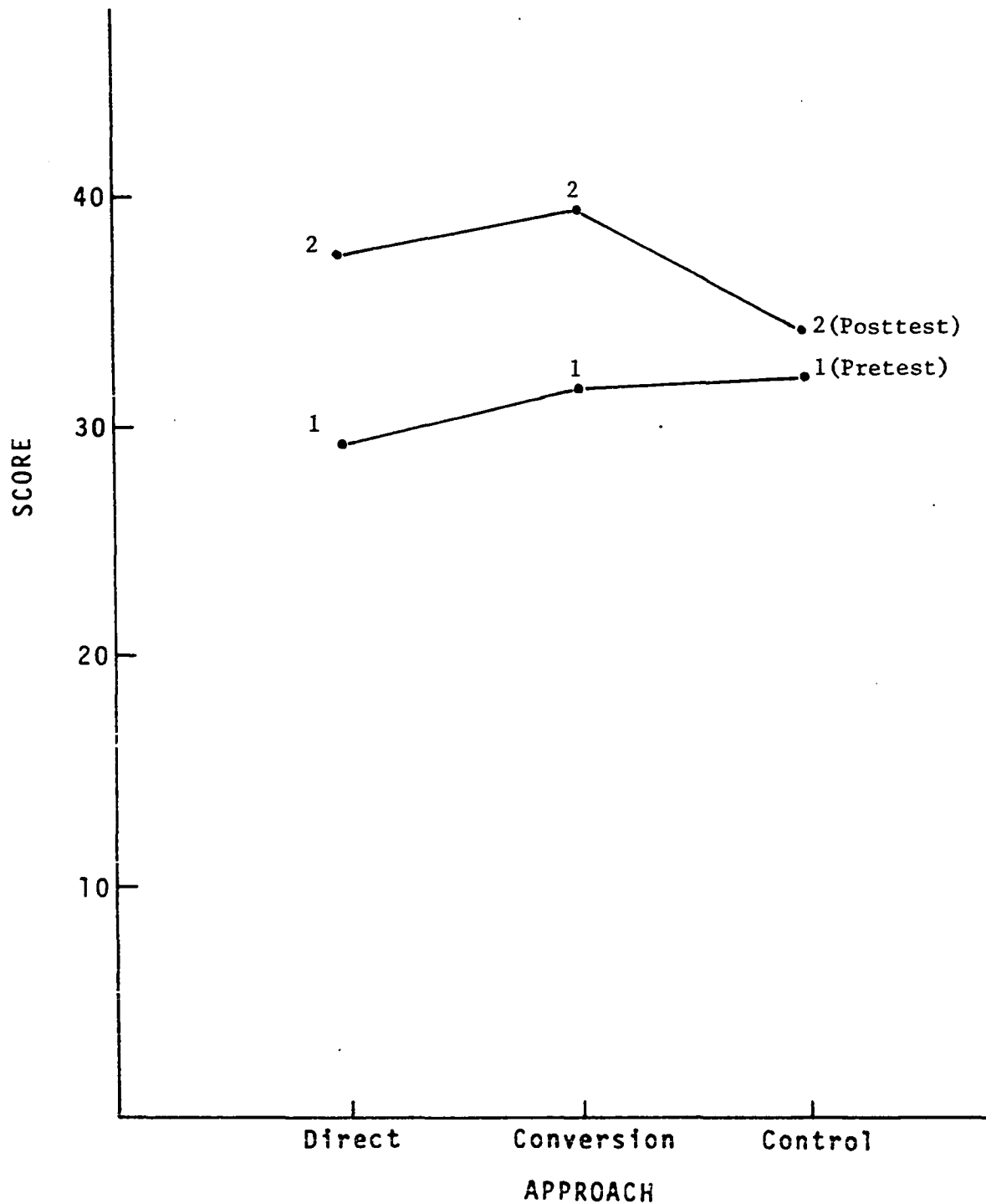


Figure 10. The interaction of factors A x D for student pretest and posttest scores (approach)

Figure 11 shows the difference between the pretest and posttest scores under the above two factor interaction pattern. This interaction effect probably was due to the Type 1 error.

Hypothesis 6-lj: No significant difference occurred at the .05 level of interaction effect between the factors of instructional method and test trial, based on student metric pretest scores and posttest scores as the criteria.

The analysis of variance (Table 41), when 1 and 84 degrees of freedom were used, concludes that a value of 0.73 was not significant at the .05 level. Therefore, there is no interaction effect between the factors of the instructional method and the test trial. Hypothesis 6-lj was not rejected.

Figure 12 shows the difference between the pretest and posttest scores under the above two factor interaction pattern.

Hypothesis 6-lk: No significant difference occurred at the .05 level of interaction effect among the factors of systems approach, test sequence, and instructional method on the basis of student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), when 2 and 84 degrees of freedom were used, a value of 0.22 was not significant at the .05 level. Therefore, no significant interaction effect existed among the factors of the systems approach, the test sequence, and the instructional method. Hypothesis 6-lk was not rejected.

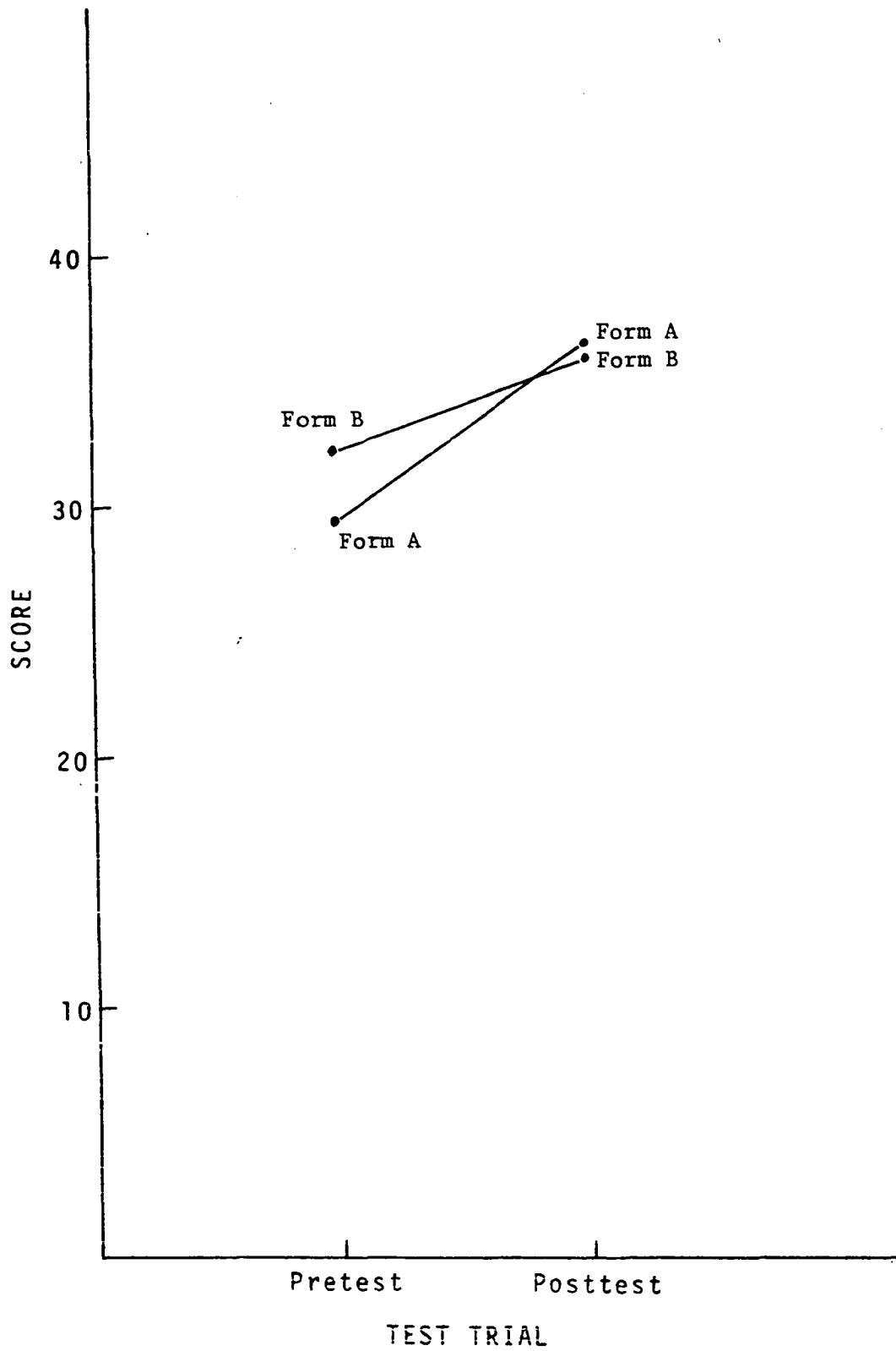


Figure 11. The interaction of factors B x D for student pretest and posttest scores

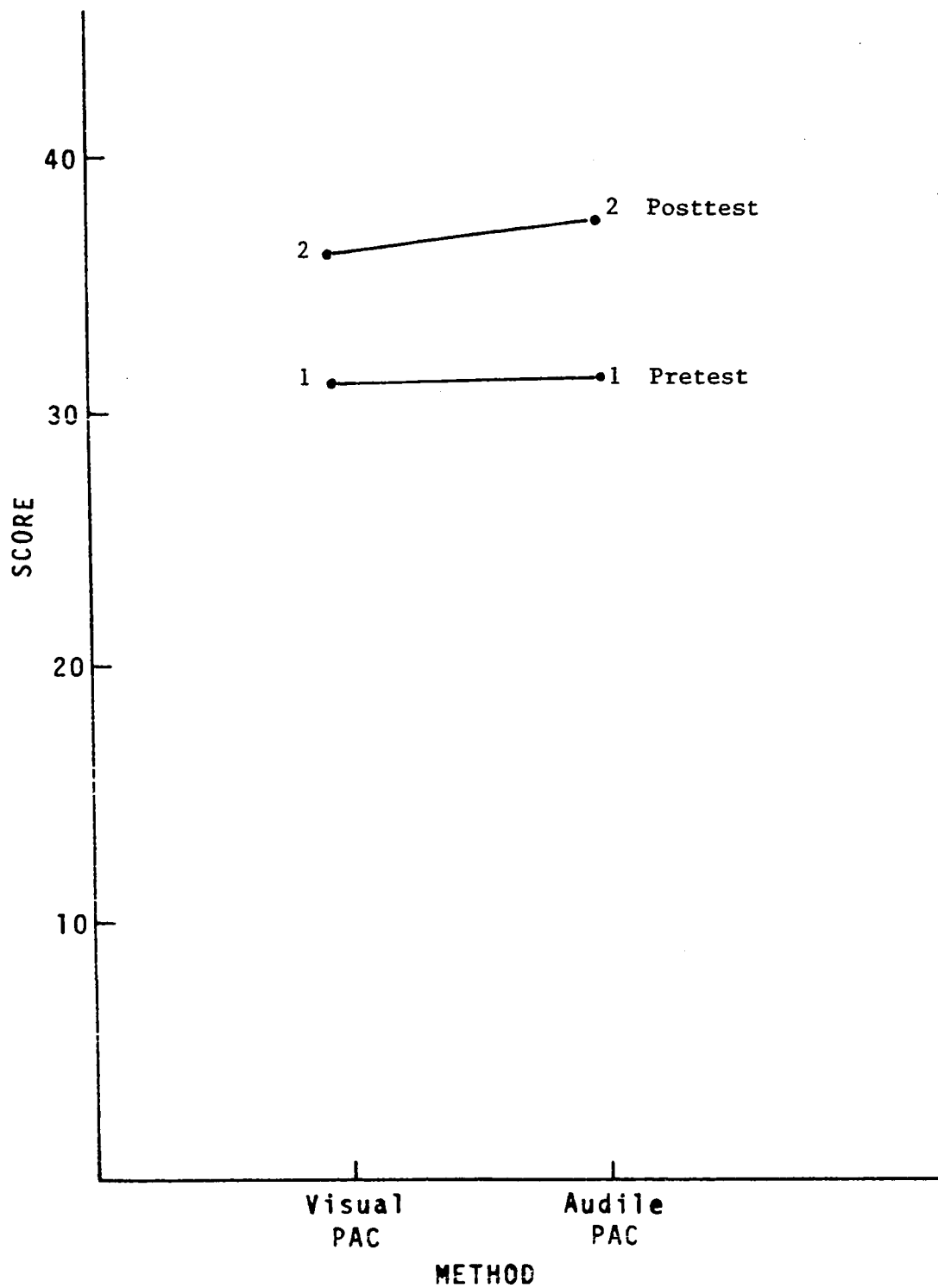


Figure 12. The interaction of factors C x D for student pretest and posttest scores

Hypothesis 6-11: At the .05 level of interaction effect, no significant difference occurred among the factors of the systems approach, the test sequence, and the test trial, on the basis of student metric pretest scores and posttest scores as the criteria.

Analysis of variance (Table 41), with 2 and 84 degrees of freedom, indicates that a value of 1.35 was not significant at the .05 level. Consequently, no significant interaction effect existed among the factors of the systems approach, the test sequence, and the test trial, and hypothesis 6-11 was not rejected.

Figure 13 shows the difference between the pretest and posttest scores under the above three factor interaction patterns.

Hypothesis 6-1m: No significant difference occurred at the .05 level of interaction effect among the factors of the systems approach, instructional method, and the test trial, on the basis of student metric pretest scores and posttest scores as the criteria.

From an analysis of variance (Table 41), when 2 and 84 degrees of freedom were used, a value of 0.19 was not significant at the .05 level. Therefore, there was no significant interaction effect among the factors of the systems approach, instructional method, and test trial. Hypothesis 6-1m was not rejected.

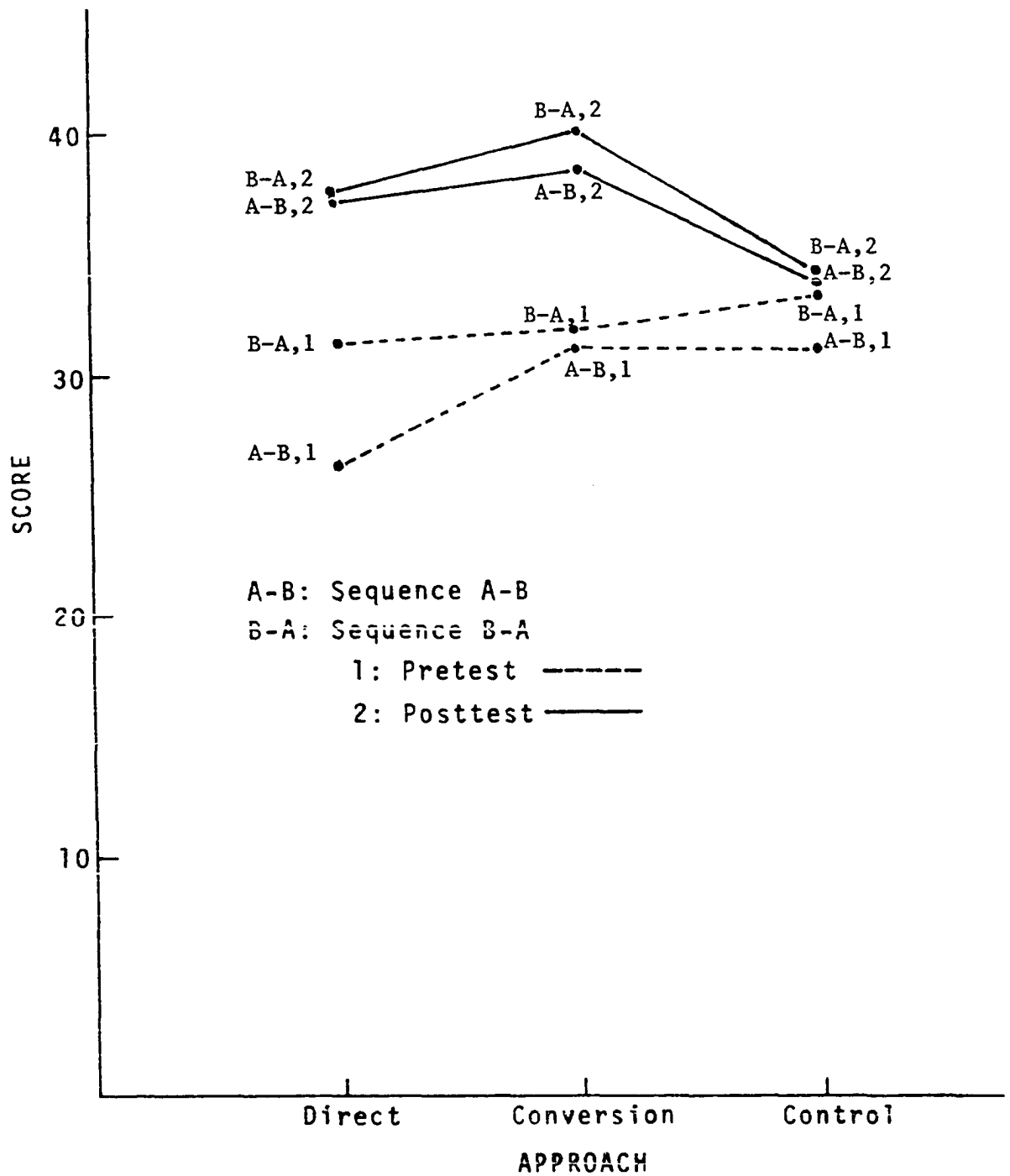


Figure 13. The interaction of factors A x B x D for student pretest and posttest scores

Figure 14 shows the difference between the pretest and posttest scores under the above three factor interaction patterns.

Hypothesis 6-1n: There was no significant difference at the .05 level of interaction effect among the factors of the test sequence, instructional method, and test trial, on the basis of student metric pretest scores and posttest scores as the criteria.

An analysis of variance (Table 41), when 1 and 84 degrees of freedom were used, indicates a value of 0.43 not to be significant at the .05 level. Hence, no interaction effect was significant among the factors of test sequence, instructional method, and test trial; hypothesis 6-1n was not rejected.

Figure 15 shows the difference among the pretest and posttest scores under the above three factor interaction patterns.

Hypothesis 6-1o: Among the systems approach, test sequence, instructional method, and test trial, on the basis of the student metric pretest score and posttest scores as criteria, no significant difference occurred at the .05 level of interaction effect.

From an analysis of variance (Table 41), with 2 and 84 degrees of freedom, a value of 0.03 had no significance at the .05 level. No significant effect thus existed among the factors of systems approach, test sequence, instructional method,

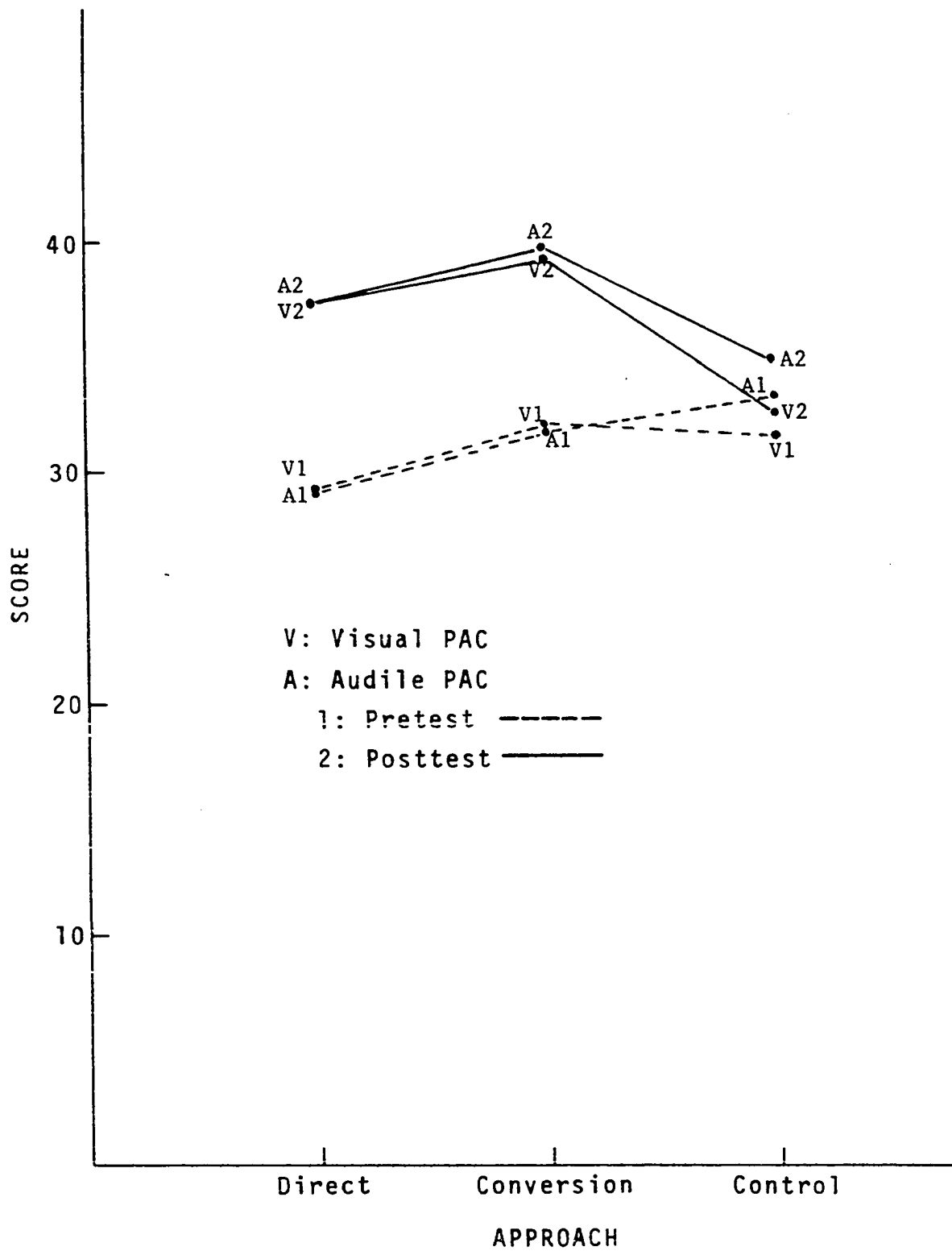


Figure 14. The interaction of factors A x C x D for student pretest and posttest scores

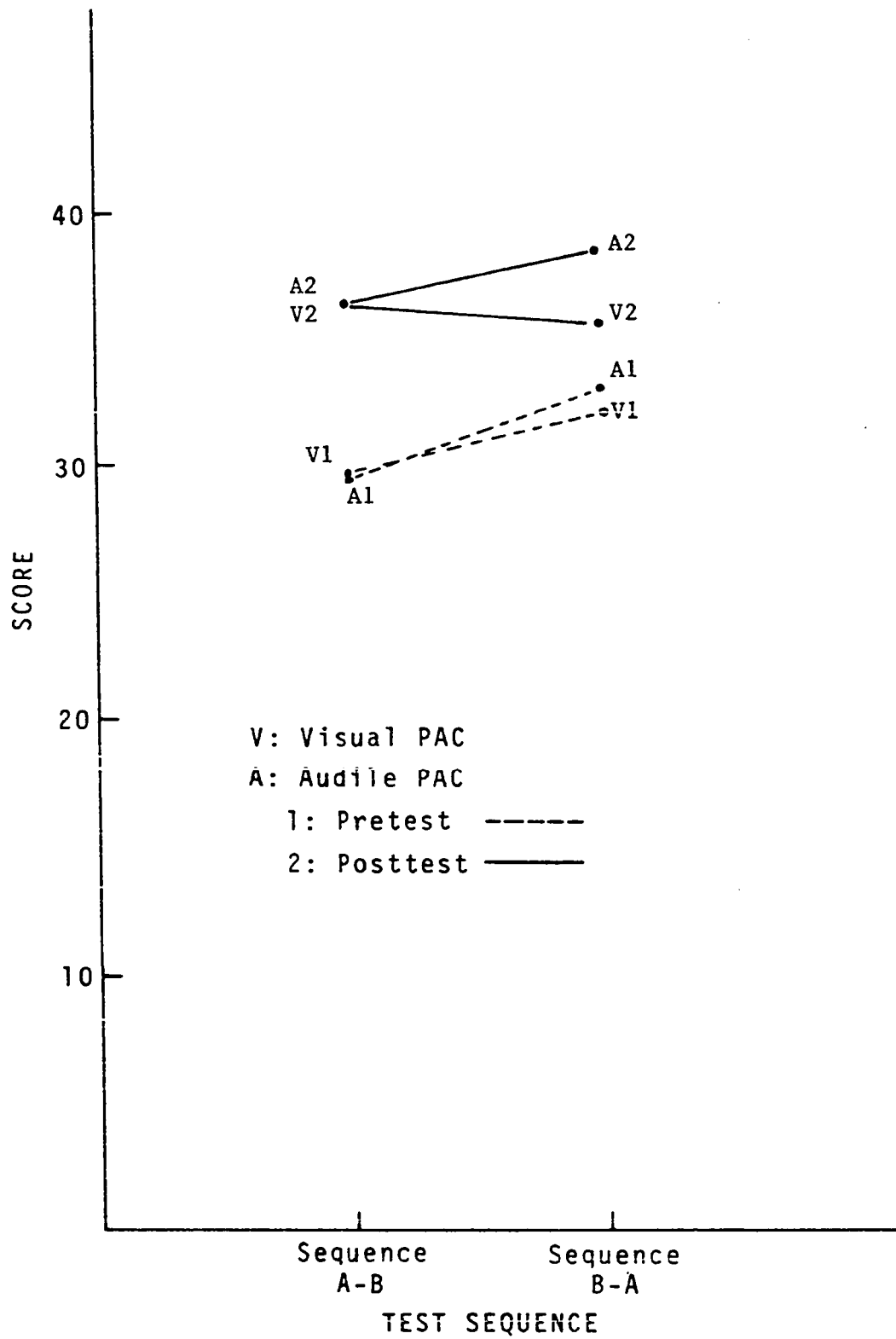


Figure 15. The interaction of factors B x C x D for student pretest and posttest scores

and test trial; hypothesis 6-1o was not rejected.

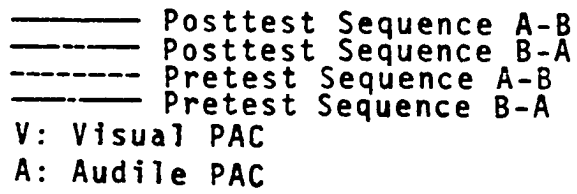
Figure 16 shows the difference between the pretest and posttest scores under the above four factor interaction patterns.

The added fourth factor, test trial, completed the four-factor model. The purpose of the four-factor model test was to reduce the possible experimental error due to the pretest - posttest effect. Since the results of the test of hypotheses 2-1a, 2-1b, 2-1c, and 2-1d indicate that there was no significant difference under any main effect and any possible interaction effects, it was not necessary to use the pretest scores as a covariate for the test of instructional treatment effects. However, in order to reinforce the results of the main hypothesis testings, the four-factor model was used (add the test trial - pretest, posttest) to verify and support the results of the experiment. Also, the major interest of the investigator to design this four-factor model is to find out if there was any significant interaction effect occurring between any one of the three main factors and the four factor-test trial.

The results of hypotheses group 6 testing were quite consistent with those related to previous hypothesis testings except the finding of hypothesis 6-1a.

The hypothesis 6-1a was not rejected. There was no significant difference indicated among the two experimental groups and the control group when data were collapsed over

Figure 16. The interaction of factors A x B x C x D for student pretest and posttest scores



test trials. However, the interaction effects between the main factors and test trials were the major interest here. The interaction between approach and test trial was highly significant. This evidence can be interpreted that the experimental groups improved significantly relative to the control group, which is completely consistent with previous findings discussed earlier.

The question of whether the learning of the experimental groups was better than that of the control group can now be answered by the results of: 1. evaluation of the learning for the experimental and control groups separately, which was discussed in the hypotheses group three, and 2. the finding of significant interaction effect between approach and test trial.

Summary

Six group hypothesis tests — (1) test of learner variables and an examination of possible covariates, (2) test of previous metric system knowledge and preferable learning ability, (3) test of the test sensitization, (4) test of achievement, (5) test of instructional treatment effects, and (6) test of the four-factor model — and two testing model designs — (1) a three-factor model, and (2) a four-factor model — with 96 subjects participating through both the analysis of variance and the analysis of covariance statistical processes resulted in the following findings:

- 1-1. The distribution of student curriculum majors was not significantly different at the .05 level, based upon the classifications of three main factors:
(1) systems approach, (2) test sequence, and (3) instructional method, and all possible interaction effects.
- 1-2. The distribution of student options of concentration was not significantly different at the .05 level, based on the classifications of three main factors: (1) systems approach, (2) test sequence, and (3) instructional method, and all possible interaction effects.
- 1-3. The distribution of student age was not significantly different at the .05 level, based on the classifications of three main factors: (1) systems approach, (2) test sequence, and (3) instructional method, and all two-factor interaction terms. However, it was found that the three-factor interaction effect existed at the .05 significance level. Because of this finding, the learner variable — age — was used as a covariate for the two final analyses.
- 1-4. The distribution of student academic classifications was significantly different at the .05 level, on the basis of the classification of the main factor

— systems approach. From further examination, it was found the control group had higher grade-level students than did the two experimental groups. But this group was not significantly different considering the classification of the other two main factors, test sequence and instructional method, and all possible interaction terms. As a result of this finding, the learner variable — academic classification — was used as a covariate for the two final analyses.

1-5. The distribution of student ACT scores was not significantly different at the .05 level, on the classifications of three main factors: (1) systems approach, (2) test sequence, and (3) instructional method, and all possible interaction effects. Because of the lack of 25 ACT scores, the analysis of variance was obtained by using the procedure of regression of the SAS program. Due to the fact that 26 percent of the subjects were missing this data, the finding is only considered as supporting information.

1-6. The distribution of student high school rank was significantly different at both the .05 and .01 levels, based on the classification of the main factor — systems approach. From further examination, it was found that the direct approach group

had a considerably lower high school-rank average than the other two groups — conversion approach group and control group — had. However, based on the classifications of other two main factors, test sequence and instructional method, and all possible interaction terms, high school rank was not significantly different. As a result of these findings, the learner variable — high school rank — was used as a covariate for the two final analyses. Four subjects were missing high school rank data for the analysis.

- 1-7. The distribution of student-graduate high school sizes was not significantly different at the .05 level, based on the classifications of three main factors: (1) systems approach, (2) test sequence, and (3) instructional method, and all possible interaction effects.
- 2-1. There were no significant differences at the .05 level of the previous metric knowledge through the classifications of three main factors: (1) systems approach, (2) test sequence, and (3) instructional method, and all possible interaction effects.
- 2-2. There were no significant differences at the .05 level of the Nelson-Denny Reading Test scores through the classifications of three main factors:

(1) systems approach, (2) test sequence, and (3) instructional method, and all possible interaction effects.

- 3-1. No significant differences occurred at the .05 level between the pretest scores and posttest scores in the control group. There was no significant interaction effects between the factors of test sequence and test trial at the .05 level, and no significant test sensitization was discovered.
- 3-2. There was a significant difference between the pretest scores and the posttest scores in the experimental groups at both the .05 and .01 levels. Compared with the findings of 3-1, it could be interpreted that the instructional treatments resulted in the significant achievement change from pretest to posttest.
- 4-1. There was a significant difference at both the .05 and .01 levels in the achievement of the direct approach, conversion approach, and control groups, on the basis of student posttest scores as the criterion and student pretest scores as the covariate. From further examination, it was found that two experimental groups — the direct approach and the conversion approach groups — showed marked achievement after receiving the instruction. However, there was no significant difference between

the achievement of the direct approach and the conversion approach groups at the .05 level.

- 5-1. (1) There was a significant difference at both .05 and .01 levels among the posttest scores of the direct approach, conversion approach, and control approach groups, along with the three covariates — age, academic classification, and high school rank. After further examination, it was found that there was an important difference at both .05 and .01 levels between the experimental group (direct approach, and conversion approach groups) and the control group on the basis of posttest performance. However, there was no significant difference at the .05 level between the direct approach group and the conversion approach group on the basis of posttest performance.

(2) There was no significant difference at the .05 level between the test sequence A - B group and the sequence B - A group on the basis of posttest score as the criterion, along with the three covariates — age, academic classification and high school rank.

(3) There was no significant difference at the .05 level between the visual learning PAC method group and the audile learning PAC method group, based on

posttest score as the criterion along with the three covariates — age, academic classification and high school rank.

(4) There was no significant difference at the .05 level of any possible factor interaction effect on the basis of posttest score as the criterion along with the three covariates — age, academic classification and high school rank.

6-1. After the fourth factor was added, test trial was fitted into the model and tested, with the following findings:

(1) There was no significant difference at the .05 level among the pretest scores and posttest scores of the direct approach, conversion approach, and control approach groups.

(2) There was no significant difference at the .05 level between the test sequence A - B group and the sequence B - A group on the basis of pretest and posttest scores as the criteria.

(3) No significant difference was seen at the .05 level between the visual learning PAC method group and the audile learning PAC method group, on the basis of pretest and posttest scores as the criteria.

(4) There was a significant difference at both .05 and .01 levels between the two test trials — pretest and posttest — on the basis of pretest and posttest scores as the criteria.

(5) A significant interaction effect of factors systems approach and test trial could be observed at the .01 level, using pretest and posttest scores as the criteria.

(6) A significant interaction effect of factors test sequence and test trial could be observed at the .05 level, using pretest and posttest scores as the criteria.

(7) There was no significant interaction effect of any other possible combined factor interaction effects at the .05 level using pretest and posttest scores as the criteria.

CHAPTER V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purposes of this chapter are to summarize the problems which prompted this research study, to present conclusions based upon the findings, and to make recommendations for further study.

Summary

First, a measurement system must be viewed as a communication tool; a language which people in business, industry, and daily life use to communicate with one another. As technology spiraled rapidly, and international interdependence also increased at an exponential rate, it became increasingly clear that a unified global measuring standard was an absolute necessity. The SI (System Internationale) metric system was developed and agreed upon due to its international necessity.

Although the United States as a member of this International Standards Organization has endorsed the SI metric system, the metric system has not been adopted nor used exclusively in this country. As more and more countries convert to metrics, the United States will be unable to resist this worldwide tide of changeover. After the three-year metric study directed by Congress and four years of debating, finally in February of 1976, the Metric Conversion Act of 1975 was signed into a law. From now on, this country will begin to convert to a metric system of measurement. Although the

changeover will affect every sector of society, the field of education will play a vital role and serve as the pioneer in promoting metric instruction and implementation. A successful and smooth conversion process fully depends upon the proper systems approach and most suitable instructional methods selected by educators in order to introduce the metric concept and content to all levels of students and the public.

These immediate needs for education and instructional methodology research led the researcher to this study, in which two problems were investigated. The first was to determine the effectiveness of two selected systems approaches — the direct approach and the conversion approach — for introducing metric concepts. The second problem was to determine the effectiveness of two sensory-based instructional methods — the visual learning PAC and the audile learning PAC — for instructing metric content.

The subjects used for the study were 96 students enrolled in selected courses of the Industrial Education Curriculum at Iowa State University during the winter quarter, 1976. The simple random sampling method with a table of random numbers was used on two repeated occasions to select subjects. These were then arranged in eight experiment cells and four control cells, with eight subjects in each cell.

During the eleven weeks of the study, the experimental groups took one of two forms of a pretest. These same groups

received two metric lessons which consisted of four different types of instructions. Then a posttest, of the same two forms as the pretest, was administered. Finally, the two groups took the Nelson-Denny Reading Ability Test and completed a Personal Information Sheet. The control groups received the same treatment but in a different sequence: the two metric lessons were given to these students after all pre- and post-testing was completed.

Analysis of variance and analysis of covariance with factorial design were applied for the six major statistical data analyses used in the study:

1. Initial status analysis (learner variable analysis);
2. Background examinations;
3. Test sensitization examination;
4. Learning achievement analysis;
5. Posttest analysis; and
6. Four-factor model analysis.

Initial status analysis and background examinations were used to determine any existing differences among the 12 groups prior to the experiment to be used as the covariate, if they occurred. To insure that no test experience took place between the pretest and posttest, the test sensitization examination was analyzed. The learning achievement analysis provided information as to whether any achievement occurred in those subjects in the treatment groups. This analysis would

indicate the validity of the different types of instructions upon which the entire experiment was based. The analysis of variance of the four-factor model would be the major interests of the researcher, with their results to be used to determine the effectiveness of two selected systems-approaches and two sensory-based instructional methods for introducing the metric system to the students.

On the basis of the data analyzed, the major findings are summarized below:

1. The distribution of the students' curriculum majors, options of concentration, ACT scores, and high school size were not significantly different at the .05 level based on the classifications of the three main factors of systems approach, test sequence, and instructional method, and all possible interaction effects.
2. A significant difference did exist at the .05 level of the three main factor interaction effect. Therefore, the learner variable of age was used as a covariate for the two final analyses.
3. The distribution of student academic classifications was significantly different at the .05 level in terms of the classification of the main factor — systems approach. Therefore, the learner variable — academic classification — was used as a covariate for the two

final analyses.

4. The distribution of student high school rank was significantly different at both the .05 and .01 levels, based on the classification of the main factor — systems approach. Therefore, the learner variable of high school rank was used as a covariate for the two final analyses.
5. There were no significant differences at the .05 level of previous metric knowledge and preferred learning style through the classifications of the three main factors of systems approach, test sequence, and instructional method, and all possible interaction effects.
6. There was no significant test sensitization discovered through testing the difference between the pretest and the posttest scores at the .05 level in the control group.
7. There was a significant achievement change for the experimental groups but not for the control groups at the .05 level. Significant learning did occur through four different types of metric instructions.
8. There was no significant difference at the .05 level between the direct approach group and the conversion approach group.

9. There was no significant difference at the .05 level between the visual learning PAC group and the audile learning PAC group.

Conclusions

Based upon the findings of the statistical analysis of data obtained from the study, the following conclusions were drawn:

1. The background knowledge of metrics of college-level industrial education students is not significantly different.
2. The knowledge of metrics of college-level industrial education students can be significantly improved by learning the system through one of the two sensory-based individualized instruction units, by either the direct approach or the conversion approach.
3. Achievement in learning metric measuring concepts was not significantly different between the direct approach and the conversion approach of instruction for the college-level industrial education students, a conclusion also supported by McFee's earlier research. Both systems approaches can be used for introducing metric measuring concepts effectively to college-level industrial education students.
4. Achievement in learning metric measuring concepts was not significantly different between the visual

learning PAC method and the audile learning PAC method of instruction for the college-level industrial education students. Both sensory-based individualized instruction methods can be used for teaching metric measuring concepts effectively to college-level industrial education students.

5. Individualized instruction can be one of the effective methods employed to teach the metric measuring concepts. The shortage of metric educators for teaching metric measurement system can be partially solved by proper development of sensory-based individualized-learning packets.

Recommendations for Further Study

As a result of the study, the following recommendations are made:

1. Additional research will be needed to determine the relationship between each of the seven identified learner variables and the learning experience of the metric system.
2. More learner variables related to the learning experience of metric system must be identified.
3. Further research should be carried out at the elementary, junior high and high school levels with regard to the effectiveness of the systems approaches (the degree of exposure to the English system might make

a difference in the learning of the metric system).

4. Further research should be carried out at all educational levels surrounding the college age with regard to suitable instructional methods for introducing metric system content.
5. Other individualized instruction methods, such as programmed instruction, computer-assisted instruction, or multimedia instruction, should be studied with regard to the possibility of teaching the metric system.
6. A complete diagnostic instrument of metric system knowledge placement should be developed at each specific educational level in order to properly place the learner within a particular teaching strategy or instructional method.
7. Additional research should be conducted in all college curriculum areas in order to further study the best systems-approach and instructional method for presenting the metric system to people of varying interests. Findings of comprehensive areas of research could be generalized to many sectors of the society for more effective introduction of metric measurements.
8. A study of the effectiveness of the two systems approaches and the sensory-based instructional

methods for conducting the metric measuring knowledge with reference to the affective and psychomotor learning domains should be made.

9. Further research should be carried out to test the instruments' capabilities to measure the full range of Blooms' taxonomy in the cognitive domain ranging from specifics to evaluation.

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APPENDICES

Appendix A: Direct Approach Audile
Learning PAC

Introduction to Metrics

Weights and measures were some of the first tools invented by humans. Early civilization needed simple measures for many tasks: constructing dwellings, making clothing, and trading food and raw materials.

People first turned to parts of the body and natural surroundings to use as measuring instruments. Early Egyptian records and the Bible show that length was first measured with the forearm, hand, and finger in units such as cubits, spans, and digits. Time was measured by the periods of the sun, moon, and other heavenly bodies. To compare the sizes of containers such as gourds or clay pots, the receptacles were often filled with plant seeds, which were counted to measure volume. When means for weighing were invented, seeds and stones served as standards; for instance, the "carat", still used as a unit of weight for precious stones, was derived from the carob seed.

As civilizations progressed, weights and measures became more complex. The invention of mathematics made it possible to create entire systems of weights and measures for use in land division, taxation, or scientific research. For these uses it was necessary not only to weigh and measure more complex things, but also to do so accurately and repeatedly, all over the world. Each country invented its own measuring system, but gradually these systems became more standardized as nations began to trade with one another. The metric system and the customary system of inches and pounds were the major two systems.

Why Do We Need to Learn the Metric System?

One might ask why we need to learn the metric system, since we have our present system already in use. Several reasons for adopting the metric system follow:

First, the metric system is much simpler than the system of feet, pounds, gallons, and degrees Fahrenheit.

Second, the rest of the world has adopted the metric system; if we don't, soon we won't be able to communicate with the rest of the world.

Let's look into this further. Today, all the people of the world, except the United States and a few small countries like Tonga and Liberia, use the standard, elegant, streamlined language of the metric system. England, Australia, and New Zealand are at the end of a 10-year program of conversion to

the metric system. Even our neighbor Canada has started a conversion program. We have been left alone, and at great disadvantage to ourselves.

The cost to industry is one example. Since we buy and sell machinery and parts in the world market, many industries must maintain a double inventory of goods. Converting to the metric system will not only save the North American economy billions of dollars every year, but it will also help us remain competitive in world markets.

Another important reason for us to adopt the metric system is because of the nature of this system. Since the metric system is based on ten, it will simplify the basic arithmetic and sciences taught in schools. As a conservative estimate, 15 percent of the time spent in elementary arithmetic is used to teach such tiresome skills as finding the least common denominator, reducing improper fractions, adding mixed numbers, and reducing fractions to their simplest terms. Since these skills are primarily needed for performing arithmetic tasks using feet and inches and pounds and ounces, they presumably can be eliminated from the curriculum. The time spent in teaching just those skills may cost us well over a billion dollars a year.

There are numerous advantages in using the metric system in our daily lives. Many sources indicate that the United States will be unable to resist this worldwide rush for change to the metric system. Sooner or later the metric system must be used in this society. Many major corporations have established programs to complete their conversion. Among them are the Ford Motor Company, General Motors, IBM, Honeywell, and others. Consumer goods are also gradually being labeled in dual measures. Some broadcasting and television stations have already begun to use weather forecasts with both temperature systems. Now is the time for America to think metric and to learn metric. We will need to know what these metric units are so we can understand the articles we will be seeing more and more frequently in newspapers and magazines as we go completely metric.

OK, now let's start to think metric. This short course of "learning metric" includes two units, one hour for each. In the first unit you will learn:

- (1) The metric system,
- (2) The SI base units,
- (3) SI metric unit prefixes,
- (4) SI metric derived units,
- (5) Symbols,
- (6) Linear measurement, and

(7) Area measurement.

In the second unit you will learn:

- (1) Volume measurement,
- (2) Weight and mass measurement,
- (3) Temperature measurement, and
- (4) Work, power, and other quantities of measurement.

Lesson 1

This first lesson will take approximately one hour.
After learning this lesson you will know:

- (1) The metric system,
- (2) The SI base units,
- (3) SI metric unit prefixes,
- (4) SI metric derived units,
- (5) Symbols,
- (6) Metric linear measurement, and
- (7) Metric area measurement.

Section 1: the metric system

The need for a single, worldwide coordinated measurement system was recognized over 300 years ago in 1670. Gabriel Mouton, a Frenchman, proposed a single decimal measurement system based on the length of one minute of an arc from the circle of the earth.

In 1790, during the French Revolution, the National Assembly of France asked its Academy of Sciences to "deduce an invariable standard for all the measures and all the weights." The unit of length was to be a portion of the earth's circumference. Measures for capacity (volume) and mass (weight) were to be based upon the unit of length, thus relating the basic units of the system to each other. Furthermore, the larger and smaller versions of each unit were to be created by multiplying or dividing the base units by 10 and its multiples. This feature made the system convenient to use by eliminating the need for such calculations as division by 16 (to convert ounces to pounds) or by 12 (to convert inches to feet). Similar calculations in the metric system, the name for this new measurement system, could be performed simply by shifting the decimal point. Thus, the metric system is a "base-10" or "decimal" system.

The Commission assigned the name "meter" (METER) to the unit of length. The physical standard for the meter was to be equal to one ten-millionth of the distance from the North Pole to the equator, measured along a line running through Paris,

France. Now modern science has made a more accurate standard possible. The meter is defined in terms of the wavelengths of light given off by the krypton-86 atom.

The metric unit of mass, called the gram (GRAM), was defined as the mass or weight of one cubic centimeter (a cube that is 1/100th of a meter on each side) of water at a certain temperature. The cubic decimeter (a cube 1/10th of a meter on each side) was chosen as the unit of fluid volume or capacity. This measure was given the name "liter" (LITER). A liter of water now weighs one kilogram.

By the late 1860's even better metric standards were needed because of technological and scientific progress. In 1875 an international treaty, the "Treaty of the Meter," set up metric standards for length and weight and established a committee to adopt other metric measures. This treaty, known as the Metric Convention, was signed by 17 countries, including the United States. As a result of the treaty, metric standards were constructed and distributed to each signer. Since 1893 the international metric standards have served as the weights and measures standards of the United States. This means, simply, that our customary inch and pound units are based upon the meter and kilogram.

By 1900, a total of 35 nations — including the major nations of Europe and most of South America — had officially accepted the metric system. Today, with the exception of the United States and a few other countries, the entire world is using or is planning to use the metric system. In 1971, the U.S. Secretary of Commerce sent to Congress the results of a three-year study authorized by the Metric Study Act of 1968. In it he recommended that the United States change to predominant use of the metric system through a coordinated national program.

The International Bureau of Weights and Measures, located at Sevres, France, is the permanent site for the Metric Convention. As more accurate ways of defining measurement units are developed, the General Conference of Weights and Measures — the organization made up of members of the convention — meets to vote on improvements in the system and the standards.

In 1960, the General Conference adopted a more modern metric system. The name Système International d'Unités (International System of Units), with the international abbreviation SI, was adopted for this modernized metric system. Further improvements in SI were made in 1964, 1968 and 1971.

Section 2: the SI base units

The SI metric system is built upon a foundation of the seven base units. They are:

1. Meter (METER) for length is usually abbreviated m.
2. Kilogram (KILOGRAM) for mass or weight, abbreviated kg.
3. Second (SECOND) for time, abbreviated with a small s. This is the same unit in use today for measuring time.
4. Kelvin (KELVIN) for temperature is usually abbreviated with a capital K. The Kelvin is used mainly for scientific measurement. For practical, everyday purposes, we use the degree Celsius ($^{\circ}\text{C}$), abbreviated capital C. Water boils at 100°C , and it freezes at 0°C .
5. Ampere (AMPERE) is used for electric current. It is abbreviated with a capital A. It is the same unit which we are using now.
6. Candela (CANDELA) is used for luminous intensity. It is abbreviated using a small c and d. The candela is used to measure an amount of light.
7. Mole (MOLE) which stands for an amount of a substance. The small letters mol are used for the abbreviation. This unit is used mainly in special scientific measurement.

There are two supplementary units, the radian (RADIAN) and the steradian (STERADIAN) used to measure plane and solid angles. These will not normally be used by most people, but it is important to know that they exist.

There are also many derived units, such as the pascal (PASCAL), to measure pressure, and Newton (NEWTON), to measure force. These will be described later.

Section 3: SI metric unit prefixes

There are different units of measurement because we need different-sized standards, depending on whether we are measuring short, long, or very long distances. The same is true for other physical quantities. We could measure everything in meters if we wanted to. But when we wanted to tell people the length of a ballpoint pen, we would have to say it was 0.15 of a meter. For convenience, we use different units to express different sizes. In the metric system, quantity conversions are very easy and convenient. You don't need to memorize the different factors which are used for changing one unit to another. And when you go to the supermarket, you don't need

to remember an entirely different set of conversions any more. Only a few prefixes and roots are needed to complete all the quantity converting work in the metric system. Many people think that the present system is just as good because we only need to remember the common conversions, which are fairly simple. But for the entire span of our lives we must consult a guide for the measurements we don't use every day under our current system. This makes no sense at all.

With the metric system we use prefixes and roots. The only conversions we need to make are from one size to another. There is a root for each physical quantity and a prefix for each significant size. To simplify things further, each prefix is a multiple of 10. For example, one common prefix is "kilo" (KILO), meaning "a thousand times." The prefix added to the root "meter" for the quantity of distance produces "kilometer" (KILOMETER). A kilometer is a measurement of distance equal to 1,000 meters. The same prefix "kilo" added to the root "gram," which is a quantity of mass, produces a "kilogram" equal to 1,000 grams.

The most common prefixes in daily use are the following. Listen carefully to their spelling, pronunciation, and meaning.

First the base unit is set. These basic units are the roots referred to earlier.

To make this base unit smaller these prefixes are added to the beginning of the roots.

1. deci (DECI) means one tenth of (0.1).
(DESS-ie)
2. centi (CENTI) means one hundredth of (0.01).
(SEN-ta)
3. milli (MILLI) means one thousandth of (0.001).
(MILL-ie)
4. micro (MICRO) means one millionth of (0.000001).
(MY-crow)

To make the base units larger these prefixes are added.

1. hecto (HECTO) means a hundred times (100).
(HECK-toe)
2. kilo (KILO) means a thousand times (1000).
(KILL-a)
3. mega (MEGA) means a million times (1,000,000).
(MEG-a)

Let's look at some examples:

1 kilometer	1,000 meters
1 milliliter	$\frac{1}{1,000}$ liter

Section 4: symbols

In practice, the name of a unit is easier to write as an abbreviation of that unit. This is a simple and easy way to read and write and saves a lot of time.

In the metric system there are symbols for both prefixes and root units which make it much easier to read and write them. The symbols for the metric prefixes and root units are handy to know. Listen carefully to these symbols:

<u>Prefix</u>		<u>Symbol</u>
mega	M	capital M
kilo	k	small k
hecto	h	small h
deci	d	small d
centi	c	small c
milli	m	small m
micro	μ (μ)	a Greek letter which looks like the letter u

<u>Root unit</u>		<u>Symbol</u>
meter	m	small m
gram	g	small g
liter	l	small l

After you learn these you can write the symbols for the different quantities by combining prefix and root symbols. For instance:

kilometer	is	km	small k, small m
milliliter	is	ml	small m, small l
kilogram	is	kg	small k, small g.

Section 5: SI metric derived units

Derived units are any combination of base, supplementary or other derived units. They are obtained by means of multiplication and division. For example, the derived unit for

area is the square meter (m^2). It is obtained by multiplying length by width. Some of the derived units have been given special names and symbols. These are used to express the derived unit in a simpler way than in terms of the base units themselves. For example, the derived unit for force is simply called the newton. Expressed in base units, it is $kg \cdot m/s^2$. Obviously, it is much easier to say "newton" than to state the more complex formula.

The following are some basic and derived units we often use.

Fundamental measure	Basic unit	Derived measure	Derived unit
Length	Meter	Area and volume	Square meter and cubic meter
Mass	Kilogram	Force work (energy) power	Newton joule, (JOULE) watt, (WATT)
Time	Second	Frequency speed	Hertz, (HERTZ) meter/second kilometer/hour
Thermodynamic temperature	Kelvin	Celsius temp.	Degree Celsius
Electric current	Ampere	Electromotive force Resistance Capacitance	Volt Ohm Farad

Section 6: distance and speed

Once the metric system is fully adopted, all cloth will be sold by the meter and centimeter; speed limits will be designated by kilometers per hour; screws, ammunition, and tools will be sized by the millimeter; and bathroom tiles will be measured by the centimeter. When you finish this section, you will be on intimate terms with these units. Equally important, you will have a much better idea of the size of a 15-millimeter hole, or the length of a 20 centimeter ruler.

Let's consider small distances first. In the metric system, the distances between a tenth of an inch and a few yards are normally expressed in three ways: (1) in millimeters (mm); (2) in centimeters (cm); and (3) as decimal parts of a meter (m).

In scientific and engineering work, the millimeter and the meter are used frequently but the centimeter is seldom used. In everyday affairs, however, the centimeter is the most common unit. Here you will learn to use all three units interchangeably. Remember, a millimeter is equal to a tenth of a centimeter and a thousandth of a meter. As a handy reference, keep in mind that a meter is about the distance from your left shoulder to the tip of your right hand when you hold your right arm horizontally.

Here are some examples to give you a better idea.

1. The width of your pen or pencil is about 5 to 8 mm; that is 0.5 to 0.8 cm, or 0.005 to 0.008 meter.
2. The width of your thumb at the knuckle is about 15 to 35 mm; that is 0.15 to 0.35 cm, or 0.015 to 0.035 meter.

If we want further practice, our bodies give us easy references for small distances. Most people will find that when they press four fingers together to form a straight edge, the measure will be close to 50 mm. If your fingers are particularly large, you may have to press them closer together to measure 50 mm. If they are particularly small, you may have to spread them slightly. Once you see how to hold your fingers to measure 50 mm, you will have a ruler that will always be with you.

The following body reference sizes will give you other measuring ideas.

1. The width of the tip of the little finger, or the width of a fingernail is about 10 mm.
2. The tips of two fingers pressed together is about 25 mm.
3. The tips of four fingers pressed together is about 50 mm.
4. The width of hand from thumb knuckle to side is about 100 mm.
5. The length of the hand is about 200 mm.
6. The distance from the left shoulder to the tip of the right hand is about 1,000 mm or 1 m.
7. The distance from hand to hand is about 1,500 mm or 1 1/2 m.

Once you know those body reference sizes, you can estimate lots of things; for example: Your shoe length will be approximately 250-350 mm. If you measure from your knee to the floor it will be approximately 50 cm (remember 10 mm = 1 cm). The length of a closed mouth will be approximately 60 mm.

The width of a package of cigarettes will be approximately 5 cm. The length of a telephone receiver will be approximately 200 mm. The length of your pencil will be approximately 19 cm.

Some other common sizes are:

1. The diameter of a quarter is about 2.5 cm.
2. The diameter of an aspirin tablet is about 10 mm.
3. The length of a king size cigarette is 80 mm.
4. The diameter of an LP record is 30 cm.
5. The diameter of a hole in the telephone dial is 13 mm.
6. The length of a dinner fork is about 19 cm.
7. The diameter of a cigarette is 8 mm.
8. The height of a can of cola is 12 cm.

Since you have some idea of small metric distances, it will be easier to look at some intermediate distances in metric measurement. Let's think in the unit meters. There is a useful body reference which is your height. The following metric measures give you approximate human heights.

A short person would be about 145 cm. Thereafter, every additional 2.5 cm would be a normal height until you reached 203 cm. This would be a very tall person.

Try to recall your body reference for a meter (the distance from left shoulder to the tips of the right hand fingers) and other handy references to estimate your height. It should be between one of the above figures. Memorize your own metric height. Try to remember how tall a few relatives and friends are - and also some children. These heights will be handy references, too. An additional set of references might be the so-called average heights for men and women. For women the average height is 165 cm, and for men it is 180 cm.

Besides body height, a pace is another convenient way to estimate distances in meters. With very little practice, you can estimate the length of a room to within a few centimeters. People usually pace off about a 1 meter stride. If you are used to pacing off less than 1 meter, add about 10 percent to your stride, since some people pace off about 90 percent of a meter. The pace will become a handy, lifetime meter rule. Let's see some examples using pace practices.

1. A football field is about 90 meters.

2. From home plate to the left-field wall is about 100 m.
3. From the pitcher's mound to home plate is about 19 m.
4. The Olympic pole vault record is about 560 cm.
5. The Olympic long jump record is about 840 cm.
6. The Olympic high jump record is about 225 cm.
7. A typical golf fairway is about 350 m.
8. The men's ski jump is about 90 m.
9. The women's ski jump is about 70 m.

As to large distances, we know that most of the world's measurement systems came from common, practical reference sizes. Metric lengths were established more scientifically. Initially, in the eighteenth century, the meter was defined as $1/10,000,000$ th of the distance between the equator and the North Pole. Since then a more precise standard has been established. Nevertheless, we can still say there are about 10,000,000 meters from the equator to the North Pole.

The next section will deal with speed and great distances. We translate great distances into time. How long does it take to get there? Here you will learn to think of distances as distances in time, especially as kilometers per hour (km/h).

All road signs will one day give distances in kilometers and speed limits in kilometers per hour, as they do now in most other countries. If you drive a foreign car, you are probably already accustomed to speedometer readings in kilometers per hour.

Let's look at some speed limits which we see on road signs every day.

1. The highway speed limit will be 88 km/hr. in the metric system, while city traffic will be 48 km/hr.
2. When you drive through a residential area, the speed limit will be 40 km/hr. in the metric system.
3. A school zone will be 24 km/hr.

To better familiarize you with the metric measures, the following examples will give you further practice.

A city block is a good reference. It is usually between 50 and 100 meters long (50 meters north to south in New York City, and 100 meters in the center of a planned city like Columbia, South Carolina).

If you are sports-minded, you know that many track and field measures are metric, such as the 100-meter race, or the 1,500-meter race.

If you are interested in traveling, some famous buildings around the country will provide you good references. The following table shows the heights of some buildings in the United States. Try to select heights of several buildings which are familiar to you and remember them as your references for the intermediate distances in metric measuring.

1. The height of the Capitol building in Austin is 94 meters.
2. The height of the John Hancock building in Boston is 241 meters.
3. The height of the Sears Tower in Chicago is 442 meters.
4. The height of the Carew Tower in Cleveland is 216 meters.
5. The height of the First International Building in Dallas is 216 meters.
6. The height of the Brooks Towers in Denver is 128 meters.
7. The height of the Penobscot Building in Detroit is 170 meters.
8. The height of the Ala Moana Hotel in Honolulu is 119 meters.
9. The height of the Indiana National Bank Building in Indianapolis is 218 meters.
10. The height of the Light & Power Building in Kansas City is 145 meters.
11. The height of the IDS Center in Minneapolis is 235 meters.
12. The height of the World Trade Center in New York is 412 meters.
13. The height of the Empire State Building in New York is 381 meters.
14. The height of the Liberty Tower in Oklahoma City is 152 meters.
15. The height of the Woodmen Tower in Omaha is 138 meters.
16. The height of the City Hall in Philadelphia is 167 meters.
17. The height of the U.S. Steel Building in Pittsburgh is 256 meters.
18. The height of the Gateway Arch in St. Louis is 192 meters.
19. The height of the Capitol in Washington, D.C. is 170 meters.

For great distances, as we mentioned before, the unit kilometer is used. Remember the prefix kilo means 1,000 times. Therefore a kilometer equals 1,000 meters. For your reference, some approximate distances from Chicago to major North American cities are given as follow:

1. Chicago to Los Angeles: 3371 kilometers.
2. Chicago to New York City: 1187 kilometers.
3. Chicago to Dallas: 1506 kilometers.
4. Chicago to Miami: 2188 kilometers.
5. Chicago to New Orleans: 1519 kilometers.
6. Chicago to Seattle: 3319 kilometers.
7. Chicago to Atlanta: 1174 kilometers.

Section 7: land area and area measurement

In metric countries, the basic unit of land area is the are (ARE, pronounced AIR). An are is 100 square meters, or 10 meters on each side.

An ordinary one-story suburban house would cover about 2 ares. However, metric real estate is sold in hectares (HECTARES, 100 ares), equal to 10,000 square meters. One square kilometer equals 100 hectares. An ordinary suburban lot would be about one fifth of a hectare.

The metric system will make people more aware of real estate values. For example, a familiar television commercial advertises "four lots: only \$5,000 for all four." These lots, as it turns out, are 75 feet by 50 feet. All four together amount to only about one-third of an acre. This means that the property is actually being sold for \$14,520 an acre. This is a rather hefty sum!

The problem is, of course, the difficulty of remembering conversion units in our English system and then calculating the cost. The metric system will make it easier for us to spot deceptions. For example, in the metric system all we need to know is the value of a square meter. If it were \$10, we would know immediately what a half-hectare would cost ($5,000 \times \$10 = \$50,000$). For small areas, the units which are used in the metric system are the square millimeter, square centimeter, and square meter.

1. A square millimeter is the area enclosed by a square whose sides are each 1 millimeter long.

2. A square centimeter is an area enclosed by a square whose sides are each 1 centimeter long.
3. A square meter, therefore, is an area enclosed by a square whose sides are each 1 meter in length.

The preferred area units are the same as those for the measurement of length, but they are preceded by the word "square."

Lesson 2

In the previous lesson you have learned the metric system, the SI base units, SI metric unit prefixes, SI metric derived units, metric symbols, linear and area measurements.

Now you will learn (1) volume measurement, (2) weight and mass measures, (3) temperature measures, and (4) measures of work, power, and some other quantities.

Section 1: volume measurement

Our English system has two separate sets of measures for volume, one dry and one liquid. Confusion is increased by units like the dry quart and the liquid quart, which are very nearly, but not exactly, the same.

The SI unit for volume or cubic capacity is the cubic meter (m^3). The cubic meter is the volume of a cube each side of which is one meter in length. Because of the large size of the m^3 , submultiples of this unit are often used. For volume calculations the cm^3 and mm^3 are used. For fluid volume or capacity, use the unit liter (LITER). One liter equals one cubic decimeter, and the milliliter is equal to 1 cubic centimeter. For dry volumes, units such as the cubic millimeter and cubic meter are used. The fluid volume units such as liter and its multiples are used for fluids (such as gases or liquids) and particles like salt or sugar. Such liquids as gasoline, milk, and oil will be sold by the liter. Large volume capacities, such as a tank truckful, will be in cubic meters.

The liter is most common, probably because it is a convenient size to measure. By definition, 1 liter = 1 cubic decimeter. In other words, a cube with each side equal to 1 decimeter (or 10 cm) will hold 1 liter.

Most familiar household items will be measured or sized in liters. Pots for example will come in liter sizes, half-

liter sizes, or 2-liter sizes. Milk will be in 1-liter, 2-liter, or 4-liter containers. Those milk containers will not be too much different from existing capacities, since 1 liter is very close to the volume unit quart. A 1-liter milk carton is only slightly larger than the 1-quart carton. Beer will probably be in half-liter cans or liter cans, and so will soda. Farmers will package their strawberries in cubic-decimeter boxes and their potatoes in cubic-meter baskets.

As was previously stated, the milliliter, reserved for much smaller measures of volume than the liter, is one-thousandth of a liter and is equal to 1 cubic centimeter, or 1 cm^3 . In other words, a cube with each side equal to 1 cm will hold a quantity of 1 ml (milliliter).

Remember, volume can be very deceptive. A pot with the volume (or capacity) of 1 liter doesn't look as if it will hold half as much as a pot with a volume of 2 liters. The following example will give you some idea.

A cube that is 4 meters on the edge is:

$$4\text{m} \times 4\text{m} \times 4\text{m} = 64 \text{ m}^3$$

But a 5-meter cube is:

$$5\text{m} \times 5\text{m} \times 5\text{m} = 125 \text{ m}^3$$

In this example, by increasing the length of a side by 20 percent, we almost double the volume.

Let's look at some familiar examples and develop a better sense of the metric volume.

1. A regular jug will hold about 4 liters of milk.
2. A pint carton will hold about 0.5 liter (or 500 milliliters).
3. A full carton of milk holds about 1 liter.

A milk carton and its divisions should help you with the liter, which is the most common measure of volume.

For small volumes, we measure in milliliters. A good way to remember what a milliliter (a cubic centimeter) looks like is to associate it with the tip of your little finger - the good ole "pinky." Remember, the width of your smallest finger or fingernail is roughly 1 cm. The length of the fingernail is about as long, so the tip of the finger itself down to the beginning of the fingernail is a box that holds roughly $1 \text{ cm} \times 1 \text{ cm} \times 1 \text{ cm}$ or 1 cm^3 .

Two other small-volume references are particularly useful:

- 1 teaspoonful = 5 milliliters
- 1 tablespoonful = 15 milliliters

This is an example of a typical salad recipe made by metric measurement:

- 1 bunch watercress
- 0.5 liter mushrooms, fresh
- 0.25 liter red kidney beans, drained
- 1 bermuda onion
- 50 milliliters olive oil
- 15 milliliters red wine vinegar
- 2 milliliters garlic powder
- 2 milliliters dry oregano
- 3 milliliters powdered rosemary
- 0.01 milliliter dry mint powder
- 200 milliliters croutons
- 1 milliliter salt

Chop vegetables in fine pieces; add beans. Combine olive oil, wine vinegar, and seasonings. Mix well. Toss salad together with dressing. Cool and serve with croutons on top. Serves four generously.

Since there is a relationship between the metric linear unit and volume unit, it is much easier to figure out the volume by merely knowing the container size. For example:

1. A 1 cubic centimeter container holds 1 milliliter water.
2. A 1 cubic decimeter container holds 1 liter water.

Therefore, if you have a box that is 10 centimeters long, 5 centimeters wide, 2 centimeters high, you easily can figure out how much water is needed to fill up the box.

The way to do this is to first figure out the size of the box by multiplying length x width x height.

This would be 10 centimeters x 5 centimeters x 2 centimeters = 100 cubic centimeters.

Since 1 cubic centimeter = 1 milliliter, a 100 cubic centimeter box will be filled with 100 milliliters of water. We can also say it is 0.1 liter.

Remember, 1 liter = 1,000 milliliter.

Section 2: weight and mass

Here you will learn to associate the weights of common objects with metric units. The practice you will get should give you a good sense of what the metric units are -- probably a much better sense than you have now with units in the English system. But before you are ready for that practice, you should have some background.

The two physical quantities, mass and force, are easily confused because weight and mass are easily confused.

If you were an astronaut in space, the things around you would have very little weight. If you held a brick in outer space and released it, it wouldn't fall; it would remain suspended in space. And if you placed the brick on a weight scale, it wouldn't weigh very much. That's because you would be so far away from the earth that its gravitational pull would be reduced. And it is the force of that gravity which, somewhat like a magnet, pulls things downward and gives them weight.

Weight, then, is the result of the force of a pull - gravitational pull. Even when you go up on a mountain, things weigh less because you are farther from the center of the earth.

But the brick never loses its mass. Although it wouldn't weigh anything in space, you could still stub your toe on it. And the more mass the brick has, the harder you would stub your toe. In other words, neither a feather nor a brick weigh much in space. But you wouldn't hurt your toe on the feather because it has so little mass, whereas you would hurt it on the brick.

In science, the distinction between mass and weight is very important. But here on the surface of the earth and in everyday life, the weight of an object changes proportionally as its mass changes. For most practical purposes, then, we can estimate the mass of an object by weighing it.

In section 4, you will learn more about force. For now you may think of it as "the strength of push or pull." That strength is measured in SI by a unit called the newton (NEWTON). Weight, however, is a special kind of force, which we often use to estimate the size of mass in the SI unit of kilogram. As we use the word "weight," it is just another name for "mass."

First, let's look at the units of mass. There are actually four major metric units of mass:

1. The milligram (MILLIGRAM) abbreviated mg,
2. The gram (GRAM) abbreviated g,
3. The kilogram (KILOGRAM) abbreviated kg, and
4. The metric ton abbreviated t.

The milligram is so light (a grain of salt weighs about 1 milligram) that it is seldom used except in medicine and other scientific areas. At the other extreme is the metric ton. Very heavy things, like cars or industrial machinery, will be measured in metric tons. For some notion of how heavy a metric ton is, think of a box 1 meter wide, 1 meter long, and 1 meter deep. This box will hold 1 cubic meter. If you were to fill this box with water, the weight of this volume of water would be 1 metric ton, or 1,000 kilograms.

The two units of weight we will use every day are the gram and the kilogram. Most dry packaged goods like rice and breakfast cereals will be measured in grams. Most canned goods will be measured in grams, too. In fact, if you check your pantry, you will find that some manufacturers already list the weights of their products in grams as well as in pounds and ounces. Can you imagine the revolution in the supermarket when all canned goods of a similar size are in grams? With built-in unit-pricing it will be so easy to tell whether a bargain is really a bargain that all producers might even be encouraged to be honest!

Larger foodstuffs, like meats, will probably be measured in kilograms. A kilogram is equivalent to a thousand grams. (And 1,000 kilograms equal 1 metric ton.) People's weights will also be measured in kilograms.

From this brief introduction, you should know that when you measure the weight of a button, you will use the unit gram.

When you measure the weight of a deck of cards, you will use the unit gram, too.

When you measure the weight of a desk, you will use the unit kilogram.

OK, now let's look at some sample items for the gram.

1. One straight pin weighs 0.5 gram.
2. A nickel weighs 5 grams.
3. One battery, size D, weighs 100 grams.
4. A small can of tuna fish weighs 250 grams.

5. A telephone receiver weighs 300 grams.

For heavy weights, measured in kilograms,

1 kilogram = 1,000 grams.

A liter of milk is a convenient object to associate with 1 kilogram, and a six-pack of beer or of soda weighs about 2.5 kilograms. A 187-centimeter man weighs about 100 kilograms. (Some well-known people who weigh about 100 kilograms are quarterback Joe Namath and boxer Muhammad Ali.)

There are still other reference points to help you remember the kilogram scale.

1. A heavy suitcase is about 25 kg.
2. A Christmas turkey is about 9 kg.
3. A pineapple is about 1 kg.
4. A heavyweight wrestler is about 125 kg.
5. A jockey is about 45 kg.
6. The average man is about 80 kg.
7. The average woman is about 60 kg.
8. A cubic meter of water is about 1,000 kg.

From the above references, you should be able to estimate your weight in kilograms very closely. In the SI system, the kilogram is the base unit for weight (mass) because the gram is so small. As a result, the measure for mass is the only base unit that carries a prefix.

In the preceding discussion of volume, the relationship between the liter and the kilogram was established: 1 liter weighs 1 kilogram. You know that there are 1,000 milliliters in a liter and 1,000 grams in a kilogram. Therefore, it follows that 1 milliliter weighs 1 gram. The relationship between volume and weight is very useful. Let's look at some examples.

Example 1: A very light plastic box can be filled with 100 milliliters of water. How much does the water weigh?

As we know, 1 milliliter of water weighs 1 gram, so 100 milliliters of water weighs 100 grams. In other words, we can say 100 milliliters of water weigh 0.1 kilogram.

Example 2: If Sam drinks a liter of milk every day, how much milk does he drink?

Since 1 liter of milk weighs 1 kilogram, Sam drinks 1 kilogram of milk a day.

Section 3: temperature

Of all the classes of units, temperature is the one that everyone understands best, especially the natural or ambient temperature (the temperature of the air surrounding us). We are all forced to experience a warm day or a hot day or a cold day. When all else fails, we can still talk about the weather and be content to do nothing about it.

We also have a good sense of body temperature, even though most of us are not concerned with this every day. A body temperature of 37° Celsius is normal and indicates good health. A person with a temperature of 38° Celsius has a low-grade fever. If his temperature rises to 39° Celsius, he is quite sick. If his temperature is much over 40° Celsius, he is near death. Small differences have large significance. No wonder we understand what body temperature means.

Those of us who cook also understand oven temperatures and what they mean. A "slow" oven is 95 to 122° Celsius, a moderate oven is 150 to 180° Celsius, and a hot oven is 205 to 240° Celsius. Broiling temperatures are 260° Celsius or more.

Conversions from the Fahrenheit to the metric scale require cumbersome arithmetic. Fortunately, you won't have to make these conversions for everyday uses of temperature. What you will need is the same sense of temperature in metric units that you have now for Fahrenheit temperatures. This section will provide that understanding.

As you may remember from physics, heat is generated by the motion of molecules; everything has some quantity of heat. Even ice in the refrigerator has moving molecules that produce heat. Of course, as we take heat out of an object the molecules move less and less. If we took the temperature of an object that had no heat (the molecules had stopped moving), we would get no reading. This zero reading is called absolute zero temperature.

We don't have any experience with absolute zero temperature since on the Celsius scale it would register -273° Celsius. That's just about as cold as anything can possibly get. The zero point of the Celsius scale, then, is just an

arbitrary point. The mercury thermometer was experimented on with temperature using a mixture of salt and ice. The coldest reading that could be made from the mixture was called absolute "zero." (Of course, we know now that it was almost 273 degrees above the absolute zero.) As a result, on a Celsius scale water freezes at 0°C and boils at 100°C . None of the convenient points (like 0, 10, 50, or 100) actually means anything.

A few years after Fahrenheit's scale was adopted, Anders Celsius, a Swede, suggested a scale on which zero would be the freezing point of water and 100 degrees the boiling point. These points are very convenient and easy to remember. Celsius's scale was adopted and has been the scale used in science and in the metric system. It used to be called the "centigrade" (CENTIGRADE) scale, because of its range from 0 to 100; now it is officially the Celsius scale (CELSIUS).

(Since the "energy crisis," suggested room temperature is set at 20°C on the Celsius thermometer.)

More recently, science has adopted the Kelvin scale (K) spelled KELVIN. By starting at "absolute" zero, the Kelvin scale has no minus numbers. Its units are the same size as the Celsius scale. This means that a change of 1 degree on the Celsius scale is the same as a change of 1 point on the Kelvin scale.

The Kelvin is the official SI unit. Because the Celsius scale will be used in most practical situations, however, we will use the degree-Celsius as our unit, and it is acceptable in the SI system.

In the newly metric countries, people have simply had to start "thinking Celsius," since the arithmetic of converting from $^{\circ}\text{F}$ to $^{\circ}\text{C}$ is too complicated for daily use. Fortunately, it is easy to "think Celsius," just memorize:

100°C and water boils, 0°C and water freezes.

Now we are going to consider how to "think" ambient temperature on the Celsius scale. You have already learned that 100°C is boiling and 0°C is freezing. The following examples will give you several reference points for temperatures in between. You will note that there are memory aids for each reference point.

100°C	Boiling.
40°C	A hot, fiery day in summer.
30°C	A thirsty hot day in summer.

20°C	Room temperature.
10°C	A cool day in fall or spring.
0°C	Freezing.
-20°C	A bitter cold day in winter.
-40°C	About as frigid as it ever gets in the United States.

As for body temperature, the following examples will give you more understanding. It might help to first memorize the normal temperature which is 37°C. Notice that a person with the flu has a temperature of 39°C and that a person convulses at a temperature of 41°C. Also keep in mind that a 1°C rise is almost twice the temperature rise of 1°F, so far as its impact is concerned.

1. If your body temperature is 37°C, you are in a "normal" condition.
2. If your body temperature is 37.5°C, you will feel a slight cold.
3. If your body temperature is 38°C, you have a low-grade fever.
4. If your body temperature is 39°C, you've got flu.
5. If your body temperature is 40°C, you are quite sick.

Two other aspects that might give you more help are industrial and kitchen temperatures. The boiling point for water is a good reference for industrial temperatures, which at the other extreme is about 3,000°C, the temperature required to melt iron. Other examples include 1,000°C to melt gold, 250°C to broil steak, 215°C to roast beef, 200°C to bake potatoes, 175°C to bake cookies, 160°C to bake fish, 150°C to bake a cake, and 125°C to warm bread.

Section 4: work, power, and other quantities

Learning units of length, weight, volume, and temperature is like learning to speak and understand a new language fluently. But learning units of force and pressure (also work and energy) is like preparing yourself to read a new language with the use of a dictionary. This section will give you this kind of practice. Try to familiarize yourself with them.

First, you will learn units of force. When you want to move an object, the force you will have to exert depends on two things:

1. How much mass the object has. (You have to push harder to move a 1,000-kg piano than a 500-kg piano.)
2. How much you accelerate the object. (More force is required for a car to accelerate from zero to 20 km/hour in a second than from zero to 10 km/hour in the same period of time.)

To measure how much force one object exerts on another, both mass and acceleration must be considered.

The basic unit is defined as the amount of force required to accelerate 1 kilogram 1 meter per second per second. This unit of force is called a newton (Newton, N), after Isaac Newton, the English philosopher who created calculus and who is often called the father of classical physics.

It's rather hard to get a feel for the definition: accelerating a kilogram 1 meter per second per second exerts a force of about 1 newton on this object. Let's try to visualize this another way. If you hold a 100-gram object in your hand, the earth's gravity exerts a force of about 1 newton on this object. Or to put it in other words, you have to apply a force of 1 newton to hold a 100-gram object in the air.

For example, a size D flashlight battery has a mass of 100 grams. If you heft this battery, you will get the sense of a newton of force. An apple may also help you remember what a newton is. A small apple which weighs about 100 grams exerts a downward force of about 1 newton. The apple is a good memory aid, if you recall the story of Sir Isaac Newton's sudden discovery of the law of gravity when an apple fell on his head as he sat under a tree.

The following examples give you more practice.

1. A 100-kilogram man exerts a downward force of 1,000 newtons. Since 100-gram object exerts a 1-newton force, a 100-kilogram object = 1,000 100-gram objects (remember 1,000 grams = 1 kilogram); therefore, it produces 1,000 newtons.
2. The same principle, a 25-kg child, riding piggyback, would exert 250 newtons of force on your back.

In section 2 of this lesson you have learned of mass and weight. Actually, the concept of weight comes from the concept of force. Weight is a kind of force when the acceleration is imparted by gravity. Technically, weight should be measured in newtons, since the pull of gravity varies from place to

place. For example, weight is less on top of a mountain than at sea level. In much technical work in physics, weight is actually measured in newtons. However, for many purposes, and certainly for everyday use, weight is a useful way of estimating the mass of an object. At any particular place on earth, the acceleration of gravity will be constant. If two stones exert different downward forces, it must be because they have different masses. So, we can estimate the mass of an object if we measure the downward force of this object on a scale at a given place on earth.

From what we have said about force, you should understand the following examples.

1. If you hold a 1-kg ball in your hand, approximately 10 newtons of force exert on you.
2. An object exerting a force of 10 newtons downward on a scale would weigh about 1 kg.
3. A 1,000-kg car exerts a force of about 10,000 newtons on the earth.

The symbol for newton is capital N. Newton is a derived unit formed by mass and acceleration.

The next quantity is pressure. Pressure is related to force, but probably more familiar. For example, in the filling station, we ask for 200,000 newtons of air in the rear tires. What we are really asking for is an amount of air that is exerting 200,000 more newtons of force per square meter on the inside of the tire than does the pressure of air on the outside of the tire.

Newton per square meter or N/m^2 is the most common pressure unit in the metric system. It is now called the pascal (PASCAL). The pascal, or Pa (capital P and small a), is equal to a force of 1 newton exerted on an area of 1 square meter.

One pascal is not really very much pressure. Since a pascal is the force of a newton spread over a square meter, you can get some idea of it if you spread half a cup (about 100 grams) of sugar evenly over the top of a table that is 1 meter on each side. The pressure of the sugar exerted at any one point on the table would be quite small. In fact, it would take 200,000 pascals to inflate an ordinary automobile tire. For larger pressures, we use a larger unit - meganewtons per square meter, or MN/m^2 . (A meganewton, remember, is 1 million newtons.) Another even larger size is the giganewton per square meter, or GN/m^2 . (A giganewton is 1 billion newtons.) There are also MPa (megapascals) and GPa (giga-

pascals). The symbol of prefix mega is capital M; giga is capital G.

Another common metric unit of pressure is the bar (small b), which is equal to 100,000 Pa. The bar is particularly useful in meteorology.

After you learned the quantities force and pressure, we will talk about the SI units of work and energy. In physics, energy is defined as the capacity to do work. When you pay your electric bill, you pay for kilowatt-hours, which is the energy the electric company supplies to do work for you. When you buy a window air conditioner, you buy BTU's - the amount of work this air conditioner will do to cool the air for an hour. When you count the calories you eat, you count units of food energy, some of which get stored in your body as fat for future work. Kilowatt-hours, BTU's, and calories are among the many units used to describe work and energy.

One reason for having so many units is that energy comes in so many forms. One kind is heat energy, the capacity of matter to do work as it burns. A calorie (CALORIE) is a metric unit for heat energy. It is defined as the amount of heat needed to raise a kilogram of water 1 degree Celsius. To get some idea of what a calorie is, consider that a teaspoonful of sugar has about 15 calories. If you burned it very efficiently, you would raise the temperature of 15 kilograms of water 1 degree Celsius.

Another kind of energy which we encounter every day is electrical energy. It is measured in both the English and metric systems as kilowatt-hours (kWh). A kilowatt-hour is about how much energy you would use to burn a couple of light bulbs all night long. Electrical engineers, electricians, and electrical contractors won't have to learn a new measurement system because electrical units are universally metric.

One property of energy is that one kind of energy can be converted to another kind. This means that we can burn gas (heat energy) to turn an engine (mechanical energy). Or we can generate electricity by turning a wheel.

Work can be defined as force exerted through a distance. An object resting on the palm of your hand exerts a force, but no work is done because nothing is moved. When you hold a heavy object, you may be doing work psychologically, but you are doing no physical work because you aren't moving the object. But if you drop the object so that it falls on a spring, it will move the spring and thus do work. The farther the object falls, the farther it will move the spring. Work, then

can be defined as force times distance.

If you exert a force of 1 newton through a distance of 1 meter, you will have done 1 metric unit of work. This unit is called a joule (JOULE, J), which is pronounced Jool. A good way to get an idea of a joule of work is to lift something. If you lift a flashlight battery 1 meter, this activity requires the energy of about 1 joule. If you then drop the flashlight battery, its impact on the floor will yield 1 joule of energy.

Next we are going to discuss power and energy. If a small child lifts a load of bricks one brick at a time from the floor to a table, he does just as much work as a strong man who lifts the same load all at once. Both are moving the same number of kilograms through the same distance. Although the strong man does the same work, he works at a faster rate. This rate or speed of work is called power.

Just as velocity is measured as meters per second or kilometers per hour, power is measured as work per second, or joules per second. If it takes me twice as long to do a joule of work as it takes you, you have twice my power even though we may use the same energy.

The SI unit for power is the watt (WATT, W). The watt is equal to 1 joule per second, or $1 \text{ W} = 1 \text{ J/S}$. Lifting a flashlight battery 1 meter equals a joule of energy; you will use 1 watt of power if you lift the battery that far in 1 second.

The metric unit of power that is used depends upon the amount of power being measured. Watts are used for measuring intermediate size power, like that required to operate home appliances. Milliwatts and microwatts are used to measure the tiny power requirements in electronic equipment. When conversion to the metric system is complete, the kilowatt will replace many larger units of power, including the very familiar unit horsepower, also the BTU-per second, and the kilocalorie per minute. The kilowatt will be used, among other things, to measure the mechanical and electrical power output of engines and generators and the heat demand of building.

The engine of a small American car can generate about 100 kilowatts of power. A tiny foreign car engine generates about 50 kilowatts of power and a large American car engine generates about 250 kilowatts. Try to replace horsepower with kilowatt in your thinking.

Now you have completed the second lesson of thinking metric. You probably won't be able to remember all of these

units or their relationships to other units. But you should have some idea now what they are, and how they are applied in daily use.

This is the end of Lesson 2. Study it until you are familiar with its contents.

**Appendix B: Conversion Approach Audile
Learning PAC**

Introduction to Metrics

Weights and measures were some of the first tools invented by humans. Early civilization needed simple measures for many tasks: constructing dwellings, making clothing and trading food and raw materials.

People first turned to parts of the body and their natural surroundings to use as measuring instruments. Early Egyptian records and the Bible show us that length was first measured with the forearm, hand, and finger in units such as cubits, spans, and digits. Time was measured by the periods of the sun, moon, and other heavenly bodies. To compare the sizes of containers such as gourds or clay pots, the receptacles were often filled with plant seeds which were counted to measure volume. When means for weighing were invented, seeds and stones served as standards; for instance, the "carat," still used as a unit of weight for precious stones, was derived from the carob seed.

As civilizations progressed, weights and measures became more complex. The invention of mathematics made it possible to create entire systems of weights and measures for use in land division, taxation, or scientific research. For these uses it was necessary not only to weigh and measure more complex things, but also to do so accurately and repeatedly, all over the world. Each country invented its own measuring system, but gradually these systems became more standardized as nations began to trade with one another. The metric system and our customary system of inches and pounds are the two major systems.

Why Do We Need to Learn the Metric System?

Someone might ask why we need to learn the metric system since we have our present system already in use. Several reasons for converting to the metric system are as follow: First, the metric system is much simpler than the system of feet, pounds, gallons and degrees Fahrenheit. Second, the rest of the world has adopted the metric system; if we don't change soon we won't be able to communicate effectively with the rest of the world.

Let's look into this further. Today, all the people of the world, except the United States and a few small countries like Tonga and Liberia, use the standard, elegant, streamlined language of the metric system. England, Australia, and New Zealand are at the end of a 10-year program of conversion to the metric system. Even our neighbor Canada has started a

conversion program. We have been left alone, and at great disadvantage to ourselves.

The cost to industry is one example. Since we buy and sell machinery and parts in the world market, many industries must maintain a double inventory of goods. Converting to the metric system will not only save the North American economy billions of dollars every year, but it will also help up remain competitive in world markets.

Another important reason for us to adopt the metric system is the nature of this system. Since the metric system is based on ten, it will simplify the basic arithmetic and science taught in schools. As a conservative estimate, 15 percent of the time spent in elementary arithmetic is used to teach such tiresome skills as finding the least common denominator and reducing fractions to their simplest terms. Since these skills are primarily needed for performing arithmetic using feet and inches and pounds and ounces, they presumably can be eliminated from the curriculum. The time spent in teaching just those skills may cost us well over a billion dollars a year.

There are numerous advantages in using the metric system in our daily lives. Many sources indicate that the United States will be unable to resist this worldwide rush for change to the metric system. Sooner or later the metric system must be used in this society. Many major corporations have established programs to complete their conversion, among which are the Ford Motor Company, General Motors, IBM, and Honeywell. Consumer goods are also gradually being labeled in dual measures. Weather forecasts of some broadcasting and television stations have begun to use both temperature systems. Now is the time for America to think metric and to learn metric. We will need to know what these metric units are so we can understand the articles we will be seeing more and more frequently in newspapers and magazines as we go completely metric.

Now let's start to think metric. This short course of "learning metric" includes two units, one hour for each. In the first unit you will learn:

- (1) The metric system,
- (2) The SI base units
- (3) SI metric unit prefixes,
- (4) SI metric derived units,
- (5) Symbols,
- (6) Linear measurement, and
- (7) Area measurement.

In the second unit you will learn:

- (1) Volume measurement,

- (2) Weight and mass measurement,
- (3) Temperature measurement, and
- (4) Work, power, and other quantities of measurement.

Lesson 1

This first lesson will take approximately one hour. After learning this lesson you will know:

- (1) The metric system,
- (2) The SI base units,
- (3) SI metric unit prefixes,
- (4) SI metric derived units,
- (5) Symbols,
- (6) Metric linear measurement, and
- (7) Metric area measurement.

Section 1: the metric system

The need for a single, worldwide coordinated measurement system was recognized over 300 years ago. In 1670, Gabriel Mouton, a Frenchman, proposed a single decimal measurement system based on the length of one minute of an arc from the circle of the earth.

In 1790, during the French Revolution, the National Assembly of France asked its Academy of Sciences to "deduce an invariable standard for all the measures and all the weights." The unit of length was to be a portion of the earth's circumference. Measures for capacity (volume) and mass (weight) were to be based upon the unit of length, thus relating the basic units of the system to each other. Furthermore, the larger and smaller versions of each unit were to be created by multiplying or dividing the base units by 10 and its multiples. This feature made the system convenient to use by eliminating the need for such calculations as division by 16 (to convert ounces to pounds) or by 12 (to convert inches to feet). Similar calculations in the metric system, the name for this new measurement system, could be performed simply by shifting the decimal point. Thus, the metric system is a "base-10" or "decimal" system.

The Commission assigned the name "meter" (METER) to the unit of length. The physical standard for the meter was to be equal to one ten-millionth of the distance from the North Pole to the equator, measured along a line running through Paris, France. Now modern science has made a more accurate standard possible. The meter is defined in terms of the wavelengths of light given off by the krypton-86 atom.

The metric unit of mass, called the gram (GRAM), was defined as the mass or weight of one cubic centimeter (a cube that is 1/100th of a meter on each side) of water at a certain temperature. The cubic decimeter (a cube 1/10th of a meter on each side) was chosen as the unit of fluid volume or capacity. This measurement was given the name "liter" (LITER). A liter of water now weighs one kilogram.

By the late 1860's even better metric standards were needed because of technological and scientific progress. In 1875 an international treaty, the "Treaty of the Meter," set up metric standards for length and weight and established a committee to adopt other metric measures. This treaty, known as the Metric Convention, was signed by 17 countries, including the United States. As a result of the treaty, metric standards were constructed and distributed to each signer. Since 1893 the international metric standard has served as the weights and measures standard of the United States. This means, simply, that our customary inch and pound units are based upon the meter and kilogram.

By 1900, a total of 35 nations — including the major nations of Europe and most of South America — had officially accepted the metric system. Today, with the exception of the United States and a few other countries, the entire world is using or is planning to use the metric system. In 1971, the U.S. Secretary of Commerce sent to Congress the results of a three-year study authorized by the Metric Study Act of 1968. In it he recommended that the United States change to predominant use of the metric system through a coordinated national program.

The International Bureau of Weights and Measures, located at Sèvres, France, is the permanent site for the Metric Convention. As more accurate ways of defining measurement units are developed, the General Conference of Weights and Measures — the organization made up of members of the convention — meet to vote on improvements in the system and the standards.

In 1960, the General Conference adopted a more modern metric system. The name System International d'Unites (International System of Units), with the international abbreviation SI, was adopted for this modernized metric system. Further improvements in SI were made in 1964, 1968, and 1971.

Section 2: the SI base units

The SI metric system is built upon a foundation of the seven base units. They are:

1. Meter (METER) for length is usually abbreviated using small m. The units for length we use today are feet and inches.
2. Kilogram (KILOGRAM) for mass or weight, abbreviated with the small letters kg. The unit for mass or weight, in our customary measures, is pound.
3. Second (SECOND) for time is abbreviated with a small s. This is the same unit we are using today for measuring time.
4. Kelvin (KELVIN) for temperature is usually abbreviated with a capital K. The kelvin is used mainly for scientific measurement. For practical, everyday purposes, the degree Celsius (CELSIUS, °C) is used and is abbreviated with a capital C. Water boils at 100°C, and it freezes at 0°C. The temperature unit which we currently use is the degree Fahrenheit. Water boils at 212°F and it freezes at 32°F.
5. Ampere (AMPERE) for electric current is abbreviated with a capital A. It is the same unit which we are using now.
6. Candela (CANDELA) is used for luminous intensity. It is abbreviated with a small cd. The candela is used to measure an amount of light.
7. Mole (MOLE) stands for an amount of a substance. The small letters mol are used for the abbreviation. This unit is used mainly in special scientific measurement.

There are two supplementary units, the radian (RADIAN) and the steradian (STERADIAN), used to measure plane and solid angles. These will not normally be used by most people, but it is important to know that they exist.

There are also many derived units, such as the pascal (PASCAL) to measure pressure and newton (NEWTON) to measure force.

Section 3: SI metric unit prefixes

There are different units (like miles, yards, feet, and inches) because we need different-sized standards depending on whether we are measuring short, long, or very long distances. The same is true for other physical quantities. We could weigh everything in tons, if we wanted to, but when we wanted

to buy a pound of steak, we would have to ask for 5 ten thousandths of a ton. For convenience, we use different units to express different sizes. The only problem is that the units we have chosen to represent these sizes require difficult conversion. For example, we must learn that:

12 inches = 1 foot
 3 feet = 1 yard
 5280 feet = 1 mile

And when we go to the supermarket, we must remember an entirely different set of conversions, such as:

8 ounces = 1 cup
 16 ounces = 1 pint
 2 pints = 1 quart
 4 quarts = 1 gallon

Each measure has its own conversion — 1 qt. = 4 cups = 32 oz. — and there are many other physical quantities for each of these measures. In practice, we remember the common conversions. But for the entire span of our lives we must consult a guide for the measurements we don't use every day. This makes no sense at all.

With the metric system of prefixes and roots, the only conversion we need to make is from one size to another. There is a root for each physical quantity and a prefix for each significant size. To simplify things further, each prefix is a multiple of 10. For example, one common prefix is "kilo", (KILO), meaning "a thousand times." The prefix added to the root "meter" produces "kilometer" (KILOMETER). A kilometer is a measurement of distance equal to 1000 meters. The prefix "kilo" added to the root "gram" (for the quantity of mass) produces "kilogram" which is equal to 1000 grams.

The most common prefixes in daily use will be the following. Try to listen carefully to their spelling, pronunciation, and meaning.

First we start with the basic units = 1. These basic units are the roots referred to earlier. To make the basic units smaller the following prefixes are added to the beginning of the roots.

1. deci (DECI) means one tenth of (0.1).
 (DESS-ie)
2. centi (CENTI) means one hundredth of (0.01).
 (SEN-ta)
3. milli (MILLI) means one thousandth of (0.001).
 (MILL-ie)

4. micro (MICRO) means one millionth of (0.000001).
(MY-crow)

To make the basic units larger, these prefixes are added.

1. hecto (HECTO) means a hundred times (100).
(HECK-toe)
2. kilo (KILO) means a thousand times (1,000).
(KILL-o)
3. mega (MEGA) means a million times (1,000,000).
(MEG-a)

Let's look at some examples:

1 kilometer	1,000 meters
1 milliliter	$\frac{1}{1,000}$ liter
1 mile	5280 feet
1 gallon	128 ounces

Section 4: symbols

When we write our customary unit, we generally use only the abbreviation of the unit. This is simple and easy to read. For example, we write foot or feet as ft, ounce as oz, and inch as in. In the metric system there are symbols for both prefixes and units which make it much easier to write and read them. The symbols for the metric prefixes and units are handy to know. They are very simple, so try to listen carefully to these symbols.

<u>Prefix</u>		<u>Symbol</u>
mega	M	capital M
kilo	k	small k
hecto	h	small h
deci	d	small d
centi	c	small c
milli	m	small m
micro	μ (mu)	a Greek letter which looks like the letter u
<u>Root unit</u>		<u>Symbol</u>
meter	m	small m
liter	l	small l

Root unit (cont.)

gram

Symbol (cont.)

g small g

After you learn them you can write the symbols for the different quantities such as:

kilometer	is	km	small k, small m
milliliter	is	ml	small m, small g
kilogram	is	kg	small k, small g

Section 5: SI metric derived units

Derived units are any combination of base, supplementary or other derived units. They are obtained by means of multiplication and division. For example, the derived unit for area is the square meter (m^2), just as the area unit in the English system is the square foot (ft^2). It is obtained by multiplying length by width. Some of the derived units have been given special names and symbols. These are used to express the derived unit in a simpler way than in terms of the base units themselves. For example, the derived unit for force is called simply the newton. Expressed in base units, it is $kg \times m/sec^2$. Obviously, it is much easier to say "newton" than to state the more complex formula.

Following are some basic and derived units we often use.

Fundamental measure	Basic unit	Derived measure	Derived unit
Length	Meter	Area and volume	Square meter and cubic meter
Mass	Kilogram	Force work (energy) power	Newton joule, (JOULE) watt, (WATT)
Time	Second	Frequency speed	Hertz, (HERTZ) meter/second kilometer/hour
Thermodynamic temperature	Kelvin	Celsius temp.	Degree Celsius
Electric current	Ampere	Electromotive force Resistance Capacitance	Volt Ohm Farad

Section 6: distance and speed

Once the metric system is fully adopted, all cloth will be sold by the meter and centimeter instead of the yard and feet; speed limits will be designated by kilometers per hour instead of today's miles per hour; screws, ammunition, and tools will be sized by the millimeter, not inch; and bathroom tiles will be measured by the centimeter. When you finish this section, you will be on intimate terms with these units. Equally important, you will have a much better idea of the size of a 15-millimeter hole than you now have of a 15-inch hole.

Let's consider the small distances first. In the metric system, the distances between a tenth of an inch and a few yards are normally expressed in three ways:

- (1) in millimeters (mm),
- (2) in centimeters (cm), and
- (3) as decimal parts of a meter (m).

In scientific and engineering work, the millimeter and the meter are used frequently, but the centimeter is seldom used. In everyday affairs, however, the centimeter is the most common unit. Here you will learn to use all three units interchangeably. Remember, a millimeter is equal to a tenth of a centimeter and a thousandth of a meter. As a handy reference, keep in mind that a meter is about 10 percent larger than a yardstick.

Some examples will give you a better idea.

1. The width of your pen or pencil is about 5 to 8 mm; that is, 0.5 to 0.8 cm, or 0.005 to 0.008 meter.
2. The width of your thumb at the knuckle is about 15 to 35 mm; that is, 0.15 to 0.35 cm, or 0.005 to 0.035 meter.

If we want to practice more, our bodies give us easy references for small distances. Most people will find that when four fingers are pressed together to form a straight edge, the measure will close to 50 mm. If your fingers are particularly large, you may have to press them closer together to measure 50 mm. If they are particularly small, you may have to spread them slightly. Once you see how to hold your fingers to measure 50 mm, you will have a ruler that will always be with you.

The following body reference sizes will give you some measuring ideas.

1. The width of the tip of the little finger, or the width of a fingernail, is 10 mm.
2. The tips of two fingers pressed together equal 25 mm.
3. The tips of four fingers pressed together equal 50 mm.
4. The width of the hand from thumb knuckle to side is 100 mm.
5. The length of the hand is 200 mm.
6. From the left shoulder to the tip of the right hand is 1,000 mm.
7. From hand to hand is 1,500 mm.

Once you know those body reference sizes, you can estimate the size of lots of things, for example: Your shoe length will be approximately 250-350 mm. If you measure from your knee to the floor, it will be approximately 50 cm. (Remember 10 mm = 1 cm) The length of a closed mouth will be approximately 60 mm; the width of a package of cigarettes will be approximately 5 cm. The length of a telephone receiver will be approximately 200 mm. The length of your pencil will be approximately 19 cm.

Some other common sizes are:

1. The diameter of a quarter is about 2.5 cm.
2. The diameter of an aspirin tablet is about 10 mm.
3. The length of a king size cigarette is 80 mm.
4. The diameter of an LP record is 30 cm.
5. The diameter of a hole in the telephone dial is 13 mm.
6. The length of a dinner fork is about 19 cm.
7. The diameter of a cigarette is 8 mm.
8. The height of a can of cola is 12 cm.

Now you have some ideas about those small distances. It will be easier to look at some intermediate distances in metric measurement. Let's think in the unit meters. There is a useful body reference, which is your height. The following English measures and metric measures give you the conversion of your height in metric equivalents.

4 ft.	9 in.	=	145	cm
4 ft.	10 in.	=	147.5	cm
4 ft.	11 in.	=	150	cm
5 ft.	0 in.	=	152.5	cm
5 ft.	1 in.	=	155	cm

5 ft.	2 in.	=	157.2	cm
5 ft.	3 in.	=	160	cm
5 ft.	4 in.	=	162.5	cm
5 ft.	5 in.	=	165	cm
5 ft.	6 in.	=	167.5	cm
5 ft.	7 in.	=	170	cm
5 ft.	8 in.	=	172.5	cm
5 ft.	9 in.	=	175.5	cm
5 ft.	10 in.	=	178	cm
5 ft.	11 in.	=	180.5	cm
6 ft.	0 in.	=	182	cm
6 ft.	1 in.	=	185.5	cm
6 ft.	2 in.	=	188	cm
6 ft.	3 in.	=	190.5	cm
6 ft.	4 in.	=	193	cm
6 ft.	5 in.	=	195.5	cm
6 ft.	6 in.	=	198	cm
6 ft.	7 in.	=	200.5	cm
6 ft.	8 in.	=	203	cm

Memorize your own metric height. Try to remember how tall a few relatives and friends are - and also some children. These heights will be handy references, too. An additional set of references might be the so-called average heights for men and women. For women the average height is 165 cm, and for men it is 180 cm.

In addition to body height, a pace is another convenient way to estimate the length of a room to within a few centimeters. Usually people pace off about a meter stride. If you are used to pacing off yards, add about 10 percent to your stride, since a meter is 10 percent longer than a yard. The pace will become a handy, lifetime meter rule. Let's look at some examples by using pace metrics.

1. A football field is about 90 meters.
2. From home plate to the left-field wall is about 100 meters.
3. From the pitcher's mound to home plate is about 19 meters.
4. The Olympic pole vault record is about 560 cm.
5. The Olympic long jump record is about 840 cm.
6. The Olympic high jump record is about 225 cm.
7. A typical golf fairway is about 350 meters.
8. The men's ski jump is about 90 meters.
9. The women's ski jump is about 70 meters.

As for large distances, we know that most of the world's measurement systems came from common, practical reference sizes. The foot obviously refers to the size of a human foot. Metric lengths were established more scientifically. Initially, in the eighteenth century, the meter was defined as $1/10,000,000$ th of the distance between the equator and the North Pole. Since then a more precise standard has been established. Nevertheless, we can still say there are about 10,000,000 meters from the equator to the North Pole.

The next section will deal with speed and great distances.

We translate great distances into time. How long does it take to get there? Here you will learn to think of distances as distances in time, especially as kilometers per hour (km/h), just as we think of the similar concept in use every day in the English system of miles per hour.

All road signs will one day give distances in kilometers and speed limits in kilometers per hour, as they do now in most other countries. If you drive a foreign car, you are probably already accustomed to speedometer readings in kilometers per hour.

Let's look at some speed limits which we see on a road-sign every day.

1. The highway speed limit 55 miles/hour translates to metric speed of 88 km/hr.
2. City traffic, 30 miles/hour, translates to a metric speed of 48 km/hr.
3. When you drive through a residential area, the speed limit is 25 miles/hour or 40 km/hr. in metric speed.
4. A school zone is 15 miles/hour or 24 km/hr.

A few approximate English-metric conversions may help you to transfer daily-used English length units to the metric measures.

1. When you know the number of inches, multiply by 25 to find the number of millimeters. For example, a 10 inch ruler is the same length as a 250 mm ruler. You multiply $10 \times 25 = 250$.
2. When you know the number of feet, multiply by 300 to find the number of millimeters. For example, John is 6 feet tall. That means he is 1800 mm, or more practically we can say he is 180 cm in height. $6 \text{ ft} \times 300 = 1800 \text{ mm}$. $1800 \text{ mm} = 180 \text{ cm}$.

3. When you know the number of yards, you can multiply by 0.9 to find the length in meters. For example, a football field is 100 yards, but in metric distance it is 90 meters. $100 \text{ yards} \times 0.9 = 90 \text{ meters}$.
4. When you know the number of miles, you multiply by 1.6 to find the length in kilometers. For example, the distance from Ames to Boone is 17 miles or it is 27.2 km. $17 \text{ miles} \times 1.6 = 27.2 \text{ kilometers}$.

There are three conversion factors for transferring metric units to English measures.

1. When you know the number of millimeters, you can multiply by 0.04 to find inches. For example, the 100's cigarette is 100 mm long, or in the English system it is 4 inches long. $100 \text{ mm} \times 0.04 = 4 \text{ inches}$.
2. If you multiply meters by 1.1, you can get yards. For example, the men's ski jump is 90 meters, or 99 yards in the English system. $90 \text{ meters} \times 1.1 = 99 \text{ yards}$.
3. If you multiply kilometers by 0.6, you can get miles. For example, the distance from Los Angeles to New York City is 4690 kilometers, or 2814 miles. $4690 \text{ kilometers} \times 0.6 = 2814 \text{ miles}$.

If you can remember these common conversion factors, you will not have a problem in translating one system to another.

Section 7: land area and area

In metric countries, the basic unit of land area is the are (ARE, pronounced AIR), which is 100 square meters, or 10 meters on each side.

An ordinary one-story suburban house would cover about 2 area. However, metric real estate is sold in hectares (HECTARES, 100 ares), equal to 10,000 square meters. One square kilometer equals a hectare. One hectare is 2.5 times the size of an acre. An ordinary suburban lot would be about one fifth of a hectare.

Perhaps the metric system will make people more aware of real estate values. For example, a familiar television commercial advertises "Four lots, only \$5,000 for all four." These lots, as it turns out, are 75 feet by 50 feet. All four together amount to only about one-third of an acre. This means that the property is actually being sold for \$14,520 an acre, which is rather a hefty sum!

The problem is, of course, the difficulty of remembering conversion units in our English system and then calculating the cost. The metric system will make it easier for us to spot deceptions. For example, in the metric system all we need to know is the value of a square meter. If it were \$10, we would know immediately what a half-hectare would cost ($5,000 \times \$10 = \$50,000$).

For small areas, the units used in the metric system are square millimeter, square centimeter, and square meter.

1. A square millimeter is the area enclosed by a square whose sides are each 1 millimeter long.
2. A square centimeter is an area enclosed by a square whose sides are each 1 centimeter long.
3. A square meter, therefore, is an area enclosed by a square whose sides are each 1 meter long.

The preferred area units are the same as those for the measurement of length, but they are preceded by the word square.

Lesson 2

In the previous lesson you learned the metric system, the SI base units, SI metric unit prefixes, SI metric derived units, metric symbols, and linear and area measurements.

Now you will learn (1) volume measurement, (2) weight and mass measures, (3) temperature measures, and (4) measurements of work, power, and some other quantities.

Section 1: volume measurement

Our English system has two separate sets of measures for volume, one dry and one liquid. Confusion is increased by units like the dry quart and the liquid quart, which are very nearly but not exactly the same.

The SI unit for volume or cubic capacity is the cubic meter (m^3). The cubic meter is the volume of a cube each side of which is one meter in length. Because of the large size of the m^3 , submultiples of this unit are often used. For fluid volume or capacity, use the unit liter (LITER); 1 liter equals 1 cubic decimeter, and the milliliter equals 1 cubic centimeter. For dry volumes, units such as cubic millimeter and cubic meter are used. The fluid volume units, such as liter

and its multiples, are used for fluids (such as gases or liquids) and particles like salt or sugar. Such liquids as gasoline, milk, and oil will be sold by the liter. Large capacity measures, such as a tank truckful, will be in cubic meters.

The liter is most common, probably because it is so much like a quart. It is actually 5 percent greater than a quart. By definition, 1 liter is 1 cubic decimeter. In other words, a cube with each side equal to 1 decimeter (or 10 cm) will hold 1 liter.

Most familiar household items will be measured or sized in liters. Pots, for example, will come in liter sizes, half-liter or 2-liter sizes. Milk will be in 1-liter, 2-liter, or 4-liter containers. Those milk containers will not be too much different than existing sizes, since 1 liter is only 5 percent greater than a quart. A 1-liter milk carton is just slightly larger than the 1 quart carton. Beer will probably be in half-liter cans or liter cans, and so will soda. Instead of dry quarts and dry bushels, farmers will package their strawberries in cubic-decimeter boxes and their potatoes in cubic-meter baskets.

As previously stated, the milliliter, reserved for much smaller measures of volume than the liter, is one-thousandth of a liter and is equal to 1 cubic centimeter or 1 cm³. In other words, a cube with each side equal to 1 cm will hold a quantity of 1 ml (milliliter). Remember, volume can be very deceptive. A pot with a volume (or capacity) of 1 liter doesn't look as if it will hold half as much as a pot with a volume of 2 liters. The following example will give you some idea.

A cube that is 4 meters on the edge is:

$$4 \text{ m} \times 4 \text{ m} \times 4 \text{ m} = 64 \text{ m}^3$$

But a 5-meter cube is:

$$5 \text{ m} \times 5 \text{ m} \times 5 \text{ m} = 125 \text{ m}^3$$

In this example, by increasing the length of a side by 20 percent, we almost double the volume.

Let's look at some familiar examples to develop a better sense of metric volume.

1. A gallon jug will hold about 4 liters of milk.
2. A pint-size carton will hold about 0.5 liter (or 500 milliliters).

3. A full carton of milk, or a quart, holds about 1 liter.
4. A milk carton and its divisions should help you with the liter, which is the most common measure of volume.

For small volumes, we measure in milliliters. A good way to remember what a milliliter (a cubic centimeter) is like is to associate it with the tip of your little finger - the "pinky." Remember, the width of your smallest finger or fingernail is roughly 1 cm. The length of the fingernail is about as long, so the tip of the finger itself down to the beginning of the fingernail is a box that holds roughly 1 cm x 1 cm x 1 cm or 1 cm³.

Two other small-volume references are particularly useful:

1 teaspoonful = 5 milliliters
1 tablespoonful equals 15 milliliters

This recipe is an example of a typical salad made using metric measurement:

1 bunch watercress
0.5 liter mushrooms, fresh
0.25 liter red kidney beans, drained
1 bermuda onion
50 milliliters olive oil
15 milliliters red wine vinegar
2 milliliters garlic powder
2 milliliters dry oregano
3 milliliters powdered rosemary
0.01 milliliter dry mint powder
200 milliliters croutons
1 milliliter salt

Chop vegetables in fine pieces; add beans. Combine olive oil, wine vinegar, and seasonings. Mix well. Toss salad together with dressing. Chill and serve with croutons on top. Serves four generously.

Some common metric-English equivalent volumes follow, to make it easier to understand container size relationships.

1 ounce = 30 milliliters
1 pint = 0.47 liter
1 quart = 0.95 liter
1 gallon = 3.8 liters
1 milliliter = 0.03 ounce
1 liter = 2.1 pints, or 1.06 quarts, or 0.26 gallons.

Remember 1 liter equals 1000 milliliters.

Section 2: weight and mass

In this section you will learn to associate the weights of common objects with metric units. The practice you will get should give you a good sense of what the metric units are -- probably a much better sense than you have now with units in the English system. But before you are ready for that practice, you should have some background.

The two physical quantities, mass and force, are easily confused. The reason is that weight and mass are easily confused.

If you were an astronaut in space, the things around you would have very little weight. If you held a brick in outer space and released it, it wouldn't fall; it would remain suspended in space. And if you placed the brick on a weight scale, it wouldn't weigh very much. That's because you would be so far away from the earth that its gravitational pull would be reduced. And it is the force of that gravity which, somewhat like a magnet, pulls things downward and gives them weight.

Weight, then, is the result of the force of a pull -- gravitational pull. Even when you go up on a mountain, things weigh less because you are farther from the center of earth.

But the brick never loses its mass. Although it wouldn't weigh anything in space, you could still stub your toe on it. And the more mass the brick has, the harder you would stub your toe. In other words, neither a feather nor a brick weighs much in space. But you wouldn't hurt your toe on the feather because it has so little mass, and you would hurt it on the brick.

In science, the distinction between mass and weight is very important. But here on the surface of the earth and in everyday life, the weight of an object changes proportionally as its mass changes. For most practical purposes, then, we can estimate the mass of an object by weighing it.

In section 4, you will learn more about force. For now you may think of it as "the strength of push or pull." That strength is measured in SI by a unit called the newton (NEWTON). Weight, however, is a special kind of force, which we often use to estimate the size of mass in the SI unit of kilogram. As we will use the word "weight," it is just another

name for "mass."

First, let's look at the units of mass. There are actually four major metric units of mass:

1. The milligram (MILLIGRAM) abbreviated mg,
2. The gram (GRAM) abbreviated g,
3. The kilogram (KILOGRAM) abbreviated kg, and
4. The metric ton abbreviated t.

The milligram is so light (a grain of salt weighs about 1 milligram), it is seldom used except in medicine and other scientific areas. At the other extreme is the metric ton, closely equivalent to the ton we use now (2000 pounds). Very heavy things, like cars or industrial machinery will be measured in metric tons. For some notion of how heavy a metric ton is, think of a box 1 meter wide, 1 meter long, and 1 meter deep. This box will hold 1 cubic meter. If you were to fill this box with water, the weight of this volume of water would be 1 metric ton, or 1000 kilograms.

The two units of weight we will use every day are the gram and the kilogram. Most dry packaged goods like rice and breakfast cereals will be measured in grams. Most canned goods will be measured in grams, too. In fact, if you check your pantry, you will find that some manufacturers already list the weights of their products in grams as well as in pounds and ounces. Can you imagine the revolution in the supermarket when all canned goods of a similar size are labeled in grams? With built-in unit-pricing it will be so easy to tell whether a bargain is really a bargain that all producers might even be encouraged to be honest!

Larger foodstuffs, like meats, will probably be measured in kilograms. A kilogram is equivalent to a thousand grams. (And 1000 kilograms is equal to 1 metric ton.) People's weights will also be measured in kilograms.

From this brief introduction, you should know that when you measure the weight of a button, you will use the unit gram.

When you measure the weight of a deck of cards, you will use the unit gram, too.

When you measure the weight of an elephant, you will use the unit metric ton.

When you measure the weight of a desk, you will use the unit kilogram.

OK, now let's look at some sample items for the gram.

1. A straight pin weighs 0.5 gram.
2. A nickel weighs 5 grams.
3. One battery, size D, weighs 100 grams.
4. A small can of tuna fish weighs 250 grams.
5. A telephone receiver weighs 300 grams.

For heavy weights, measured in kilograms:

1 kilogram = 1,000 grams.

A liter of milk (a little more than a quart) is a convenient object to associate with 1 kilogram, and a six-pack of beer or soda weighs about 2.5 kilograms. A 187-centimeter man (about 6'2") weighs about 100 kilograms. (Some well-known people who weigh about 100 kilograms are quarterback Joe Namath and boxer Muhammad Ali.)

Since the conversion from pound to kilogram is simple, you can multiply 0.45 times your weight in pounds and get kilograms.

For examples: a 100-pound girl weighs 45 kilograms; a 220-pound football player weighs 100 kilograms. $100 \text{ lb.} \times .45 = 45 \text{ kg.}$ $220 \text{ lb.} \times .45 = 100 \text{ kg.}$ Now you should find your own weight in kilograms.

There are still more reference points to help you remember the kilogram scale.

1. A heavy suitcase is about 25 kg.
2. A Christmas turkey is about 9 kg.
3. A pineapple is about 1 kg.
4. A heavyweight wrestler is about 125 kg.
5. A jockey is about 45 kg.
6. The average man is about 80 kg.
7. The average woman is about 60 kg.
8. A cubic meter of water is about 1000 kg.
9. A six-pack of canned beer is about 2.5 kg.

In the SI system, kilogram is the base unit for weight (mass) because the gram is so small. (One gram equals 0.035 ounce.) As a result, the measure for mass is the only base unit that carries a prefix.

In the preceding discussion of volume, the relationship between the liter and the kilogram was established: 1 liter weighs 1 kilogram. You know that there are 1000 ml in a liter and 1000 g in a kilogram. Therefore, it follows that 1 ml weighs 1 g. Following are some common metric-English weight equivalents:

- 1 ounce = 28 grams
- 1 pound = 0.45 kilogram
- 1 ton = 0.9 metric ton
- 1 gram = 0.04 ounce
- 1 kilogram = 2.2 pounds
- 1 metric ton = 1.1 tons.

Section 3: temperature

Of all the classes of units, temperature is the one that everyone understands best, especially the natural or ambient temperature (the temperature of the air surrounding us). We are all forced to experience a 70-degree day or a 90-degree day or a 10-degree day. When all else fails, we can still talk about the weather and be content to do nothing about it.

We also have a good sense of body temperature, even though most of us are not concerned with this every day. A body temperature of 98.6° Fahrenheit is normal and indicates good health. A person with a temperature of 100°F has a low-grade fever. If his temperature rises to 101 or 102, he is quite sick. If his temperature is much over 105, he is near death. Small differences have larger significance. No wonder we understand what body temperature means.

Those of us who cook also understand oven temperatures and what they mean. A "slow" oven setting is 200 to 250°F; a moderate oven is 300 to 350°F; and a hot oven is 400 to 450°F. Broiling temperatures are 500°F or more.

Conversions from the Fahrenheit to the metric scale require cumbersome arithmetic. Fortunately, you won't have to make these conversions for everyday uses of temperature. What you will need is the same sense of temperature in metric units that you have now for Fahrenheit temperatures. This section will provide that understanding.

As you may remember from physics, heat is generated by the motion of molecules; everything has some quantity of heat. Even ice in the refrigerator has moving molecules that produce heat. Of course, as we take heat out of an object the molecules move less and less. If we took the temperature of an object that had no heat (that is, the molecules had stopped moving), we would get no reading. This zero reading is called absolute zero temperature.

We don't have any experience with absolute zero temperature since on the Fahrenheit scale it would register -459.67°F . That's just about as cold as anything can possibly get. The zero point of the Fahrenheit scale, then, is just an arbitrary point. Gabriel Fahrenheit, a German who developed the mercury thermometer, experimented with temperature using a mixture of salt and ice. The temperature of the coldest mixture he could make he called "zero." (Of course, we know now that he was almost 460 degrees above absolute zero.) As a result, on a Fahrenheit scale water freezes at 32°F and boils at 212°F . None of the convenient points (like 0, 10, 50, or 100) actually means anything.

A few years after Fahrenheit's scale was adopted, Anders Celsius, a Swede, suggested a scale on which zero would be the freezing point of water and 100 degrees the boiling point. These points are, of course, much more convenient than are the Fahrenheit 32° and 212° .

Celsius's scale was adopted and has been the scale used in science and in the metric system. It used to be called the "centigrade" (CENTIGRADE) scale, because of its range from 0 to 100, but now it is officially the Celsius (CELSIUS) scale.

When you compare the two temperature systems, the temperature at 212°F is equal to 100°C , and 32°F is equal to 0°C . Room temperature, since the energy crisis, is suggested to be set at 68°F , or 20°C on your Celsius thermometer.

More recently, science has adopted the Kelvin scale (K) spelled KELVIN. By starting at "absolute" zero, the Kelvin scale has no minus numbers. Its units are the same size as the Celsius scale. This means that a change of 1 degree on the Celsius scale is the same as a change of 1 point on the Kelvin scale.

The Kelvin is the official SI unit. Because the Celsius scale will be used in most practical situations, however, we will use the degree-Celsius as our unit, and it is acceptable in the SI system.

In the newly metric countries, people have simply had to start "thinking Celsius," since the arithmetic of converting from °F to °C is too complicated for daily use. Fortunately, it is easy to think Celsius if you just memorize:

100°C and water boils, 0°C and water freezes.

Now we are going to consider how to "think" ambient temperature on the Celsius scale. You have already learned that 100°C is boiling and 0°C is freezing. The following examples will give you several reference points for temperatures in between. You will note that there are memory aids for each reference point.

100°C	Boiling.
40°C	A hot, fiery day in summer.
30°C	A thirsty, hot day in summer.
20°C	Room temperature.
10°C	A cool day in fall or spring.
0°C	Freezing.
-20°C	A bitter cold day in winter.
-40°C	About as frigid as it every gets in the United States.

As for body temperature, the following examples will give more understanding. It might help to first memorize the equivalent of a normal temperature: $98.6^{\circ}\text{F} = 37^{\circ}\text{C}$. Notice that a person with the flu has a temperature of 39°C and that a person convulses at a temperature of 41°C . Also keep in mind that a 1°C rise is almost twice the temperature rise of 1°F , so far as its impact is concerned.

1. If your body temperature is 98.6°F , that is 37°C , you are "normal."
2. If your body temperature is 99.5°F , that is 37.5°C , you will feel a slight cold.
3. If your body temperature is 100.5°F , that is 38°C , you have a low-grade fever.
4. If your body temperature is 102°F , that is 39°C , you've got the flu.
5. If your body temperature is 104°F , that is 40°C , you are quite sick.

Two additional aspects might give you more help. These are industrial and kitchen temperatures. The boiling point for water is a good reference for industrial temperatures. At the far extreme is 3000°C , the temperature required to melt iron. More examples indicate that 1000°C will melt gold, 250°C is necessary for broiling steak, 215°C for roasting beef,

250°C is necessary for broiling steak, 215°C for roasting beef, 200°C for baking potatoes, 175°C for baking cookies, 160°C for baking fish, 150°C for baking a cake, and 125°C is used for warming bread.

If you want to try converting between degrees Celsius and degrees Fahrenheit, there are two formulas you can use.

1. If you have °C and you want to know the °F equivalent, you use °C times 1.8 then plus 32. The figure you get is °F.
2. If you have °F and you want to know the °C equivalent, you subtract 32 from the °F then multiply by 0.6. And you have the °C.

Section 4: work, power, and other quantities

Learning units of length, weight, volume, and temperature is like learning to speak and understand a new language fluently. But learning units of force and pressure, as well as work and energy, is like preparing yourself to read a new language with the use of a dictionary. This section will give you this kind of practice. Try to familiarize yourself with them.

First, you will learn units of force. When you want to move an object, the force you have to exert depends on two factors:

1. How much mass the object has. (You have to push harder to move a 1000-kg piano than to move a 500-kg piano.)
2. How much you accelerate the object. (More force is required for a car to accelerate from zero to 20 km/hour in a second than from zero to 10 km/hr. in the same period of time.)

To measure how much force one object exerts on another, both mass and acceleration must be considered.

The basic unit is defined as the amount of force required to accelerate 1 kilogram 1 meter per second per second. This unit of force is called a newton (NEWTON, N), after Isaac Newton, the English philosopher who created calculus and who is often called the father of classical physics.

It's rather hard to get a feel for the definition: accelerating a kilogram 1 meter per second per second exerts a force of about 1 newton on an object. Let's try to visualize this another way. If you hold a 100-gram object in your hand, the earth's gravity exerts a force of about 1 newton on this

object. Or to put it another way, you have to apply a force of 1 newton to hold a 100-gram object in the air.

For example, a size D flashlight battery has a mass of 100 grams. If you lift this battery, you will get the sense of a newton of force. An apple may also help you remember what a newton is. A small apple which weighs about 100 grams exerts a downward force of about 1 newton. The apple is a good memory aid, if you recall the story of Sir Isaac Newton's sudden discovery of the law of gravity when an apple fell on his head as he sat under a tree.

Following are some examples, which give you more practice.

1. A 100-kilogram man exerts a downward force of 1000 newtons. Since a 100-gram object exerts a 1-newton force, a 100-kilogram object = 1000 100-gram objects. (Remember, 1000 grams = 1 kilogram; therefore, it produces 1000 newtons.)
2. According to the same principle, a 25-kg child, riding piggyback, would exert 250 newtons of force on your back.

In section 2 of this lesson, you have learned the metric concepts of mass and weight. Actually, the concept of weight comes from the concept of force. Weight is a kind of force when the acceleration is imparted by gravity. Technically, weight should be measured in newtons, since the pull of gravity varies from place to place. For example, weight is less on top of a mountain than at sea level. In much technical work in physics, weight is actually measured in newtons. However, for many purposes, and certainly for everyday use, weight is a useful way of estimating the mass of an object. At any particular place on earth, the acceleration of gravity will be constant. If two stones exert different downward forces, it must be because they have different masses. So, we can estimate the mass of an object if we measure the downward force of this object on a scale at a given place on earth.

From what we have said about force, you should have some idea about the following examples.

1. If you hold a 1-kg ball in your hand, approximately 10 newtons of force are exerted upon your hand.
2. An object exerting a force of 10 newtons downward on a scale would weigh about 1 kg.
3. A 1000-kg car exerts a force of about 10,000 newtons on the earth.

The symbol of newton is capital N. Newton is a derived

unit formed by mass and acceleration. In the English system, the units of force are poundal and pound force, in which they use English mass and acceleration units.

1 newton = 7.23 poundals = 0.22 pound-force.
 1 poundal = 0.14 newton.
 1 pound force = 4.45 newtons.

Next is pressure, a quantity related to force, but probably more familiar to most people. For example, in the filling station, we ask for 28 pounds of air in the rear tires. What we are really asking for is an amount of air that is exerting 28 more pounds of force per square inch on the inside of the tire than the pressure of air on the outside of the tire.

Pounds per square inch (PSI), the most common English unit of pressure will be replaced by the newton per square meter or N/m^2 . This is called the pascal (PASCAL). The pascal, or Pa (capital P and small a), is equal to a force of 1 newton exerted on an area of 1 square meter.

One pascal is not really very much pressure — not nearly as much as one psi. Since a pascal is the force of a newton spread over a square meter, you can get some idea of it if you spread half a cup (about 100 grams) of sugar evenly over the top of a table that is 1 meter on each side. The pressure of the sugar exerted at any one point on the table would be quite small. In fact, it would take 200,000 pascals to inflate an ordinary automobile tire. (Compare this with the 28 pounds.) For larger pressures, we use a larger unit — meganewtons per square meter, or MN/m^2 . (A meganewton, remember, is 1 million newtons.) Another even larger size is the giganewton per square meter, or GN/m^2 . (A giganewton is 1 billion newtons.) There are also MPa (megapascals) and GPa (gigapascals). The symbol of the prefix "mega" is capital M, for "giga" it is capital G.

Another common metric unit of pressure is the bar (small b), which is equal to 100,000 Pa. The bar is particularly useful in meteorology.

After you have learned the quantities force and pressure, we will talk about the SI units of work and energy.

In physics, energy is defined as the capacity to do work. When you pay your electric bill, you pay for kilowatt-hours, which is the energy the electric company supplies to do work for you. When you buy a window air conditioner, you buy BTU's -- the amount of work this air conditioner will do to cool the air for an hour. When you count the calories you eat, you

count units of food energy, some of which are stored in your body as fat for future work. Kilowatt-hours, BTU's, and calories are among the many units used to describe work and energy.

One reason for having so many units is that energy comes in so many forms. One example is heat energy, the capacity of matter to do work as it burns. A BTU (British Thermal Unit) is defined as the amount of heat needed to raise 1 pound of water 1 degree Fahrenheit. Obviously, it isn't a metric unit. A calorie (CALORIE) is a metric unit for heat energy. It is defined as the amount of heat needed to raise a kilogram of water 1 degree Celsius. To get some idea of what a calorie is, consider that a teaspoonful of sugar has about 15 calories. If you burned it very efficiently, you would raise the temperature of 15 kilograms of water 1 degree Celsius.

Another kind of energy which we encounter every day is electrical energy. It is measured in both English and metric systems as kilowatt-hours (kWh). A kilowatt-hour is about how much energy you would use to burn a couple of light bulbs all night long. Electrical engineers, electricians, and electrical contractors won't have to learn a new measurement system because electrical units are universally metric.

A significant property of energy is that one kind of energy can be converted to another kind. This means that we can burn gas (heat energy) to turn an engine (mechanical energy). Or we can generate electricity by turning a wheel.

Work can be defined as force exerted through a distance. An object resting on the palm of your hand exerts a force, but no work is done because nothing is moved. When you hold a heavy object, you may be doing work psychologically, but you are doing no physical work because you aren't moving the object. But if you drop the object so that it falls on a spring, it will move the spring and thus do work. The farther the object falls, the farther it will move the spring. Work, then, can be defined as force times distance.

If you exert a force of 1 newton through a distance of 1 meter, you will have done 1 metric unit of work. This unit is called a joule (JOULE, J). A good way to get an idea of a joule of work is to lift something. If you lift a flashlight battery (about 100 grams) 1 meter, this activity requires the energy of about 1 joule. If you then drop the flashlight battery, its impact on the floor will yield 1 joule of energy.

Next, we are going to discuss power and energy. If a small child lifts a load of bricks one brick at a time from the floor to a table, he does just as much work as a strong man who lifts the same load all at once. Both are moving the same number of kilograms through the same distance. Although the strong man does the same work, he works at a faster rate. This rate or speed of work is called power.

Just as velocity is measured as meters per second or kilometers per hour, power is measured as work per second, or joules per second. If it takes me twice as long to do a joule of work as it takes you, you have twice my power, even though we may use the same energy.

The SI unit for power is the watt (WATT, W). The watt is equal to 1 joule per second, symbolized $1 \text{ W} = 1 \text{ J/S}$. Lifting a flashlight battery 1 meter equals a joule of energy; you will use 1 watt of power if you lift the battery that far in 1 second. In the English system, horsepower and BTU per second are the familiar units of power.

$$\begin{aligned} 1 \text{ kilowatt} &= 1.34 \text{ horsepower} \\ 1 \text{ horsepower} &= 0.75 \text{ kilowatts.} \end{aligned}$$

The metric unit of power that is used depends upon the amount of power being measured. Watts are used for measuring intermediate amounts of power, like that required to operate home appliances. Milliwatts and microwatts are used to measure the tiny power requirements in electronic equipment. When conversion to the metric system is complete, the kilowatt will replace many larger units of power, including the very familiar unit horsepower, the BTU per second, and the kilocalorie per minute. The kilowatt will be used, among other things, to measure the mechanical and electrical power output of engines and generators, and the heating demand of buildings.

The engine of a small American car can generate about 100 kilowatts of power. A tiny foreign car engine generates about 50 kilowatts of power and a large American car engine generates about 250 kilowatts. Try to replace horsepower with kilowatt in your thinking. One horsepower equals about three-quarters of a kilowatt.

Now you have completed the second lesson of "thinking metric." You probably won't be able to remember all of these units or their relationships to other units. But you should have some idea now as to what they are, and how they are applied in daily use.

Appendix C: Metric Test Form A
(McFee Metric Test)

METRIC TEST

General Proficiency Section

- _____ 1. If you were in Europe and asked a policeman how far it was to the ball field, he might answer that it is 4,000 meters. This distance would be equivalent to how many kilometers?
- (A) .04
 - (B) 4
 - (C) 40
 - (D) 400
- _____ 2. The distance through the earth is 12,742,000 meters. This amount would be equivalent to how many kilometers?
- (A) 1,274.2
 - (B) 12,742
 - (C) 127,420
 - (D) 1,274,200
- _____ 3. If a person drank a jar of kool-aid holding 1 liter, how many milliliters would one have consumed?
- (A) 10
 - (B) 100
 - (C) 1,000
 - (D) 10,000
- _____ 4. A boy filled his father's car with gasoline and it held 10 liters. How many milliliters would this amount to?
- (A) 10,000
 - (B) 100,000
 - (C) 1,000,000
 - (D) 10,000,000
- _____ 5. If Sam found his weight to be 50 kilograms, one could also say that he weighed how many grams?
- (A) 5,000
 - (B) 50,000
 - (C) 500,000
 - (D) 5,000,000

- _____ 6. John's watch weighed .05 kilograms. One could also say the weight of the watch was how many grams?
- (A) 50
 - (B) 500
 - (C) 5,000
 - (D) 50,000
- _____ 7. About how many cubic centimeters of water will 1,000 milliliters of water equal?
- (A) 1
 - (B) 10
 - (C) 100
 - (D) 1,000
- _____ 8. About how many cubic centimeters of water will 90 milliliters of water equal?
- (A) .09
 - (B) 9
 - (C) 90
 - (D) 900
- _____ 9. One important race in the Olympics is the 1,500 meter run. This distance is the same as . . .
- (A) 150,000 millimeters
 - (B) 150,000 centimeters
 - (C) 150,000 kilometers
 - (D) 1,500,000 kilometers
- _____ 10. If a city block is found to be 80 meters long, one could also say that the distance is the same as . . .
- (A) 800 millimeters
 - (B) 8,000 millimeters
 - (C) 8,000 centimeters
 - (D) 8,000 kilometers
- _____ 11. The milkman put 10,000 milliliters of milk in a bottle. One could also say that the bottle contained which of the following amount?
- (A) .001 liters
 - (B) .01 centiliters
 - (C) .01 kiloliters
 - (D) 10 kiloliters

- _____ 12. While washing his car a man used 50,000 milliliters of water. It would also be proper to state that he used the following amount of water:
- (A) .05 kiloliters
 - (B) .5 kiloliters
 - (C) 500 centiliters
 - (D) 500 liters
- _____ 13. If a farmer sold a sack of grain and found it to weigh 40,000,000 milligrams, he could also express the weight as . . .
- (A) .04 grams
 - (B) 4 kilograms
 - (C) 40 grams
 - (D) 40 kilograms
- _____ 14. A lump of coal weighing 2,000,000 milligrams may also be expressed as . . .
- (A) 2 kilograms
 - (B) 20 kilograms
 - (C) 20 grams
 - (D) 200 grams
- _____ 15. What would be the weight (approximately) of enough water to fill a .01 kiloliter container?
- (A) 1 kilogram
 - (B) 10 milligrams
 - (C) 10 kilograms
 - (D) 1,000 grams
- _____ 16. If an elephant drank .1 kiloliter of water, one could also say that the elephant drank the following weight of water:
- (A) 1 kilogram
 - (B) 100 kilograms
 - (C) 100 grams
 - (D) 10,000,000 milligrams
- _____ 17. If Bill drank 50 cubic centimeters of water for breakfast, 0.1 liters of water for lunch, and .00025 kiloliters of water for dinner, what would be the total weight of all the water he drank?
- (A) 400 grams
 - (B) 50.100025 grams
 - (C) 502.5 grams
 - (D) 4,000 milligrams

- _____ 18. When Jane watered the flowers, she sprinkled .02 kiloliter of water on the red flowers, 2 liters of water on the white flowers, and 2 cubic centimeters of water on the yellow flowers. What would be the total weight of the water she used?
- (A) 4.002 grams
(B) 4.02 milligrams
(C) 6,000 milligrams
(D) 22,002 grams
- _____ 19. When Alice stopped at the store, she purchased the following items: 100,000 milligrams of distilled water; 1,000 cubic centimeters of canned milk; and 1 liter of regular milk.
- (A) 30.1 milliliters
(B) 101.001 liters
(C) 2,100 milliliters
(D) 2,100 liters
- _____ 20. John wanted to find out the total amount of water used by his family in one day. He found that his father used 10,000,000 milligrams, his mother used about 10 liters, and he used about 8,000 cubic centimeters. The total volume used would equal . . .
- (A) 28,000 milliliters
(B) 28,000 liters
(C) 82,000 milliliters
(D) 100,000 liters

Intuition Section

- _____ 21. Approximately what is the width of this paper in centimeters?
- (A) 5
(B) 22
(C) 102
(D) 1,000
- _____ 22. Approximately how long is the length of this paper in centimeters?
- (A) 8
(B) 28
(C) 108
(D) 500

- _____ 23. A thimble would hold about how many milliliters of water?
- (A) 5
 - (B) 20
 - (C) 200
 - (D) 2,000
- _____ 24. A fountain pen would hold about how many milliliters of ink?
- (A) .1
 - (B) 1
 - (C) 10
 - (D) 20
- _____ 25. A new pencil would weigh about how many grams?
- (A) .1
 - (B) 5
 - (C) 50
 - (D) 500
- _____ 26. An unused piece of chalk (for writing on the blackboard) would weigh about how many grams?
- (A) .0001
 - (B) .001
 - (C) 10
 - (D) 100
- _____ 27. An American made (regular-sized) automobile would be approximately how many centimeters long?
- (A) 50
 - (B) 500
 - (C) 5,000
 - (D) 50,000
- _____ 28. The length of a motor scooter (Honda) would be about how many centimeters long?
- (A) 1
 - (B) 10
 - (C) 100
 - (D) 1,000
- _____ 29. The volume of water to fill a kitchen sink would be about how many liters?
- (A) 20
 - (B) 200
 - (C) 1,000
 - (D) 10,000

- _____ 30. The volume of water to fill a bathtub would be about how many liters?
- (A) 2
 - (B) 20
 - (C) 200
 - (D) 20,000
- _____ 31. The weight of an average schoolbook would be closest to how many kilograms?
- (A) .1
 - (B) 1
 - (C) 10
 - (D) 100
- _____ 32. The weight of ten oranges would be closest to the following kilograms:
- (A) 1
 - (B) 10
 - (C) 1,000
 - (D) 10,000
- _____ 33. If one were to add the size of a step taken by a 7th grader plus the length of the average 7th grader's arm, he would find it to be about . . .
- (A) .1 kilometer
 - (B) 10 meters
 - (C) 1,000 centimeters
 - (D) 1,000 millimeters
- _____ 34. If a 7th grader added the length of his trousers plus the length of his shirt sleeve (long sleeves), he would find them to be about . . .
- (A) .1 meters
 - (B) 10 centimeters
 - (C) 1,000 millimeters
 - (D) 10,000 millimeters
- _____ 35. If a 7th grader filled his football helmet and both of his shoes with water, how much total water would he have?
- (A) .1 liter
 - (B) 1 liter
 - (C) 1 kiloliter
 - (D) 100 milliliters

- _____ 36. John filled both of his shoes with sand, and another 7th grader filled both of his shoes with sand. Together what volume of sand did they most likely have?
- (A) 3 liters
 - (B) 3 kiloliters
 - (C) 300 liters
 - (D) 300 milliliters
- _____ 37. The weight of an average 7th grade boy plus the weight of an average 7th grade girl would be closest to . . .
- (A) 10 kilograms
 - (B) 100 kilograms
 - (C) 1,000 grams
 - (D) 100,000 milligrams
- _____ 38. The weight of an average sized 7th grader plus the weight of 20 bricks would be about . . .
- (A) 60 kilograms
 - (B) 800 kilograms
 - (C) 10,000 grams
 - (D) 1,000,000 milligrams
- _____ 39. In a contest, John had to guess the total weight of the following items: a 7th grader's football helmet filled with water, two average sized schoolbooks, and 10 average sized apples, plus 1,000 cubic centimeters of water. What would the total weight be?
- (A) 1 kilogram
 - (B) 100 grams
 - (C) 4,000 grams
 - (D) 1,000,000,000 milligrams
- _____ 40. How much do you think the total weight of the following items would be: a shoe box filled with water, one brick, 10 average sized oranges, plus 1,000 cubic centimeters of water?
- (A) 1 kilogram
 - (B) 5,000 grams
 - (C) 100,000 grams
 - (D) 100,000 milligrams
- _____ 41. The normal freezing point of water on the Celsius Scale is how many °C?
- (A) -10
 - (B) 32
 - (C) 0
 - (D) 5

- _____ 42. A fiery day in August in Arizona is approximately how many °C?
- (A) 100
 - (B) 40
 - (C) 20
 - (D) 10
- _____ 43. A person under normal condition has temperature about how many °C?
- (A) 98
 - (B) 37
 - (C) 39
 - (D) 40
- _____ 44. What is the official SI unit of temperature?
- (A) Kelvin
 - (B) Celsius
 - (C) Centigrade
 - (D) Fahrenheit
- _____ 45. An object exerting a force of 10 N downward on a scale would weigh about how many kg?
- (A) 1
 - (B) 10
 - (C) 100
 - (D) 1,000
- _____ 46. If you hold a 1-kg ball in your hand, approximately how many Newtons of force exerts on you?
- (A) 1
 - (B) 10
 - (C) 100
 - (D) 1,000
- _____ 47. As we know pressure is force/area. In SI metric system what is the unit of pressure?
- (A) Newton
 - (B) Pascal
 - (C) PSI
 - (D) kilogram
- _____ 48. Newtons per square centimeter would be a measure of what unit?
- (A) force
 - (B) pressure
 - (C) energy
 - (D) power

- _____ 49. If you exert a force of 1 Newton through a distance of 1 meter, you will have done 1 metric unit of work. This unit is called a . . .
- (A) Pascal
 - (B) kilowatt
 - (C) joule
 - (D) Newton
- _____ 50. Electric power companies use what unit as a measure of power they supply their customers?
- (A) Newton
 - (B) kilowatt
 - (C) BTU
 - (D) horse power

Appendix D: Metric Test Form B

METRIC TEST

General Proficiency Section

- _____ 1. If you were in France and asked a person how far it was to the post office, he might answer that it is 1,000 meters. This distance would be equivalent to how many kilometers?
- (A) .01
(B) 1
(C) 40
(D) 400
- _____ 2. The distance from Los Angeles to New York is 4,690,000 meters. This amount would be the same as how many kilometers?
- (A) 469
(B) 4,690
(C) 46,900
(D) 469,000
- _____ 3. If a person drank a jar of orange drink holding 0.5 liter, how many milliliters would one have consumed?
- (A) 5
(B) 50
(C) 500
(D) 5,000
- _____ 4. John filled his car with gasoline and it held 60 liters. How many milliliters would this amount to?
- (A) 60,000
(B) 600,000
(C) 6,000,000
(D) 60,000,000
- _____ 5. If Cathy found her weight to be 47 kilograms, one could also say that she weighed how many grams?
- (A) 4,700
(B) 47,000
(C) 470,000
(D) 4,700,000

- _____ 6. Jean's watch weighed .025 kilograms. One could also say the weight of the watch was how many grams?
- (A) 25
 - (B) 250
 - (C) 2,500
 - (D) 25,000
- _____ 7. About how many cubic centimeters of water will 2,000 milliliters of water equal?
- (A) 2
 - (B) 20
 - (C) 200
 - (D) 2,000
- _____ 8. About how many cubic centimeters of water will 60 milliliters of water equal?
- (A) .06
 - (B) 6
 - (C) 60
 - (D) 600
- _____ 9. The height of the Equitable Building in Des Moines is 97 meters. This height is the same as . . .
- (A) 9,700 millimeters
 - (B) 9,700 centimeters
 - (C) 9,700 kilometers
 - (D) 9,700,000 kilometers
- _____ 10. If the height of a kitchen table is 0.9 meters, one could also say that his kitchen table is the same as . . .
- (A) 9 millimeters
 - (B) 90 millimeters
 - (C) 90 centimeters
 - (D) 90 kilometers
- _____ 11. Sam put 20,000 milliliters of gasoline in a can. One could also say that the can contained which of the following amounts?
- (A) .002 liters
 - (B) .02 centiliters
 - (C) .02 kiloliters
 - (D) 20 kiloliters

- _____ 12. While wetting his garden a man used 60,000 milliliters of water. It would also be proper to state that he used the following amount of water:
- (A) .06 kiloliters
 - (B) .6 kiloliters
 - (C) 600 centiliters
 - (D) 600 liters
- _____ 13. If a person bought a sack of grain and found it to weigh 50,000,000 milligrams, he could also express the weight as . . .
- (A) .05 gram
 - (B) 5 kilograms
 - (C) 50 grams
 - (D) 50 kilograms
- _____ 14. A six-pack of canned soda weighing 2,500,000 milligrams may also be expressed as . . .
- (A) 2.5 kilograms
 - (B) 25 kilograms
 - (C) 25 grams
 - (D) 250 grams
- _____ 15. If you want to fill water in a .02 kiloliter container, you would fill about how much water in weight?
- (A) 2 kilogram
 - (B) 20 milligrams
 - (C) 20 kilograms
 - (D) 2,000 grams
- _____ 16. If a horse drank .05 kiloliter of water, one could also say that the horse drank the following weight of water:
- (A) .5 kilogram
 - (B) 50 kilograms
 - (C) 50 grams
 - (D) 5,000,000 milligrams
- _____ 17. If John drank 40 cubic centimeters of water for breakfast, 0.2 liters of water for lunch, and .00032 kiloliters of water for supper, what would be the total weight of all the water he drank?
- (A) 560 grams
 - (B) 40.200032 grams
 - (C) 402.32 grams
 - (D) 5,600 milligrams

- _____ 18. When Betty watered the flowers, she sprinkled .03 kiloliter of water on the red flowers, 3 liters of water on the white flowers, and 3 cubic centimeters of water on the yellow flowers. What would be the total weight of the water she used?
- (A) 6.003 grams
 - (B) 6.03 milligrams
 - (C) 9,000 milligrams
 - (D) 33,003 grams
- _____ 19. When Nancy went to Safeway, she purchased the following items: 100,000 milligrams of distilled water; 5,000 cubic centimeters of canned punch; and 4 liters of orange drink. The total volume of them is:
- (A) 54.1 milliliters
 - (B) 504.01 liters
 - (C) 9,100 milliliters
 - (D) 9,100 liters
- _____ 20. Bob wanted to find out the total amount of water used by his family in one day. He found that his father used 20,000,000 milligrams, his mother used about 20 liters, and he used about 7,000 cubic centimeters. The total volume used would equal . . .
- (A) 47,000 milliliters
 - (B) 47,000 liters
 - (C) 74,000 milliliters
 - (D) 120,000 liters

Intuition Section

- _____ 21. Approximately what is the length of this paper in centimeters?
- (A) 7
 - (B) 28
 - (C) 130
 - (D) 1,000
- _____ 22. Approximately how wide is the width of this paper in centimeters?
- (A) 5
 - (B) 22
 - (C) 120
 - (D) 500

- _____ 23. A tumblerful is about how many milliliters?
- (A) 5
 - (B) 20
 - (C) 250
 - (D) 2,000
- _____ 24. A tablespoonful would hold about how many milliliters of water?
- (A) .1
 - (B) 15
 - (C) 150
 - (D) 1,500
- _____ 25. A small can of tuna weighs about how many grams?
- (A) 25
 - (B) 250
 - (C) 2,500
 - (D) 25,000
- _____ 26. A nickel weighs about how many grams?
- (A) 0.005
 - (B) 0.05
 - (C) 0.5
 - (D) 5
- _____ 27. The length of a telephone receiver is about how many centimeters?
- (A) 2
 - (B) 20
 - (C) 200
 - (D) 2,000
- _____ 28. The height of a can of Coca-Cola is about how many centimeters?
- (A) 1.2
 - (B) 12
 - (C) 120
 - (D) 1,200
- _____ 29. A glass of milk, or one-fourth of a carton, holds about how many liters?
- (A) 0.25
 - (B) 2.5
 - (C) 25
 - (D) 250

- _____ 30. The volume of gasoline to fill a tank of the full size American car would be about how many liters?
- (A) 0.76
 - (B) 7.6
 - (C) 76
 - (D) 760
- _____ 31. The weight of an average man would be closest to how many kilograms?
- (A) 0.8
 - (B) 8
 - (C) 80
 - (D) 800
- _____ 32. The weight of a Thanksgiving turkey would be closest to the following kilograms:
- (A) 0.9
 - (B) 9
 - (C) 90
 - (D) 900
- _____ 33. The distance from your left shoulder to tip of right hand when you hold your right arm horizontally would be about . . .
- (A) 10 millimeters
 - (B) 100 centimeters
 - (C) 1,000 meters
 - (D) 1,000 kilometers
- _____ 34. The average height for women is about . . .
- (A) 165 millimeters
 - (B) 165 centimeters
 - (C) 165 meters
 - (D) 165 kilometers
- _____ 35. If a person filled an aquarium of 2 meters long 1 meter high and 1 meter wide with water, how much total water would he have?
- (A) 2 kiloliters
 - (B) 20 liters
 - (C) 200 liters
 - (D) 200,000 milliliters

- _____ 36. Bob filled a milk jug with sand, and Jean filled 3 beer cans with sand. Together what volume of sand did they most likely have?
- (A) 5.13 liters
 - (B) .513 kiloliter
 - (C) 513 liters
 - (D) 513 milliliters
- _____ 37. The weight of an average man plus the weight of an average women would be closest to . . .
- (A) 14 kilograms
 - (B) 140 kilograms
 - (C) 1,400 grams
 - (D) 140,000 milligrams
- _____ 38. If a football player carried a six-pack of canned beer, the total weight would be close to . . .
- (A) 102.5 kilograms
 - (B) 1,025 kilograms
 - (C) 1,025,000 grams
 - (D) 1,025,000,000 milligrams
- _____ 39. In a game, everyone had to guess the total weight of the following items: a liter of milk, a six-pack of canned soda, and a Christmas turkey, plus 1,000 cubic centimeters of water. What would the total weight be?
- (A) 1.3 kilograms
 - (B) 13 kilograms
 - (C) 130 grams
 - (D) 130,000 milligrams
- _____ 40. How much do you think the total weight of the following items would be: an average man, a cubic meter of water, 100 pineapples, and 10 six-packs of canned soda?
- (A) 100 kilograms
 - (B) 1,200 kilograms
 - (C) 1,200,000,000 grams
 - (D) 120,000 milligrams
- _____ 41. The normal boiling point of water on the Celsius scale is how many °C?
- (A) 212
 - (B) 100
 - (C) 180
 - (D) 200

- _____ 42. A very cold day in winter in Ames is approximately how many °C?
- (A) -80
 - (B) -20
 - (C) 10
 - (D) 5
- _____ 43. If you want to bake a cake, the temperature which you set on the oven is how many °C?
- (A) 500
 - (B) 150
 - (C) 600
 - (D) 800
- _____ 44. The suggested room temperature setting during the winter under the energy crisis condition is how many °C?
- (A) 68
 - (B) 20
 - (C) 50
 - (D) 60
- _____ 45. A 100-kilogram man exerts a downward force of how many Newtons?
- (A) 100
 - (B) 1,000
 - (C) 10
 - (D) 50
- _____ 46. What is the SI unit of force called?
- (A) kilogram
 - (B) kilowatt
 - (C) Newton
 - (D) joule
- _____ 47. Gravity acting on an object is a kind of . . .
- (A) force
 - (B) pressure
 - (C) energy
 - (D) power
- _____ 48. The pressure required to inflate a toy balloon would be about 1,000 . . .
- (A) Newtons
 - (B) Pascals
 - (C) pounds per square inch
 - (D) grams

- _____ 49. If you lift a heavy man 1 meter, about 1,000 _____ of energy you would expend.
- (A) Pascals
 - (B) kilowatts
 - (C) joules
 - (D) Newtons
- _____ 50. If a resident in each of the 100 houses in a town used a clothes iron for 100 seconds a day, but everyone used his iron at a different time, the electric company would have to generate 1,000 _____ of power.
- (A) watts
 - (B) B.T.U.
 - (C) horsepower
 - (D) Newtons

Appendix E: Letter of Permission to use
McFee Metric Test

Iowa State University of Science and Technology



Ames, Iowa 50010

College of Education
Industrial Education
Telephone 515-294-1033

Wan-Lee Cheng
208 B Building O
Industrial Ed. Dept.
Iowa State University
Ames, Iowa 50010
September 12, 1975

Dr. Evan Mc Fee
Professor,
Department of Education
College of Education
Bowling Green State University
Bowling Green, Ohio 43403

Dear Dr. Mc Fee:

I am a graduate assistant in the Industrial Education Department at Iowa State University. I am doing my Ph.D. dissertation dealing with determining the effectiveness of two selected system approaches (Direct and Conversion approaches) and two sensory based instructional methods for introducing the metric system to students enrolled in a post-secondary level teacher education program.

I understand you have done a similar research study about metrication and developed a complete test instrument unique to the field. I have read over your dissertation which I ordered from the Inter-library Loan Department at Iowa State University. I think the test instrument you used for your study is what I am looking for. Is it possible to ask your favor to allow me to use your test instrument as well as the information about the validity and reliability of the test. If you can give me the permission of using them it will be a very great help to me. Your kindness will be appreciated. Thank you very much.

Sincerely yours,

Wan-Lee Cheng
Wan-Lee Cheng
Graduate Assistant
Graphic Communications

*I have permission for the above
providing you give proper credit. Good
luck with your work. Evan Mc Fee*

Appendix F: Information on Results of
Metric Test Form A

Experimental Group (1), Metric Test Form A (Pretest)
Score Distribution

KR-20 Reliability estimate = 0.85

Average test score = 58%

Error variance = 9.01

Standard error of measurement in raw scores = 3.00

Standard error of measurement in T scores = 38.84

Number taking test = 32

Mean = 28.81

Variance = 59.71

Standard deviation = 7.73

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
13	1	1	3	295	*
17	1	2	6	347	*
13	0	2	6	360	
19	2	4	13	373	**
20	0	4	13	386	
21	1	5	16	399	*
22	1	6	19	412	*
23	2	8	25	425	**
24	2	10	31	438	**
25	4	14	44	451	****
26	1	15	47	464	*
27	1	16	50	477	*
28	0	16	50	489	
29	2	18	56	502	**
30	1	19	59	515	*
31	0	19	59	528	
32	2	21	66	541	**
33	2	23	72	554	**
34	2	25	78	567	**
35	1	26	81	580	*
36	1	27	84	593	*
37	1	28	88	606	*
38	0	28	88	619	

39	0	28	88	632	
40	1	29	91	645	*
41	1	30	94	658	*
42	0	30	94	671	
43	1	31	97	684	*
44	0	31	97	697	
45	0	31	97	709	
46	1	32	100	722	*

Control Group (1), Metric Test Form A (Pretest)
Score Distribution

KR-20 Reliability estimate = 0.90

Average test score = 62%

Error variance = 8.11

Standard error of measurement in raw scores = 2.85

Standard error of measurement in T scores = 31.59

Number taking test = 16

Mean = 31.13

Variance = 81.23

Standard deviation = 9.01

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
16	1	1	6	332	*
17	1	2	13	343	*
18	0	2	13	354	
19	0	2	13	365	
20	0	2	13	377	
21	1	3	19	388	*
22	0	3	19	399	
23	0	3	19	410	
24	1	4	25	421	*
25	0	4	25	432	
26	0	4	25	443	
27	3	7	44	454	***
28	0	7	44	465	
29	0	7	44	476	
30	0	7	44	488	
31	1	8	50	499	*
32	2	10	63	510	**
33	0	10	63	521	
34	1	11	69	532	*
35	0	11	69	543	
36	1	12	75	554	*
37	0	12	75	565	
38	0	12	75	576	

39	0	12	75	587	
40	1	13	81	598	*
41	0	13	81	610	
42	0	13	81	621	
43	1	14	88	632	*
44	0	14	88	643	
45	1	15	94	654	*
46	1	16	100	665	*

Experimental Group (2), Metric Test Form A (Posttest)

Score Distribution

KR-20 reliability estimate = 0.83

Average test score = 78%

Error variance = 6.60

Standard error of measurement in raw scores = 2.57

Standard error of measurement in T scores = 40.84

Number taking test = 32

Mean = 39.03

Variance = 39.59

Standard deviation = 6.29

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
19	1	1	3	182	*
20	0	1	3	198	
21	0	1	3	213	
22	0	1	3	229	
23	0	1	3	245	
24	0	1	3	261	
25	0	1	3	277	
26	0	1	3	293	
27	1	2	6	309	*
28	0	2	6	325	
29	0	2	6	341	
30	0	2	6	356	
31	1	3	9	372	*
32	1	4	13	388	*
33	3	7	22	404	***
34	0	7	22	420	
35	1	8	25	436	*
36	2	10	31	452	**
37	2	12	38	468	**
38	1	13	41	484	*
39	1	14	44	500	*
40	3	17	53	515	***
41	1	18	56	531	*

42	2	20	63	547	**
43	2	22	69	563	**
44	4	26	81	579	****
45	3	29	91	595	***
46	1	30	94	611	*
47	1	31	97	627	*
48	1	32	100	643	*

Control Group (2), Metric Test Form A (Posttest)

Score Distribution

KR-20 reliability estimate = 0.86

Average test score = 69%

Error variance = 7.15

Standard error of measurement in raw scores = 2.67

Standard error of measurement in T scores = 36.88

Number taking test = 16

Mean = 34.69

Variance = 52.59

Standard deviation = 7.25

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
20	1	1	6	297	*
21	0	1	6	311	
22	0	1	6	325	
23	0	1	6	339	
24	0	1	6	353	
25	1	2	13	366	*
26	0	2	13	380	
27	0	2	13	394	
28	1	3	19	408	*
29	2	5	31	422	**
30	0	5	31	435	
31	0	5	31	449	
32	3	8	50	463	***
33	0	8	50	477	
34	0	8	50	491	
35	1	9	56	504	*
36	0	9	56	518	
37	0	9	56	532	
38	1	10	63	546	*
39	0	10	63	559	
40	1	11	69	573	*
41	1	12	75	587	*
42	2	14	88	601	**

43	0	14	88	615	
44	1	15	94	628	*
45	0	15	94	642	
46	1	16	100	656	*

Appendix G: Information on Results of
Metric Test Form B

Experimental Group (2), Metric Test Form B (Pretest)

Score Distribution

KR-20 reliability estimate = 0.87

Average test score = 64%

Error variance = 8.40

Standard error of measurement in raw scores = 2.90

Standard error of measurement in T scores = 35.53

Number taking test = 32

Mean = 32.22

Variance = 66.55

Standard deviation = 8.16

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
18	1	1	3	326	*
19	1	2	6	338	*
20	0	2	6	350	
21	0	2	6	362	
22	2	4	13	375	**
23	2	6	19	387	**
24	2	8	25	399	**
25	2	10	31	412	**
26	2	12	38	424	**
27	0	12	38	436	
28	1	13	41	448	*
29	1	14	44	461	*
30	0	14	44	473	
31	0	14	44	485	
32	1	15	47	497	*
33	1	16	50	510	*
34	3	19	59	522	***
35	0	19	59	534	
36	1	20	63	546	*
37	0	20	63	559	
38	1	21	66	571	*
39	2	23	72	583	**
40	1	24	75	595	*

41	3	27	84	608	***
42	2	29	91	620	**
43	2	31	97	632	**
44	0	31	97	644	
45	1	32	100	657	*

Control Group (2), Metric Test Form B (Pretest)

Score Distribution

KR-20 reliability estimate = 0.92

Average test score = 69%

Error variance = 6.95

Standard error of measurement in raw scores = 2.64

Standard error of measurement in T scores = 27.94

Number taking test = 16

Mean = 34.38

Variance = 88.98

Standard deviation = 9.43

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
12	1	1	6	263	*
13	0	1	6	273	
14	0	1	6	284	
15	0	1	6	295	
16	0	1	6	305	
17	0	1	6	316	
18	0	1	6	326	
19	0	1	6	337	
20	0	1	6	348	
21	0	1	6	358	
22	0	1	6	369	
23	0	1	6	379	
24	1	2	13	390	*
25	1	3	19	401	*
26	2	5	31	411	**
27	0	5	31	422	
28	0	5	31	432	
29	0	5	31	443	
30	0	5	31	454	
31	0	5	31	464	
32	1	6	38	475	*
33	2	8	50	485	**
34	0	8	50	496	

35	0	8	50	507	
36	0	8	50	517	
37	0	8	50	528	
38	1	9	56	538	*
39	1	10	63	549	*
40	0	10	63	560	
41	0	10	63	570	
42	2	12	75	581	**
43	2	14	88	591	**
44	1	15	94	602	*
45	0	15	94	613	
46	0	15	94	623	
47	0	15	94	634	
48	1	16	100	644	*

Experimental Group (1), Metric Test Form B (Posttest)

Score Distribution

KR-20 reliability estimate = 0.88

Average test score = 76%

Error variance = 6.65

Standard error of measurement in raw scores = 2.58

Standard error of measurement in T scores = 34.69

Number taking test = 32

Mean = 38.19

Variance = 55.28

Standard deviation = 7.43

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
24	1	1	3	309	*
25	2	3	9	323	**
26	0	3	9	336	
27	1	4	13	350	*
28	0	4	13	363	
29	1	5	16	376	*
30	1	6	19	390	*
31	2	8	25	403	**
32	0	8	25	417	
33	1	9	28	430	*
34	1	10	31	444	*
35	2	12	38	457	**
36	1	13	41	471	*
37	0	13	41	484	
38	2	15	47	497	**
39	1	16	50	511	*
40	2	18	56	524	**
41	1	19	59	538	*
42	3	22	69	551	***
43	0	22	69	565	
44	1	23	72	578	*
45	2	25	78	592	**

46	1	26	81	605	*
47	4	30	94	619	****
48	1	31	97	632	*
49	1	32	100	645	*

Control Group (1), Metric Test Form B (Posttest)
Score Distribution

KR-20 reliability estimate = 0.91

Average test score = 69%

Error variance = 7.06

Standard error of measurement in raw scores = 2.66

Standard error of measurement in T scores = 30.10

Number taking test = 16

Mean = 34.50

Variance = 77.88

Standard deviation = 8.82

Number of scored items = 50

Score	N	CUM	%ILE	T score	(Number of asterisks = N)
17	1	1	6	302	*
18	0	1	6	313	
19	0	1	6	324	
20	1	2	13	336	*
21	0	2	13	347	
22	0	2	13	358	
23	0	2	13	370	
24	0	2	13	381	
25	1	3	19	392	*
26	0	3	19	404	
27	0	3	19	415	
28	1	4	25	426	*
29	0	4	25	438	
30	1	5	31	449	*
31	1	6	38	460	*
32	0	6	38	472	
33	1	7	44	483	*
34	1	8	50	494	*
35	0	8	50	506	
36	0	8	50	517	
37	0	8	50	528	
38	3	11	69	540	***
39	1	12	75	551	*

40	0	12	75	562	
41	0	12	75	574	
42	2	14	88	585	**
43	0	14	88	596	
44	0	14	88	608	
45	0	14	88	619	
46	0	14	88	630	
47	0	14	88	642	
48	1	15	94	653	*
49	1	16	100	664	*

Appendix H: Information on the Validity
and Reliability of the McFee
Metric Test

CHAPTER III
PROCEDURES AND INSTRUMENTS USED IN THE STUDY
(McFee, 1967, p. 27-28)

Preparation of Instrument

The collection of data for this study was dependent upon the development of an instrument which would measure the students' ability to perform tasks in metric measures. Items for the instrument were developed by the investigator. After items were constructed and assembled, they were evaluated by advanced graduate students in science education. The instrument (Appendix A) was then revised and mailed to seven science education and/or test construction experts (Appendix B) for validation. An evaluation sheet (Appendix C) was completed and returned by the validators, and modifications were made to include their applicable suggestions.

The instrument was administered by the investigator to 57 seventh grade general science students at a large junior high school located in the midwest on April 25, 1967. These students were used to establish test reliability and did not participate in the experimental teaching program. Test data were processed on the Control Data 3600 series computer (program BM02D Correlation with Transgeneration Version of November 13, 1964, Health Science Computing Facility, UCLA) and a split-half reliability was determined. Upon application of

the Spearman-Brown Prophecy Formula,¹ it was found that the instrument possessed a reliability coefficient of .63.

Thorndike and Hagen reported that a value of this amount is highly sufficient for the comparison of group performance.²

¹Edwards, Allen, Statistical Methods for the Behavioral Sciences, p. 176.

²Thorndike, Robert, and Hagen, Elizabeth, Measurement and Evaluation in Psychology and Education, pp. 190-191.

NAMES AND BACKGROUNDS OF EXPERTS WHOSE OPINIONS
WERE SOUGHT TO VALIDATE THE INSTRUMENT
(McFee, 1967, p. 98)

1. Ronald D. Anderson, Ph.D., Assistant Professor of Science Education, University of Colorado; 2 years experience as a secondary school science teacher, 3 years college teaching experience. He is author of numerous articles in professional publications.
2. Thomas E. Bibler, Ed.D., Research Associate, Evaluation and Testing Department, Educational Research Council of Greater Cleveland; w years teaching experience in junior high school, 1 year experience in senior high school.
3. Alfred De Vito, Ph.D., Assistant Professor of Elementary Education, Purdue University; 7 years experience as a science teacher in public schools, 1 year experience in college teaching, 2 years research participation and teaching in NSF Summer Institutes at Cornell University.
4. Donald K. Hamilton, Ed.D., Assistant Professor of Science Education, Western Illinois University; 8 years experience teaching in secondary schools, 2 years experience in a university laboratory school, 1 year experience in college teaching.
5. Clarence H. Nelson, Ph.D., Professor, Office of Evaluation Services, Michigan State University; 10 years experience as secondary school teacher, 25 years experience at the college level, Chairman of Graduate Record Examination Committee--Advanced Biology, Chairman of Panel on Evaluation and Testing for the Commission on Undergraduate Education in the Biological Sciences.
6. John C. Rosemergy, MBA, MA, Science Coordinator, Public Schools, Ann Arbor, Michigan; 18 1/2 years of science teaching and supervision, Past President of Michigan Science Teachers Association, former member of Executive Committee of National Science Supervisors Association, member of the Board of Directors and Executive Committee of the National Science Teachers Association, Fellow of the American Association for the Advancement of Science.
7. Ray Stonecipher, Ed.D., Associate Professor of Physics, Wisconsin State University; 4 years experience as secondary science teacher, 2 years experience on the college level.

EVALUATION FORM FOR METRIC SYSTEM TEST developed by
 Evan E. McFee, Science Education, Indiana University
 (McFee, 1967, p. 100)

EVALUATOR _____

POSITION & SCHOOL _____

1. Please read each item for ambiguity and/or proper wording.
2. Verify each answer.
3. Do you feel that the test increases in difficulty from item 1 to 20? YES _____ NO _____
4. Do you feel that the test increases in difficulty from item 20 to 40? YES _____ NO _____
5. At which earliest age level do you think that students can properly work with the metric measures on this test?
 5 - 10 years _____ 9 - 11 years _____ 12 - 14 years _____
6. In your opinion will a student with a high arithmetic reasoning ability score high on the general proficiency section? YES _____ NO _____
7. In your opinion will a student with a high arithmetic reasoning ability score high on the intuition section? YES _____ NO _____
8. In your opinion will a student who scores high in arithmetic fundamentals also score high on the general proficiency section? YES _____ NO _____
9. In your opinion will a student who scores high in arithmetic fundamentals also score high on the intuition section? YES _____ NO _____
10. Comments on specific questions. (Use back of paper is necessary)
11. Comments in general. (Use back of paper if necessary)

Appendix I: Personal Information
Data Sheet

- THANK YOU VERY MUCH

Appendix J: Test Instruction
Sheet

Before you start the test read the following things carefully:

1. Check to be sure the name printed on the label on your test is entirely correct.
2. Print your name and mark the corresponding blocks with a soft lead pencil.
3. At the bottom of your computer answer sheet, (If you hold the sheet vertically, it will be on the upper right corner.) there is a block marked "student number." In this space, put your number which is on the label following your name. It is necessary to use the two digits only and not the letters.
4. You must mark answers on the computer answer sheet.
5. The answer should be marked with a soft lead pencil in order to be dark enough.
6. Note the sequence of spaces on the computer sheet. Be sure you blacken the right space.

NOW YOU MAY START THE TEST

Appendix K: Schedule Sheet

1. Print your full name.
2. There are two blocks for each hour.
3. This schedule is for both weeks.

	MON Jan. 5 & 12	TUES Jan. 6 & 13	WED Jan. 7 & 14	THUR Jan. 8 & 15	FRI Jan. 9 & 16	SAT Jan. 10 & 17
8:00						
9:00						
9:00						
10:00						
10:00						
11:00						
11:00						
12:00						
12:00						
1:00						
1:00						
2:00						
2:00						
3:00						
3:00						
4:00						
4:00						
5:00						
7:00						
8:00						

Appendix L: Lesson Instruction
Sheet

Metric Study

first

You will take the second lesson of the Introduction to Metrics this week. Please read the following information carefully:

1. This is individualized instruction. You will ^{view} listen a set of slides to a tape for learning this lesson.

2. Bring your pencil and notebook with you when you take the lesson, since you will need to write down some things for your review.

3. Don't hesitate to ^{view} listen part or whole lesson repeatedly, if you think something is not clear to you.

4. Go to the assigned classroom 10 minutes earlier than your scheduled time.

5. Bring the information sheet with you.

6. If you have any question, please contact:

Wan-Lee Cheng
208 B Building O
Industrial Education

294-8064

Metric Study
Information Sheet

WHERE: Building O, Room _____, Industrial Education
(second floor, Building O)

WHEN: January _____, 1976. _____

WHAT: A set of slides
Title of the lesson: Introduction to Metrics
Name of the lesson : Lesson _____
Name of the copy : Copy _____

PROCEDURES YOU SHOULD FOLLOW:

1. Go to the assigned classroom.
2. Check the label of the slide tray. It should have the sign:

Introduction to Metrics,
Lesson _____,
Copy _____.
3. Check the name list and sign your name. This is very important; the attendance will be part of your grade.
4. Start your lesson.
5. Turn off the switch when you leave.

Metric Study

first
You will take the second lesson of the Introduction to Metrics this week. Please read the following information carefully:

1. This is individualized instruction. You will view listen a set of slides to a tape _____ for learning this lesson.

2. Bring your pencil and notebook with you when you take the lesson, since you will need to write down some things for your review.

3. Don't hesitate to listen view part or whole lesson repeatedly, if you think something is not clear to you.

4. Go to the assigned classroom 10 minutes earlier than your scheduled time.

5. Bring the information sheet with you.

6. If you have any questions, please contact:

Wan-Lee Cheng
208 B Building O
Industrial Education

294-8064

Metric Study
Information Sheet

WHERE: Media and Microforms Center, University Library.
(Ground Floor, Room 55, Library)

WHEN: January _____, 1976. _____

WHAT: A cassette tape
Title of the lesson: Introduction to Metrics
Name of the lesson : Lesson _____
Name of the copy : Copy _____

PROCEDURES YOU SHOULD FOLLOW:

1. Go to the counter of the Media and Microforms Center.
2. Tell them you need to check out the tape which is:
Introduction to Metrics,
Lesson _____,
Copy _____.
3. Check the name list and sign your name. This is very important; the attendance will be part of your grade.
4. Start your lesson.
5. Return the tape to the counter when you leave.

Appendix M: Test Answer
Sheet

[illegible]

Appendix N: Attendance Sheet

INTRODUCTION TO METRICS

I.Ed. 130 x, I.ED. 224 , I.ED. 323
I.Ed. 357 , I.ED. 490 D

TIME	NAME	COURSE NO.	COPY NO.	STUDENT SIGNATURE
8:00				
9:00				
9:00				
10:00				
10:00				
11:00				
11:00				
12:00				
12:00				
1:00				
1:00				
2:00				
2:00				
3:00				
3:00				
4:00				
4:00				
5:00				
7:00				
8:00				

Appendix O: Letters to
Instructors

Date: December 17, 1975

To: Mr. Marvin Sarapin, Mr. Raymond Schlueter,
Mr. Earl Yarbrough

From: Wan-Lee Cheng

Subject: Metric Study

Thank you for your help. I appreciate your providing the chance for me to conduct the Metric Study in your classes.

The first test will be on December 18, 1975 (or December 19, 1975). This test will last about an hour or less. The following items are my suggestions to administer the test:

1. Pass out the information sheet to every student.
2. Call the name which was labeled on the test and hand to individual student.
3. Pass out the computer answer sheets and remind students to print their names, numbers and mark the corresponding boxes on the computer answer sheet first.
4. Remind them to take the Metric lessons after the X'mas Holiday. (The detailed information will be given to every student by the first contact hour, Jan. 5, 1976.)
5. If the student does not show up, please keep his test sheet separate and inform him to contact me on Jan. 5, 1976.

My office is: 208 B Building O
(second floor)

Phone No.: 294-8064

My home is: 887 Pammel Court

Phone No.: 292-2720

Thank you again. Merry Christmas and Happy New Year.

IOWA STATE UNIVERSITY
INDUSTRIAL EDUCATION

AMES, IOWA

Wan-Lee Cheng
208 B Building O
Industrial Educa-
tion Department
Iowa State Univer-
sity
Ames, Iowa 50011
(515)-294-8064

DATE: January 26, 1976

TO: Dr. John Riley, Dr. Duane Gimmel
Mr. Marvin Sarapin, Mr. Raymond
Schlueter, Mr. Earl Yarbrough

FROM: Wan-Lee Cheng

SUBJECT: Metric Study

Thank you for your help. I appreciate your providing the chance for me to conduct the Metric Study in your class.

The second test will be on January 28, 1976 (or January 29, 1976). This test will last about an hour or less. The following items are my suggestions for administering the test:

1. Pass out the PERSONAL INFORMATION FOR METRIC STUDY sheet to all students, and ask them to fill in the blanks.
2. Pass out the procedure sheet to every student.
3. Call the name which was labeled on the test and hand to individual student.
4. Pass out the computer answer sheets and remind students to print their names, numbers, and mark the corresponding boxes on the computer answer sheet first.
5. If the student doesn't show up, please keep his test sheet separate and inform him to contact me.

My office is: 208 B Building O

Phone No: 294-8064

My home is: 887 Pammel Court

Phone No: 292-2720

Thank you again.