7-1-1952

A comparison between the use of projection planes and the non use of projection planes in the teaching of mechanical drawing in the high schools

Arthur Wendell Allison

A COMPARISON BETWEEN THE USE OF PROJECTION PLANES AND THE NON USE OF PROJECTION PLANES IN THE TEACHING OF MECHANICAL DRAWING IN THE HIGH SCHOOLS

A Thesis
Presented to
the Graduate Faculty of the
University of Richmond

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Education

by
Arthur Wendell Allison

August, 1952

Approved
E. F. Overton
8/19/52

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to Doctor Edward F. Overton, Chairman of the Department of Education, University of Richmond, under whose guidance and direction this experiment was conducted.

Deeply indebted is the writer to Mr. Austin E. Grigg, Assistant Professor of Psychology, University of Richmond, for his cooperation and constructive suggestions and criticisms. Acknowledgement is also due to Mr. G. Rey Bennett, teacher of English, of the Thomas Jefferson High School of Richmond, Virginia, for his many suggestions and careful reading and editing of the material prior to binding of the thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM, DEFINITIONS OF TERMS USED, AND REVIEW OF THE EXTANT LITERATURE ON THIS SUBJECT

For many years the planes of projection have been forgotten or ignored by many teachers in the teaching of mechanical drawing in the high schools. The reasons suggested by those teachers who do not use the planes of projection in their teaching have been based upon their observations and conclusions, and in no instance which the writer has discovered has experimental evidence been presented to support these contentions.

I. THE PROBLEM

Statement of the problem. It is the purpose of this study to determine the value of the use of the projection planes in the teaching of high school mechanical drawing. A relative comparison of this teaching method was made with modern teaching methods now in use by many mechanical drawing teachers. Two control groups were used; one group was taught mechanical drawing using the planes of projection, whereas the other group was taught by a method not using the planes of projection. The problem was, "What is the difference in achievement of pupils in high school mechanical drawing, when some are taught using the planes of projection, and others are taught not using the planes of projection?"

Importance of the study. Efficiency of learning, coupled with the complete mastery of ideas, has been a goal of many educational systems for many centuries. Teaching methods have been changed and altered, always with hope that the new method would better achieve these educational goals. Research has helped to prove the inferiority or superiority of the new methods. But the writer has been unable to discover any published results of research dealing with the teaching methods of mechanical drawing, using the projection planes. The teaching procedures in this field have been left, more or less, with the exception of a few minor research studies, to develop in their own way. In this study, an attempt has been made to utilize scientific research techniques whereby the relative value of two teaching methods could be obtained.

II. DEFINITIONS OF TERMS USED

Mechanical drawing. Mechanical drawing can be defined as the language of industry. French and Svenson aptly state, "Language is defined as the expression of thought....If we attempt to describe in words the appearance and details of a machine, a bridge, or a building, we find it not only difficult, but in most cases impossible. Here we must use another language, the universal graphic language of drawing."[1] This is likened to the old Chinese proverb, "One picture is worth 10,000 words." Words, either spoken or written, are very limited in their ability to describe forms.

Lines can be put together to form images and pictures. This is the original and natural method of describing forms. These lines of varying weights and types can accurately and definitely provide a description far better than words. To the beginner, these lines are very confusing, but to an expert in the interpretation of drawings, they are as clear as can be possible. One must therefore master the symbols of mechanical drawing to be able to read and interpret drawings.

The idea of these drawings cannot be read aloud nor can they be printed. They must be intelligently interpreted by forming a mental image of the object that is represented by the aggregation of lines and symbols. By so doing, we learn to master the language of industry.

Mechanical drawing is wide in scope and coverage. It includes those drawings made with the use of a draftsman's kit, which includes instruments of precision such as compasses, triangles, scale, and T-square. Freehand drawings are likewise included in this field. These freehand drawings use

---

[1] Thomas E. French, and Carl L. Svenson, Mechanical Drawing. New York: McGraw-Hill Book Company, Inc., 1948, p. 1.

the graphic language of industry and are so called merely because they are drawings made without the use of instruments. Both freehand and mechanical drawings may be subdivided into four categories: orthographic, isometric, oblique, and perspective drawing, according to the method used. Each of these divisions may be further subdivided into the specific areas of drawing, with each area having its own symbols and idiomatic forms of expression, such as architectural, machine, structural, topographical, and airplane drawing. Thus, one may easily grasp the scope, importance, and value of mechanical drawing in our daily lives.

The above stated concepts will be the definition of the term mechanical drawing used throughout this paper.

A brief history of mechanical drawing. As drawing is the universal graphic language, it must have been known long ago. The Bible implies as much in its description of the planning of Solomon's Temple: "Then David gave to Solomon, his son, the pattern of the porch, and of the houses thereof, and of the treasuries thereof, and of the upper chambers thereof, and the inner parlours thereof, and of the place of the mercy seat."[2] It is very unlikely that the detailed and complex buildings and structures of the ancients were built

---

[2] The Holy Bible, I Chronicles, 28:11.

without plans or without drawings for those assembling the parts. Further, it seems impossible to think of the Parthenon or a pyramid being constructed and assembled without drawings to guide those in charge of the building.

By the early part of the fifteenth century, the theory and use of projections on single planes were well established by Italian architects, of whom Brunelleschi was one of the first to use scientific laws of perspective in architecture.[3] It was a simple theory being entirely pictorial in nature, and not until the end of the eighteenth century did our present complex, scientific drawing theory evolve. This means that the science of mechanical drawing is relatively new. A French mathematician, Gaspard Monge, *circa* 1790-1800, introduced a new concept to mechanical drawing -- that of using two planes of projection placed at right angles with each other.[4] From this new development came the basis of descriptive geometry, a science using analytical methods to give the graphical description of objects having length, width, and height. Descriptive geometry is the scientific basis of practically all mechanical drawing.[5] This science is

---

3 "Filippo Brunelleschi", *Encyclopedia Britannica*, 1949, IV, 285.

4 "Gaspard Monge," *Encyclopedia Britannica*, 1949, XV, 704.

5 William Raymond Longley, "Descriptive Geometry," *Encyclopedia Britannica*, 1949, VII, 254-257.

designed to develop the mind in mentally visualizing objects which occupy space.

Thus, mechanical drawing has evolved from the past by two clear, distinct steps. First, only one projection plane existed until the close of the eighteenth century. Second, at this time another plane, perpendicular to the first, was added. More projection planes later were added to these two planes until, at present, any number may be used, depending upon the complexity of the problem.

Planes of projection. These will be referred to throughout this study. It will be noted that there are three types of projection; namely, orthographic, oblique, and perspective. The planes of projection are common to all types of projection and are the plane surfaces upon which the object is projected or drawn.

A well known mathematical fact is that a point may be projected upon a plane surface. Any object which occupies space has many points upon its surfaces. If all points of the object are projected parallel to each other, perpendicularly to the plane of projection, it is called Orthographic Projection. Oblique Projection is the parallel projection of all points of an object, wherein the plane of projection is other than 90 degrees to the parallels. If the points of the object are projected to the plane of projection in a converging manner, a Perspective Projection is obtained.

These planes of projection are planes in the strict mathematical sense. They may be defined in a layman's sense as flat surfaces. To the mathematician, they are surfaces as determined by three points, or if only two points were chosen and a straight line were to connect the two chosen points, the entire line would be in the surface of a plane.

With the present theory of mechanical drawing, three planes of projection are used. Each plane is mutually perpendicular to the other two. If the reader will visualize the ceiling, the front wall, and a side wall, each of these three surfaces upon examination will be found to be perpendicular to the other two surfaces. If an object is assumed to be placed in the center of the room, and a "top" view of that object is drawn on the ceiling, a "front" view drawn on the front wall, and a "side" view drawn upon the side wall, a fairly good idea of the planes of projection and their use and value may be gained.

> However, it is a growing practice in the United States to teach elementary projection drawing without reference to the planes of projection.
>
> . . . .
>
> The argument for this teaching method is that the student visualizes the object itself without being confused in trying to visualize the projections. Its success is indicated in that some engineering schools are now teaching the whole subject of descriptive geometry [mechanical drawing] without

using the reference [projection] planes.[6]

The study of the relative merits of the use in contrast to the non use of projection planes in the teaching of mechanical drawing is the purpose of this study. The use of projection planes seems to be in little practice as a survey of all mechanical drawing teachers in the Richmond, Virginia, Public Schools indicates that no teachers are using this method and that many teachers have not even heard of it! Unsuccessful library searches for mechanical drawing teaching techniques indicate that no recorded research experiments have ever been undertaken on this particular pedagogical method. The popular trend is away from the use of projection planes, without documental evidence of its inferiority or superiority. The purpose of this study is to determine to what extent this trend is justifiable and pedagogically sound.

The modern method of teaching mechanical drawing. As has been previously stated, the modern trend ignores the use of projection planes in teaching mechanical drawing. It substitutes models and pictures from which the pupil may develop an ability to form a mental image from a drawing. In its essence, the pupil is given a model and is asked to draw the

---

[6] Thomas E. French, "Engineering Drawing," Encyclopedia Britannica, 1949, VII, 632.

top, front, and side view of the object. Practice of this sort is thought to develop the ability of pupils to visualize drawings mentally, and to enable the pupil to transfer this ability to instances where a model is not available. An important fact is that the goals of this teaching method are the same as the goals of teaching using the planes of projection: mainly to develop the ability to form mentally an image of an object represented by lines on a drawing. This is the popular system in present use by many teachers of mechanical drawing.

III. HOW THE PROBLEM AROSE

This problem slowly took place in the writer's thinking, observation, and philosophy during the experience of teaching mechanical drawing for four years. It was the writer's philosophy that new ways of teaching should continually be used so as to improve the existing techniques. Consequently, the method of using the projection planes was used for instruction in some classes, and in some other classes the projection planes were not used. From a subjective evaluation and observation of these situations, it seemed that the pupils using the planes of projection in their drawing were mastering the mental visualization processes more easily, more quickly, and more efficiently than those who were not taught by the projection plane method, not only in the beginning classes, but also in the advanced classes where this discrepancy seemed even greater in an accumulative fashion.

If these observations were false, then there should be some documented proof showing that the method not employing the projection planes was the best. If these observations were true, then there should be some concrete evidence indicating that the use of the projection planes was the better instructional method. Upon a review of the literature, there was no obtainable evidence for the superiority of either method. Was the popular modern method of teaching a justifiable course for teachers to follow blindly without proof? Thus, the question of superiority of one method over the other became an issue. Did one method rank above the other in excellence? Did the modern, popular trend follow a reasonable teaching method? Was there any tangible evidence to prove or disprove the values of either method? To answer these questions, a study would have to be made of the conditions of each teaching procedure. It is hoped that this study will show that one of these instructional techniques is preferable to the other.

IV. A REVIEW OF THE LITERATURE

The first step taken in this study was the review of the extant literature on the subject at hand. It was surprising and enlightening to find that little or no research had been done on this particular problem, either on college, high school, or elementary school level. Researchers have ignored or overlooked the teaching methods of mechanical drawing. Yet many books have been written and much research has been done in the field of mechanical drawing, but nothing has been done in methodology. Professor Hoelscher, in 1929, claimed to have written the first book concerned with the teaching of mechanical drawing. He states that, "There have been textbooks upon the teaching of almost all of the other high school subjects, but this text presents a pioneer effort in the field of teaching methods for the subject of mechanical drawing."[7] He uses the planes of projection in his recommended methods.[8]

The libraries of the University of Richmond, the University of Virginia, the United States Office of Education, and the Library of Congress were searched in this study. From the files of this large number of publications, there was only one article dealing with the use of the planes of projection in the teaching of mechanical drawing. The author of this article in expressing a personal viewpoint

---

[7] Randolph Philip Hoelscher, The Teaching of Mechanical Drawing. New York: John Wiley & Sons, Inc., 1929. Preface.

[8] Ibid., p. 164.

concludes, "If the projection box is given a trial anywhere above the sixth grade, it will never again become the property of the tech school and college."[9] This article explains the use of the projection planes in the theory of mechanical drawing and how they may be used in schools. The article is unsubstantiated by research and it represents only a subjective viewpoint and experience of the author. From these remarks an impression may be inferred that the projection planes were not in common use in the grade or high schools at that time. A search of a bulletin of the American Vocational Association[10] indicates that there are no articles from 1930 to 1948 dealing with the value of the projection planes. It may be interpreted, therefore, that while the projection planes may have been in use by some high school teachers since 1920, their use is not too common. The lack of literature on this topic would seem to indicate that there has been very little interest in research dealing with these projection planes in relation to learning processes. No recorded scientific basis, either for or against the use of projection planes in teaching procedures, has been found in

---

[9] W. V. Winslow, "The Projection Box: Its Use in the Schools," Industrial Arts Magazine, 9:35, May, 1920.

[10] Studies in Industrial Education, American Vocational Education Bulletin, No. 4. Washington: American Vocational Association, Inc., 1949. 160 pp.

the review of the publications listed in several libraries.

The apparent lack of scientific reports upon this topic, therefore, would seem to indicate that this study may be an original scientific research.

V. THE VALUE OF THE STUDY

The values of this study have many implications, and they are important to many groups.

From an educational standpoint, classroom teachers should always strive to find better ways and methods of teaching. Learning by pupils should be by the most efficient methods available. Teachers using obsolete or inefficient methods cannot justify such inadequate techniques to society and to the teaching profession. The teaching occupation, as a profession, should always strive to improve its methods. This study should be of interest to every teacher of mechanical drawing.

The pupils, likewise, should benefit from this study. Psychology has sought to prove that material remembered longest is the easiest material learned. It would seem, therefore, to be to the pupil's advantage if the easiest method of learning were inherent in the present teaching procedures. The ease of learning provides for a thoroughness of understanding of the subject. This is of greatest importance to the high school pupil or technical student. Sorenson states

"...difficult material is forgotten more rapidly than is easy material. This is largely caused by the condition that easy material is learned more thoroughly and is better understood, while the difficult material has not been grasped so thoroughly."[11] Undoubtedly, mechanical drawing has as one of its goals the development of mental visualization. If a thoroughness of teaching and ease of learning occur in mechanical drawing courses, the pupil should well benefit in his increased mental visualization ability.

All institutions which provide instruction in mechanical drawing may also benefit from this study. It should be of especial interest to the institutions that prepare teachers, for their pupils, as prospective teachers, should benefit from efficient teaching methods as well as being trained in these methods. The technical schools should be interested in that their goals are to train specialists in a thorough manner. As this research is limited to the high school level, the results may prompt others to carry it into other grade levels, such as college, technical, elementary, and adult educational programs. Science may well discover obsolete methods in use in these institutions, which facts should be welcomed by the educational administrative officials.

---

[11] Herbert Sorenson, Psychology in Education. New York: McGraw Hill Book Company, Inc., 1948, p. 356.

Industry always has a stake in studies of this nature. Most graduates of our schools are employed in industry. The scope and nature of mechanical drawing is such that it can be of value to many industrial workers. Industrial personnel management is concerned with the adequacy of the education that its future employees receive in the schools. They expect and demand the best prepared workers available for employment. Because mechanical drawing is so widely used by so many trades, craftsmen, and workers, private industry does have a stake and interest in the teaching methods of our school.

But the adequacy of teaching methods of our schools is not the only interest that industry should have in this study. It must be pointed out that industry trains many of its employees for specific jobs as training for most of these specific jobs is not given in many schools. The extensive use of mechanical drawing in industry is a reason that this subject is taught by private enterprise, where time is money. The most efficient method of teaching mechanical drawing for special, specific positions should be of vital concern to the persons of industry in charge of an educational program for its employees.

VI. ORGANIZATION OF THESIS

In this study, as has been pointed out, the material was of an original, experimental nature. Thus no previous study was available to analyze for weaknesses and inadequacies. Accordingly, this thesis was undertaken as a presentation of an original experiment. Chapters in the following pages are devoted to each of the following topics: the basis for the grouping of pupils, the experiment, the construction of final achievement test, the administration of the final test and the equating of the groups, analysis of the final test results, and the summary, recommendations and conclusions.

The basis for the grouping of the pupils and a survey of the students involved in the experiment is discussed in Chapter II. The description of the experiment is the basis for Chapter III. This gives a detailed teaching method for each group, as the two control groups were taught by two different methods. Chapter IV is the description of the formation of an objective test designed to test both groups upon their achievement at the conclusion of the experiment. The administration of this test and the equating of the groups is discussed in Chapter V. Experimental techniques used in this study are thoroughly described throughout Chapters II, III, IV and V. The analysis of the final test scores is treated in Chapter VI. The summary, conclusions, and recommendations are described in Chapter VII.

CHAPTER II

THE BASIS OF THE GROUPING OF PUPILS

This study hinged upon equating two control groups. The groups were equated with each other in terms of I. Q., age, sex, spatial ability, and initial skill, which also was to include a previous knowledge of geometry. This chapter is concerned with the selection of these factors as a basis for equalization of groups, the process of equalizing the two control groups, and the administration of the experiment.

Preliminary steps and approval. After consulting with Mr. H. Clay Houchens, Richmond Director of Industrial Arts, and Mr. C. C. Hancock, Principal of Thomas Jefferson High School, permission and approval were obtained for conducting this experiment. Thereupon, the purpose, function, and scope of the experiment were thoroughly and carefully explained to the administrative and guidance personnel of Thomas Jefferson High School. This step was of vital importance as it was necessary to gain the understanding and co-operation of these persons in order to conduct the experiment successfully. As a result, all beginning mechanical drawing pupils for two semesters were assigned to the writer for their instruction in this subject. The guidance workers were most co-operative in not changing pupils' schedules, so that the beginning pupils would not thereby have a change of instructors. Consequently, not one pupil had to be discarded from this experiment because of a change of teachers.

Determining the experimental techniques used in this study. From a brief survey of this proposed experiment, it was at once evident that this study had one specific purpose; namely, to investigate the relative value of the use of projection planes in contrast to the non use of projection planes in the teaching methods used in a course of senior high school mechanical drawing.

In order to investigate and to examine this situation, the equivalent-groups method was used. The equivalent-groups experimental procedure is a controlled situation wherein the variables of the experiment are observed and measured in two identical pupil groups. The variables of this study are the two contrasting teaching techniques. It must be pointed out that the experimental situation was subject to many limiting factors such as time, money, effort, and the uncontrollable situations. The compensating factor of keeping these factors as constants made the equivalent-groups a plausible experimental method.

The chief difficulty with the equivalent-groups method was the control of all factors and all conditions involved so as to isolate the two factors under observation; to wit, the two types of mechanical drawing teaching procedures. There were many factors operating in addition to the aforementioned two variables (the teaching procedures). Changing social conditions and influences, such as home background, community experiences, social rank and prestige, size of groups in the experiment, sex, social forces, school achievement, natural endowed intelligence, age, family forces, teacher influences, etc. *ad infinitum*, were at play throughout the experiment. Undoubtedly, there were many unknown influences also. Even many of the known influences were likewise uncontrollable and unmeasureable.

To surmount this difficulty of the control of *all* involved and inherent factors, the law of the single variable had to be obeyed. Herein the teacher variables and one pupil factor were held constant by dividing the pupils into two equal groups and using one teacher for both groups. In this isolated state, the two teaching methods seemingly were isolated, observed, measured, and evaluated, using the pupil achievement results as the yard stick.

Determining the administration of the experiment. The limitation of time and the small number of beginning pupils prevented equating pupils of one group with identical pupils in the other group. Equating pupil-pairs normally requires large numbers of pupils from which only a few identical pairs can be salvaged. To utilize fully the few pupils in this experiment, they were grouped and equated as groups with equal factors, and not as pairs with equal factors.

After a close study of the school situation, the plan of using only one teaching method per semester was adopted. This administrative detail offered many advantages. It permitted the guidance personnel to adjust pupils' schedules. Pupils could be freely shifted from one mechanical drawing class period to another period without disrupting their total class schedule. Consequently there were no pupils discarded from the experiment because of class conflicts.

Another great advantage of this administrative plan was that it lessened the possibilities of one group influencing the other group. There existed the possibility that the members of one group could pass advantages and knowledge of the teaching techniques used with them to the members of the other experimental group. But with only one distinct teaching method used each semester of the experiment and with a summer's vacation between halves of the experiment, the possibility of this cross influence was greatly reduced.

This cross influence would be reduced from several other points. First, the pupils' retention of mechanical drawing principles, which could be given to the other experimental group, would not be too great after a three months' vacation. Second, the possibility of pupils of the second half of the experiment intimately knowing the members of the first half of the experiment was not great in a school as large as Thomas Jefferson. Third, the possibility of the writer's mixing the teaching techniques was greatly diminished by using only one teaching method at a time.

A further advantage of using only one teaching procedure per semester was that all pupils of both semesters were better possibilities for being group members, thus providing larger identical groups. Most pupils taught using this plan were group possibilities, as few discards were necessary because of class conflicts. This experimental plan by its very nature permitted the pupils to be taught, tested, and grouped at a leisurely pace at some later convenient date in each semester. Thus the plan of using only one teaching method per semester allowed the school administration officials great freedom in shifting pupils from period to period without concern of intermingling the personnel of the experiment. Under this adopted plan, all pupils of each semester could be tested at the beginning and end of the semester and their equating with the other pupils was not necessary until final completion of the experiment.

<u>Survey of the pupils used in this experiment</u>. After the administration of the experiment had been settled, it

was necessary to evaluate those enrolling for the beginning course in terms of interests, age, previous mechanical drawing, I. Q., spatial ability, and number of pupils. An entrance questionnaire,[12] devised by the writer, was given to each pupil at the beginning of the term. Two standardized tests were also given at this time. The following was a composite of beginning pupils of mechanical drawing enrolled with the writer for the school terms of February 1951 to February 1952.

By way of introduction, the curriculum of Thomas Jefferson High School uses the departmental plan based upon subject matter. There are many subjects available to the pupils. Some are prescribed by law; others are prescribed by the graduation diploma which the pupils desire; others are elective. Mechanical drawing is an elective course available to all pupils and it must be taken for a complete year, two semesters, before school credit for any diploma is given for the subject. Thereafter, each semester carries individual school credit. Consequently, those who do select mechanical drawing usually take a complete year before withdrawing or dropping the subject. As is true of other subjects, mechanical drawing is given in single periods of fifty-five minutes duration. Each semester is ninety days in length. Because

---

[12] Infra, Appendix A, p. 93.

the course is elective, some pupils enroll for beginning mechanical drawing as freshmen; others wait until their junior or senior year to begin. Pupils of all high school grades were enrolled in this experiment. Their ages were accordingly spaced from age thirteen years and eleven months to twenty years and four months.

There were forty-four pupils enrolled in the first semester and fifty-eight pupils in the second semester. This gave a total of 102 beginning pupils in mechanical drawing who finished the experiment. Preparation for a technical college course was given by fifty-two pupils as a reason for taking mechanical drawing. Well over half indicated that they had a specific reason for being in the class, which fact should indicate that classes were formed largely of pupils interested in the subject. From all entrance questionnaires it was determined that twelve pupils had previously taken mechanical drawing for only part of a term; eighteen had taken it for one term; six had taken it for two terms; one had taken it for three terms; two had taken it for four terms. All this previous mechanical drawing experience was in the junior high schools. There were no repeaters enrolled; all were new pupils to the experimenter.

The drawing given in the Richmond junior high schools is, for the most part, of an elementary nature. The courses vary from school to school and from teacher to teacher.

There the mechanical drawing is usually given for one-half semester in close connection with a shop course. Only one-view drawings are required. Some junior high schools give more advanced courses after the introductory and explanatory course. These junior high schools have mechanical drawing as unit courses, which teach mechanical drawing exclusively.

From this non-uniformity of mechanical drawing in the junior high schools, the beginning mechanical drawing pupils of Thomas Jefferson had gained their previous mechanical drawing experience. No credit was given by the high school for any junior high school drawing. Consequently, all pupils selecting mechanical drawing in Thomas Jefferson had to take the same course, regardless of their previous experience.

From the results of the <u>Otis Quick-Scoring Mental Ability Tests</u> given at the beginning of the respective semesters of the experiment, the distribution of I. Q. scores indicated a slight skewing to the right. Figure I, page 25, shows the distribution of these test results. These results may be accounted for on two grounds. First, those who choose the technical occupations usually are of high intelligence. Thus, if nearly 52 per cent of the pupils were taking the course in preparation for engineering or architecture, then the skewing of the scores to the right should be expected as shown in Figure I, because the more gifted pupils would

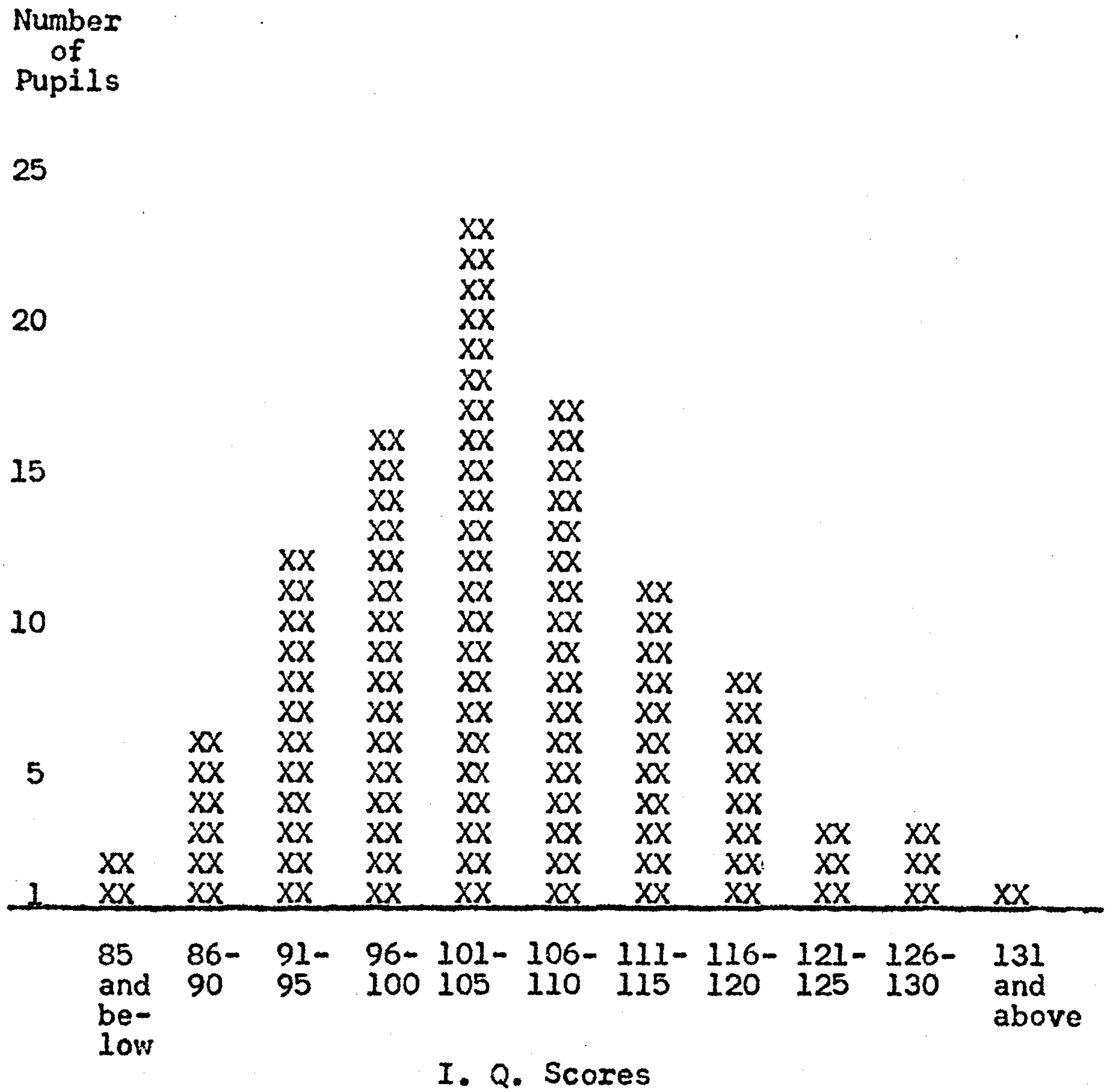


FIGURE 1

DISTRIBUTION OF I. Q.'S OF ALL PUPILS TESTED FOR THIS EXPERIMENT select this subject in preparation for their future vocation. Secondly, the skewing of the intelligence scores to the right is very dominant in the student body as a whole at Thomas Jefferson High School. If the trend for the results of the whole school is toward the right of the normal distribution curve, then one should generally expect the same curve pattern to follow in the pupil distribution within the classes of the school unless some selective processes were at work to upset this pattern, mainly the placing of the non-gifted pupils in classes upon the advice of the counselors. Only eight pupils stated that the counselors had recommended mechanical drawing to them. This was no indication that the counselors were loading the mechanical drawing classes with the exceptional pupils. Table I indicates the success and ability of the Thomas Jefferson High School graduates of three previous years in doing college work.

TABLE I

ABILITY OF THOMAS JEFFERSON GRADUATES OF THREE RECENT YEARS TO DO COLLEGE WORK

Year	Number of Graduates	Number to Colleges	Per Cent of Graduates to Colleges	Successfully Passed Per Cent of College Classes
1948	504	325*	64.5*	91.1*
1949	467	332*	71.1*	87.9*
1950	480	333*	69.4*	89.7*

* Figures include those <u>not</u> recommended to colleges by the office of the principal.

In general, the results of the other standardized test, the revised _Minnesota Paper Form Board Test_, were spread from extreme low to extreme high, ranging from the first percentile to the ninety-ninth percentile. The distribution of these scores was not skewed. It was very near to a normal distribution.

In summary, the above information regarding the pupils, as a group, indicates that a majority had a definite reason for, and interest in, taking the course. The distribution of their intelligence scores was skewed to the right. Over 38 per cent had some previous mechanical drawing experience in the junior high schools. This high percentage of the initial skill factor, for the most part, had to be discarded from the results of the experiment. Only those pupils with a partial semester's experience in the junior high schools were utilized in the final grouping. The spatial visualization ability differed greatly as evidenced by results of the revised _Minnesota Paper Form Board Test_. The range in age was nearly as wide as that of the entire school.

Determining the factors in equalizing the two experimental groups. The factors of age, I. Q., initial skill, sex, and spatial ability were selected for equating the two groups. Previous mechanical drawing experience was not used as a factor in equating because the value of this experiment lay in the teaching of the neophytes.

Hereupon, the writer arbitrarily decided that the first semester of teaching would not use the planes of projection. As previously noted, there were forty-four pupils registered and forty pupils finished this semester in the beginning course. One of these pupils was a girl, who was subsequently eliminated from this experiment because there were no girls in the following semester. The equating of groups by sex was, therefore, not a problem.

Age, as an index to growth and maturity, was another chosen factor upon which to equate the groups. This was necessary, as maturation of ability to judge spatial relations seems to develop in early teens with little increase after fifteen or sixteen.[13] But in this experiment, there were pupils of age thirteen. It is doubtful that their spatial ability had been fully developed. Therefore each group should have an equal number of the lower age groups.

If intelligence is a mental ability which is used in solving problems, then this factor must likewise be equated in the two groups under observation. A rather high degree of intelligence is needed for success in the technical fields

---

[13] Donald E. Super, Appraising Vocational Fitness. New York: Harper & Brothers, 1949, p. 306.

using mechanical drawing.

The initial skill of the groups should likewise be evened, in that one group should not have an unfair beginning advantage. This initial skill included the previous mechanical drawing experience. As mathematics, especially geometry, is involved in this subject matter, the initial skill was interpreted also to include previous geometry courses.

Spatial ability, according to Super, "is an aptitude which has long been considered important in such...activities as...mechanical drawing."[14] This ability, being considered as a factor of equation, had to be considered in the choosing of the two groups. Only groups equal in the chosen factors necessary for group classification could give any validity to this study.

Further careful consideration did not reveal any other factors which seemingly would influence the equating of the groups.

<u>Summary of chapter</u>. Most successful intelligent human endeavor appears to be achieved with planning aforethought. This chapter, in a modest attempt, points out and discusses those planning factors which were necessary for the equivalent

---

[14] <u>Ibid</u>., p. 282.

grouping of pupils. Upon this beginning arises the topics for discussion in the following chapters.

An over-all picture of the graduates of Thomas Jefferson High School and their success in college was presented as a background for the experiment and an indication of the students involved. From the questionnaires distributed during the opening of classes, the specific items of pupils' interest were obtained. Two standardized tests administered to the pupils at the beginning of each semester gave added information for the equating of the groups. It was seen that the I. Q. scores were skewed to the right. Fifty-two per cent of the pupils expressed a definite vocational preparation as a reason for selecting this subject. The spatial ability scores of administered tests were widely divergent, as was to be expected, ranging from the first to the ninety-ninth percentile.

Thus, from a brief survey of Thomas Jefferson graduates, gained from standardized tests and the entrance questionnaires, an insight was gained as to the abilities and potentialities of those pupils subject to the experiment. Accordingly, this collected data from the various sources were the basis for equalization of both groups in terms of sex, age, initial skill, I. Q., and spatial ability.

CHAPTER III

THE DESCRIPTION OF THE EXPERIMENT

Having selected the factors upon which to equate the two equivalent groups, the writer proceeded with the study as given below.

The experiment. Prior to the beginning of the experiment, some standardized tests were obtained from commercial firms dealing in psychological tests. These were the revised edition of the *Minnesota Paper Form Board Test* and the *Otis Quick-Scoring Ability Mental Test*. These tests were used to determine the spatial ability and the I. Q., respectively, of the individual pupils.

It was necessary, also, to determine the factors of age, previous mechanical drawing experience, sex, and prior mathematics instruction. To achieve these goals, an entrance questionnaire was prepared by the experimenter for obtaining the necessary information from the pupils.[15] Given to the pupils at the beginning of their first class, this questionnaire served a two-fold function. Not only did it serve to enroll pupils, but it served as a source of ready and valuable information about each pupil. In addition, the

---

[15] *Infra*, Appendix A, p. 93.

questionnaire served as a means of recording all experimental data in one definite place. On the reverse side of these sheets were printed forms and spaces to record all collected data from the psychological tests given.

The first half of the experiment was started in February, 1951, and ended in June, 1951. The group taught during the first half of the experiment was designated as Group One. The writer arbitrarily selected the non-use of the projection planes for the teaching method throughout this semester. The second half of the experiment was conducted from September, 1951, to January, 1952. The group of this last half of the experiment was designated as Group Two. The use of projection planes was employed exclusively during this semester.

The teaching of mechanical drawing theory for Group One. The projection planes were not discussed or explained to this group. All theory and mechanical drawing practices were explained and discussed in the non-technical language. No formal lectures of explanation or discussion were given. Informal aid and assistance were given to pupils whenever and wherever needed.

The pupils had two main resources in addition to the teacher in working the problems: the text book, and small actual paper models of each individual problem. The pupils were expected to read the text and to ask questions, if necessary, before attempting any problem. The small actual models were freely used by the pupils in attempting to work the problem. These models could be easily viewed from the top, side, and front positions. From these three observations, the three views of the object could be drawn, the visible edges represented by solid lines, and the invisible edges represented by hidden lines.

It was hoped that with practice in using the models, a mastery of the three-view theory would be attained by the students. The mastery of the theory would be the ability to solve three views of an object, or mentally to visualize the object, and to interpret the three views <u>when an actual model of the problem was not available</u>.

This method of teaching which utilizes models presupposes that there will be training in the ability to read and to interpret mechanical drawings. It is hoped that with practice and use, this ability is transferred from the simple problems with models to the difficult problems not using models. Thus, the models were utilized as mental crutches or aids to train the ability of students in interpreting drawings. With the growth of this ability, the models, as crutches, were discarded, if possible. Difficult problems were solved by the learnings achieved in the use of models.

There was another mental aid available for this group. Instead of an actual model, a pictorial view was added to the problems in the text. From this graphic representation of an object, the three views could be ascertained with a little mental manipulation.[16] This extra assistance was available to Group Two, also.

The teaching of mechanical drawing theory for Group Two. The teaching method for the second semester used the projection planes. In all class explanations and discussions, a repetitive reference was made to the relationships of the object to the horizontal, vertical, and profile planes. Formal lectures were given prior to the studying of a new ideal or concept. Reviews were of a formal character. They were individual, informal discussions wherever and whenever needed, but always couched in terms of the horizontal, vertical, and profile planes.

To make clear these explanations, the writer constructed a projection box of clear transparent plastic. It consisted of a wooden base 8" by 10" with one plastic sheet securely fastened to the base. To this front sheet of plastic, two other 8" by 10" plastic sheets were hinged. The side plastic sheet folded back against the side of the base. The top plastic sheet folded down and rested directly over the base. Thus assembled and folded, it corresponded

---

[16] *Infra*, Appendix D, problem 1, p. 101, as an example.

to the front wall, the side wall, and the ceiling of a room. Figure 2, page 36, is a photograph of the actual model used in this experiment. On these plastic sheets were drawn the front, top, and side views of an object which was enclosed by the folded plastic sheets. Photographs of these views are given in Figures 3, 4, and 5 on pages 37, 38, and 39. By folding the top and side plastic sheets, one has all three views in a single plane. Figure 6, page 40, shows how the three views would appear on a sheet of paper, which represents the front picture plane.

Note that the front plane now includes the other two planes, namely the top and side plastic sheets. This front plane, as do all planes, has only two dimensions. But the three views now folded into one plane represent three dimensions of length, width, and height. To one unlearned in the theory of mechanical drawing, a projection box must be seen and studied carefully to grasp clearly and to understand all of its underlying principles.

The mathematical and mechanical drawing principles concerning the projection box were taught as thoroughly and completely as possible to Group Two. The relationships, the interrelationships, and implications were discussed whenever possible. The concept of two intersecting planes forming a straight line was carefully explained as the reason for the lines forming the outline of an object. The interrelationship

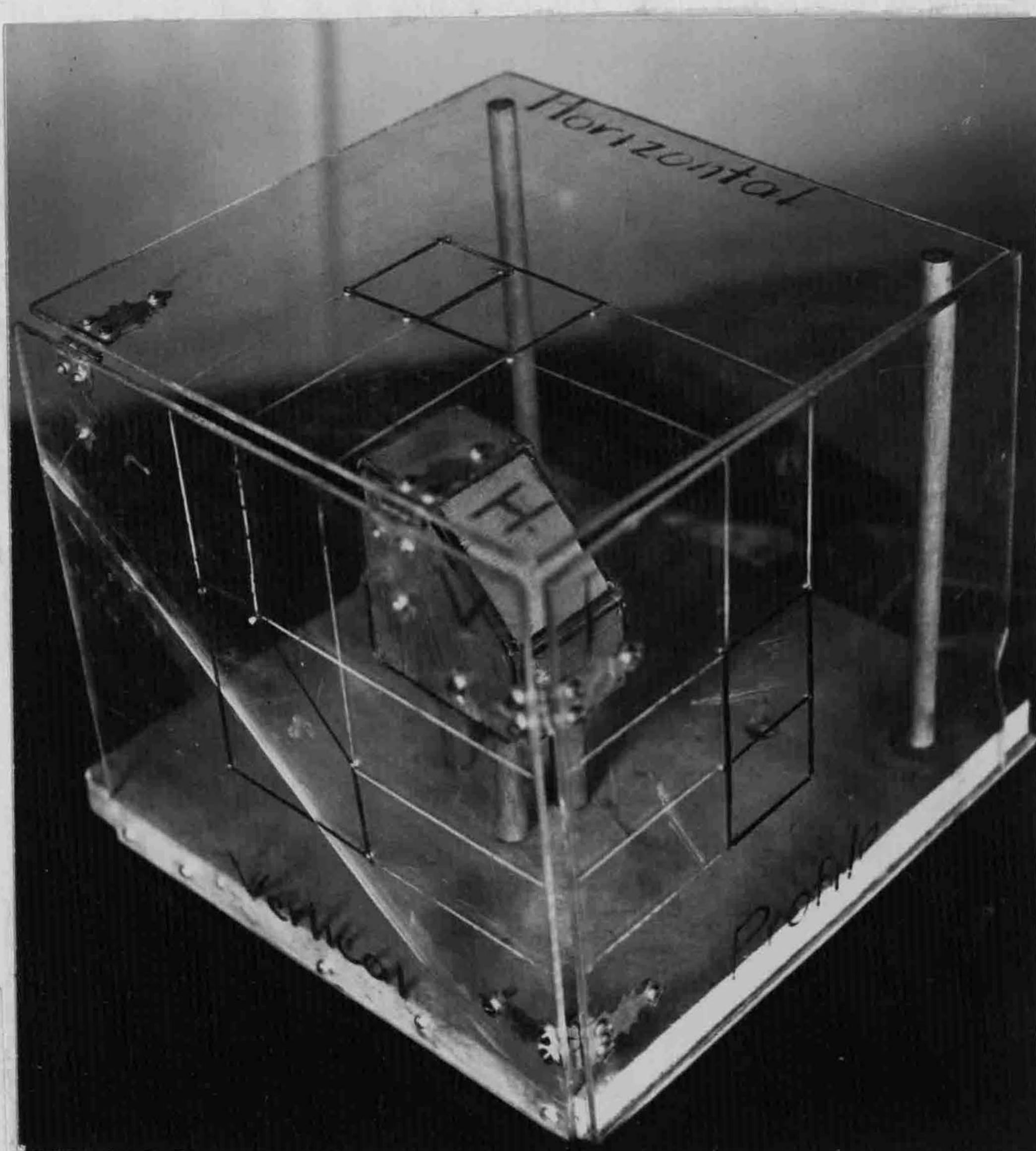


FIGURE 2.

PHOTOGRAPH OF PLASTIC PROJECTION BOX

FIGURE 3

PHOTOGRAPH OF TOP VIEW OF THE PROJECTION BOX

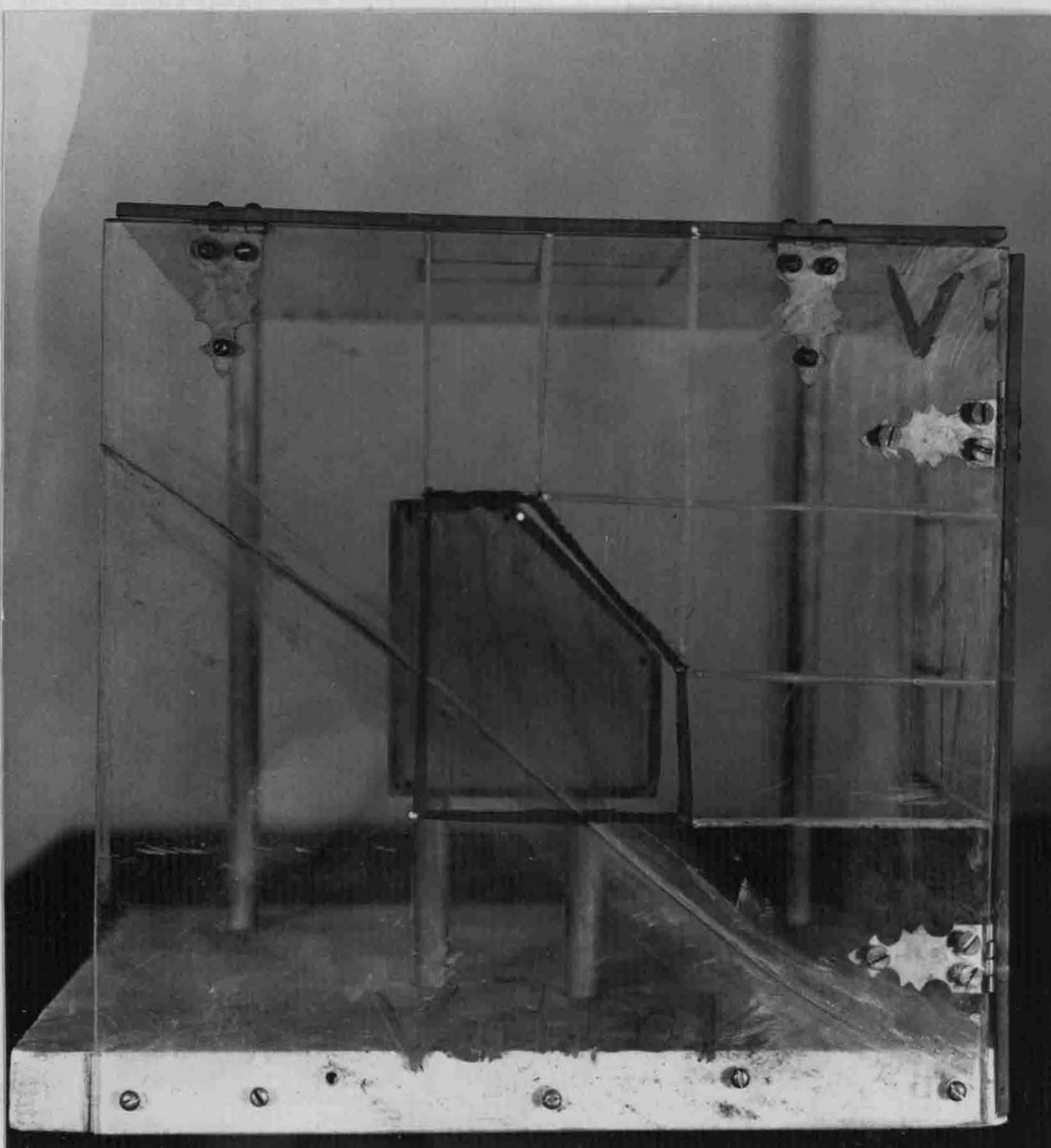


FIGURE 4

PHOTOGRAPH OF FRONT VIEW OF THE PROJECTION BOX

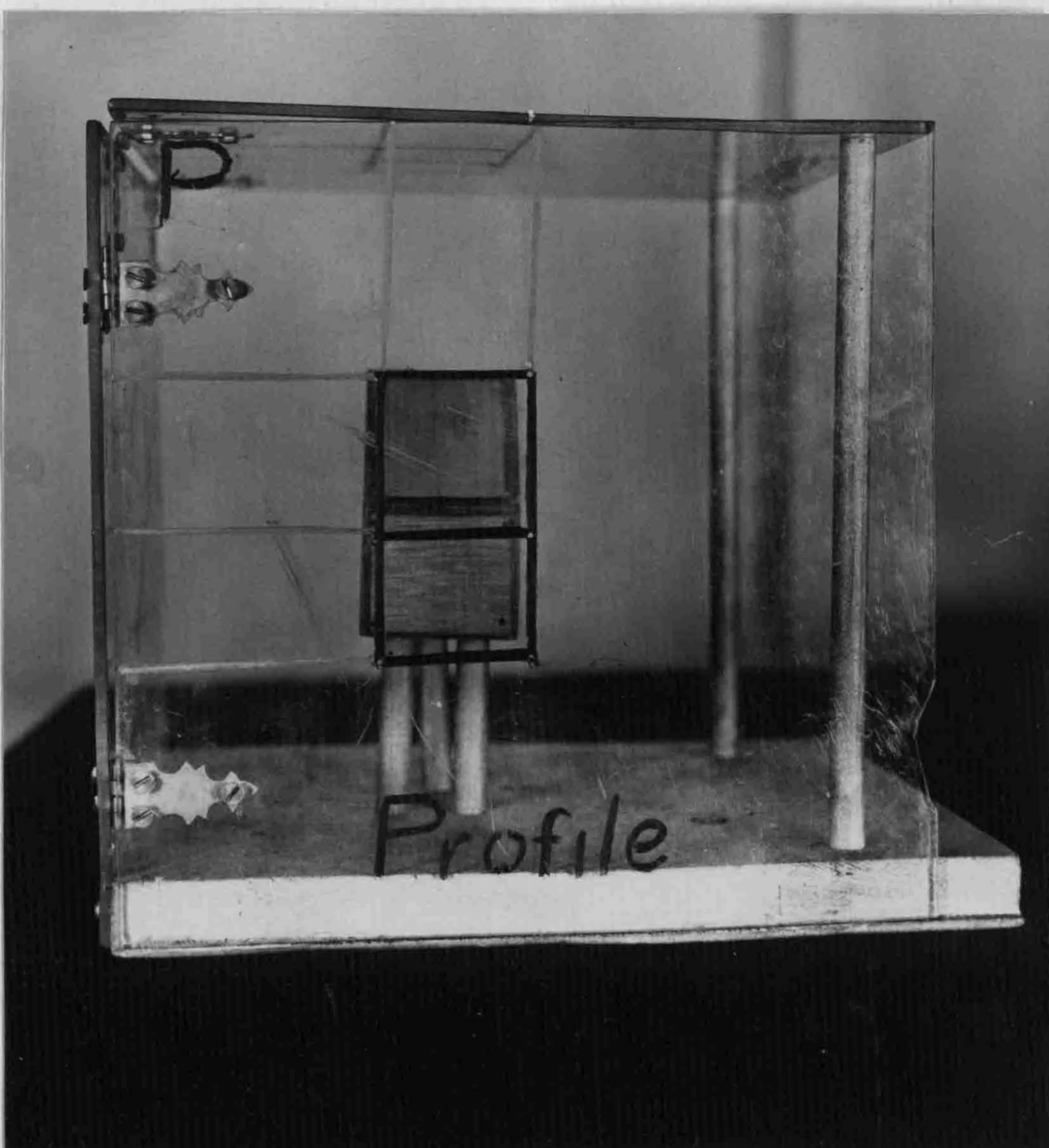


FIGURE 5

PHOTOGRAPH OF SIDE VIEW OF PROJECTION BOX

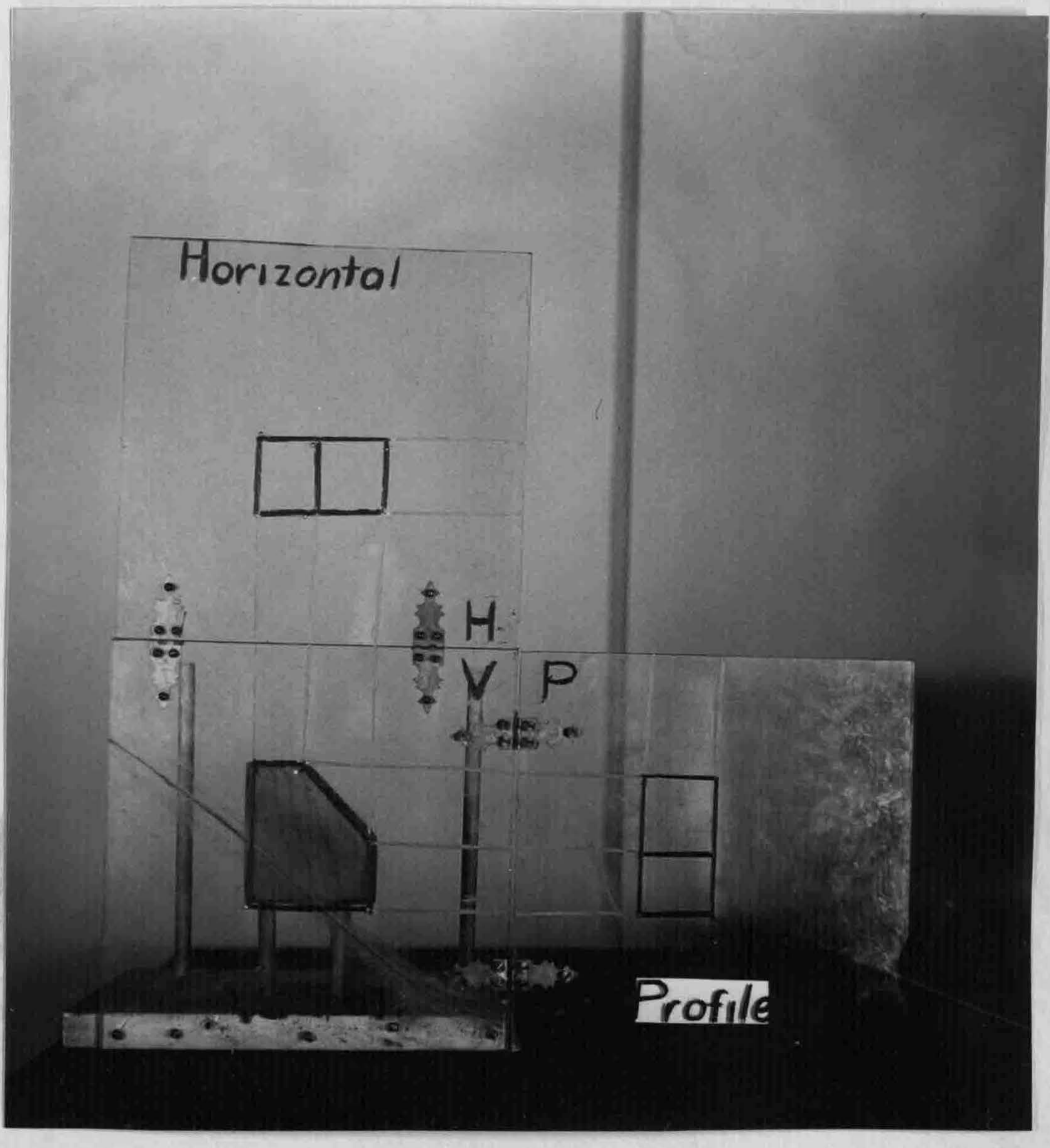


FIGURE 6

PHOTOGRAPH OF THE HORIZONTAL AND PROFILE PLANES INTO THE VERTICAL PLANE OF THE PROJECTION BOX points, lines, planes, and solids were taught to this group. These concepts were carefully developed so that the students could apply them to mechanical drawing problems.

The plastic projection model was available for students to take to their desks, if necessary, for further study in an attempt to gain an insight of the principles evolved during the term. The object being drawn was studied in its relation to the plastic box. There were no models of the problems available. Only one model was available to use in the plastic box throughout the term. The rules, observations, and concepts applicable to all mechanical drawing problems were derived from this one example. It was hoped that the students' ability to read and to interpret drawings would be transferred from a study of the plastic projection box with its simple problem to the difficult problems.

Factors equally affecting both groups. First on this list is that of the teacher factor. The writer served as teacher for both groups. As far as possible and practical, the teacher influences were held constant in both groups. The teacher diligently and conscientiously instructed both groups. The class procedures were held as constant as possible in class administration in such things as taking roll, discipline, grading, etc. The teaching method was the only teacher factor intended to be varied in the course of the experiment.

As the experiment was planned, there was a summer vacation between parts of the experiment. This was fortunate on two counts. First, the psychological laws of forgetting would apply to the teacher in regard to the teaching method for Group One. This was desirable, as an entirely different teaching method was used for Group Two. The second count was equally as favorable. Not only would the teacher forget, but the pupils likewise would forget some mechanical drawing principles. These two factors were quite acceptable for the experiment, as it lessened the possibilities of intermingling the two contrasting teaching methods. The summer vacation likewise served to separate friends for an additional period of time. It must be remembered that beginning pupils are largely drawn from the incoming students from the junior high schools. As these two groups were already separated into different schools during the first semester, and the groups separated longer by a summer vacation, the possibilities of friends being in the different groups was greatly reduced. This also lessened the possibilities of a cross influence of the teaching methods.

The physical makeup of the room was another experimental factor. Things such as lighting, available spare desks, instruments, and equipment were unchanged during the study. At the beginning of each term, some class periods were reserved for class planning. Herein the number of problems to be worked by the pupils as a requirement for passing the course was decided upon in class co-operation and agreement. The method of grading problems and the class procedures were established with student participation. Both experimental groups decided upon twenty problems as being the required number for the term. The students agreed, with minor exceptions, upon the fairness of the method of determining grades as outlined in a memorandum to the parents.[17] The factors of neatness, accuracy, speed, and legibility were mutually agreed upon as a basis for grading the quality of the problems. Because a certain number of problems was required for a student successfully to pass the course, the par for each problem was duly noted at the beginning of the time allotted for it. Thus, each pupil could judge for himself his retardation or progress. The slower students were able to finish only the required number, while the superior pupils were able to complete some extra assigned problems.

The writer, in using only one teaching method per semester, enjoyed the advantage of being able to permit pupils behind in their work to come in for makeup work during any class period or after school without fear of the two teaching methods intermingling. Pupils were encouraged to come in,

---

[17] Infra, Appendix B, p. 96.

whether behind in their work or not. Consequently, the drawing room was open and available almost every afternoon after school until 4:00 P.M.

During the two semesters, only a few individuals dropped out of school. Only four of forty-four pupils and three of fifty-eight were drop-outs during the experiment. These few drop-outs were due to school disciplinary action to those who were poorly adjusted to the school, in that the school had little to offer them. The withdrawals were relatively few in number because the majority of those enrolling stated a definite reason and interest for the course. Further, withdrawals were also discouraged in that a whole year, two semesters, of mechanical drawing had to be taken before credit for graduation was given. Therefore, most pupils had usually definitely decided, before entering, to stay enrolled in the course.

It may be pointed out that there is a slight discrepancy in the number of pupils of the halves of the experiment. This may be accounted for by several reasons. As usual, there are fewer pupils entering school in February than there are entering school in September. Because mechanical drawing is an elective two semester subject, most pupils prefer to start their training in the fall term so that a summer vacation does not intervene. Another factor contributing to this difference in numbers was the shift of Richmond's public schools from an eleven year to a twelve year system. This shift affected the number of incoming pupils just as the experiment was started. The junior high schools were holding their pupils for another year. The number of incoming pupils to Thomas Jefferson was thereby drastically reduced.

Summary of chapter. An appropriate administrative plan of experimental procedure was selected. It entailed the use of only one teaching method per semester for all beginning mechanical drawing pupils. The other teaching technique was used exclusively for all pupils in the following semester.

Group One was taught without the planes of projection. Actual models of the problems were provided. Group Two was taught with the planes of projection; there were no models available for the pupils. A summer vacation favorably intervened between the experimental semesters.

There were certain factors which affected both groups. The influence of the teacher affected both groups. Each group was taught as diligently as possible. The same room was used for both semesters of the experiment and similar class procedures were used throughout the study.

The drop-outs were few. There were forty-four pupils enrolled for the first half of the experiment and fifty-eight for the second half. Forty pupils finished the first half of the experiment; fifty-five concluded the second half.

CHAPTER IV

THE CONSTRUCTION OF A FINAL ACHIEVEMENT TEST

During each half of the experiment, the classes were taught according to the respective teaching methods. With reference to the mechanical drawing assignments, the content of beginning drawing is concerned with acquainting the pupils with the use of the instruments, the spoken and written vocabulary of the subject, and the theory of the three-viewed drawings.[18] The results of the experiment, however, were chiefly concerned only with the three-view drawing theory. As the writer was unable to find a standardized mechanical drawing test concerned only with the three-view drawing theory, he designed a test for this purpose.[19] It was to determine the achievement of both groups by which the two contrasting teaching methods could be compared. By comparing the results of the tests of both groups, it was hoped that the superiority of one of the teaching methods would be indicated.

This test was modeled after the standardized tests administered in the experiment. Its purpose was to discover

---

18 *Infra*, Appendix C, p. 98. The three-view theory begins with problem eleven and continues through problem eighteen.

19 *Infra*, Appendix D, p. 100.

the achievement of each group to serve as a basis of group comparison. Because the theory of the three views may be tested in several ways, the test was subdivided into five divisions. Each division was to test a different aspect of mechanical drawing theory of the three views. Dividing the test into these five divisions served as an additional means of group comparison. Perhaps one teaching method of the experiment was superior only in teaching some divisions of the test. This comparison of group scores on the individual test divisions was an important guide in forming conclusions of the results of the experiment. These conclusions are discussed in detail in Chapter VI.

For each division of this test, a time limit was established. This time limit was determined with the co-operation of thirty mechanical drawing students who had just finished the introductory drawing course in the prior semester. These were established by observation of the writer on the reaction of the pupils, their test results, the opinions of these pupils, the number of problems attempted, and the number of problems correctly solved. The limits were established so that it was highly improbable that any beginning pupil could correctly finish all the problems, and that all pupils could finish some problems. If these limits had not been established, no true testing results could have been attained; i.e. if the superior pupils had correctly finished all of the problems before the time limit, then a test of their ability would not have been complete.

With the exception of those problems in group two of this final test,[20] all problems in all divisions were arranged from easy to difficult. Those in group two were not so arranged as it was a multiple choice type of test. Hence a quick guess for a pupil would be appropriate for an easy problem as well as for a difficult one. Consequently, to make allowances for those who guessed on this part of the test, the problems were not arranged in an ascending order of hardness. It should be noted that on division three of this test,[21] the range of difficulty increases as more solutions are drawn, for each subdivision decreases the number of remaining possible solutions.

As has been implied in the foregoing paragraphs, the test was devised so that different psychological approaches to testing were utilized. The first division is a type of testing that requires a definite understanding of the two given views before the missing third view can accurately be drawn. This division has a pictorial object accompanying the introductory problems.[22] As has been noted, the second

---

[20] Infra, Appendix D, p. 102.

[21] Infra, Appendix D, p. 103.

[22] Infra, Appendix D, p. 101.

division is a multiple choice. Division three utilizes the determination of many possible front views from one given top view. The fourth division is a strict interpretation of two views to solve the third view without the assistance of clues. The fifth division is a matter of completing the views. This final division represents interpretation in its highest form -- that of completing the solution of the existing incomplete views. These completion types of problems require a very high degree of mental manipulation.

Five mechanical drawing teachers of Richmond, Virginia Public Schools were asked to evaluate the individual problems of the test. The teaching experience of these teachers ranged from five to twenty years of classroom teaching. A summary sheet gives the average opinion of these teachers.[23] The values of the problems range on a relative basis from one to ten points.

For the most part, the writer had arranged the problems in an ascending order of difficulty. A study of the summary sheet will reveal that only in minor instances did the average opinions of the teachers place some hard problems prior to the easier ones. This order of difficulty was so planned, and the relative values assigned to the problems,

---

23 <u>Infra</u>, Appendix D, p. 106, which lists the values used for individual problems in scoring this test.

because of the following possibilities. If a value of one point were assumed for each problem throughout the test, and one experimental group solved only a few more problems than the other group, the difference in score would not be indicative of the true difference between the groups. If one group solved more problems arranged in increasing difficulty in the same amount of time as another group, the differential of scores constitutes a great difference in the abilities of the experimental groups. A value of one point could not, therefore, be assigned to each problem. Thus, the problems were assigned a different weighted value.

To illustrate more clearly this difference, if only one point per problem were assigned to the problems of group one of the test,[24] a total value of only ten points would be possible. By weighting the problems according to their difficulty, as evidenced by the opinion of five mechanical drawing teachers, a total of fifty-five points is possible. Thus a consideration of the scoring was an important part of the experiment. Any differences in scores of the groups using the weighted values would be more significant.

The items of this test were taken from many sources, including the files and records of the writer. Some were taken from the professional magazines and bulletins which

---

24 Infra, Appendix D, p. 101.

have features containing some mechanical drawing problems as puzzlers. Some test problems were gained from text books and work book supplements with variations by the writer. Some items were obtained from other teachers, from their files or memory. The writer felt free to use these items as they have been more or less common knowledge for many years. They are not the property of any specific individual. No one has an exclusive right to them.

Summary of chapter. It was necessary to test the ability in solving and understanding problems of each group in order to compare the effectiveness of the two teaching techniques. A test to determine these problem solving abilities was devised by the experimenter, using examples from various books and other sundry places. These examples were arranged in an increasing order of difficulty. In administering the test, the pupils worked under a time limit. The final test scores were the basis for comparing the two groups.

CHAPTER V

THE ADMINISTRATION OF THE FINAL TEST AND THE EQUATING OF THE GROUPS

From the results of the standardized tests and the entrance questionnaires, the factors were obtained by which the writer equated the two groups. The results of the final tests, devised by the experimenter, served as a means of comparing the group results. This chapter is concerned with administering the final test, which concluded the pupil information needed for the experiment.

I. ADMINISTERING AND SCORING OF THE FINAL TEST

The content of this final non-standardized test, and how it was devised, was discussed in the foregoing chapter. This test concluded all information that was necessary for the experiment. The results of this test were not actually necessary prior to the equating of the groups, but it was expedient to administer and to record the final test scores before the groups were equated.

As there were no known standardized mechanical drawing tests which included only the necessary part of the projection theory used in this experiment, the writer devised this final test. The problems were weighted according to an average opinion of five mechanical drawing teachers. The test was divided into five divisions, or groups, because there seem to be five different phases, approaches, or understandings of the three-view theory.

Consequently, procedures of administration were necessary for each division. Time limits were empirically determined with the co-operation of thirty pupils who had just finished the beginning course of mechanical drawing. The test was administered to them without time limits. By observing their reactions and analyzing test results, a time limit for each test division was obtained. Seven minutes was thereby allotted for group one, five minutes for group two, ten minutes for group three, eighteen minutes for group four, and fifteen minutes for group five. These time limits were quite satisfactory in that not one pupil correctly worked all problems of any division, and all pupils worked some problems in all divisions. Only the poorer students, in a futile, desperate attempt to make a high score, tried unsuccessfully to work all of them.

The total working time was fifty-five minutes, which required that the test be given in two consecutive class periods. A short testing procedure each period was in accordance with the short testing time required by the standardized tests given at the beginning of the experimental semesters. A few minutes were needed prior to each test for the reading of the instructions and discussions of questions pertaining thereto.

The scoring of this test presented much more difficulty than of standardized tests. The standardized tests provided scoring keys by which the answers could be easily and quickly scored. In these tests, answers were either right or wrong; there were no possibilities of partial correctness. Since there was so much more effort in visualizing and working a drawing problem than by merely marking an answer in the standardized tests, the writer arbitrarily decided to give one half credit for drawings that were essentially correct but for minor mistakes. A drawing, if not absolutely correct, would not necessarily be totally disregarded. But if it did not qualify for one half credit, it was considered as totally incorrect and discarded from the scoring.

The half credit for a problem was given if only one of the following conditions was wrong with the problem:

1. The view correct with an extra line.
2. The view correct with one line lacking.
3. The view correct, but broken lines shown instead of solid lines.
4. The view correct, but solid lines shown instead of broken lines.
5. The view correct, but one line sloping in an opposite direction.

6. The view correct, but reversed in directions; i.e., a rear view given instead of a front view.
7. The view correct, but rotated 90° in position.
8. The view correct, but a curved line given instead of a straight line.
9. The view correct, but a straight line given instead of a curved line.
10. The view incorrect, but a correct pictorial view sketched by the pupil.
11. The view incorrect with a line joining a correct corner to an incorrect corner.

The writer felt this was a liberal scoring scheme which made allowances for those who become emotionally upset on tests with time limits. It was doubtful that finer gradations in scoring of less than one half credit would be practical.

The results and scores of this test were recorded on the reverse side of the entrance questionnaire of the respective students. The scoring was finished as soon as possible after the end of each half of the experiment. Immediately after the scoring of Group Two, the equating of the groups began.

II. THE EQUATING OF THE GROUPS

It was expedient to wait until the recording of the final scores of Group Two before equating the groups. It was easier to record all final test scores of both groups and then to do the equating, than first to do the equating and then to record the final test scores. This saved much effort in shuffling the questionnaires. When the equating was started, there remained forty pupils in Group One and fifty-five pupils in Group Two.

Equating the groups according to sex. This factor included only one pupil discard from the experiment. Only one girl was taught during the first semester of the experiment, and no girls were registered for the second half of the study. After this equating factor was adjusted, thirty-nine boys were left in Group One, whereas the total of fifty-five boys in Group Two was unaffected.

Equating the groups in terms of initial skill. Initial skill was broadened to include mathematics experience as well as previous mechanical drawing experience. The plane and solid geometry were the only mathematics which could noticeably influence the experiment. Since the junior high schools correlated their mechanical drawing with shop courses, and the initial semester was devoted only to one view drawings, one semester or less of junior high school drawing was permitted for the grouping. It was thought that any initial advantage of any pupil with only one prior semester of junior high school drawing would be overcome by the end of the study of three-view drawing theory in high school.

Upon investigating the status of the remaining pupils in the equating groups, it was found that only five had taken geometry. These few were upperclassmen, who were the older students. The writer decided to equate the groups upon these factors after all other factors had been equated. Perhaps these five would be discarded in the equating to follow. If these few were not discarded or balanced by then, the number of future discards for mathematics would be relatively few.

In the discarding of pupils for previous mechanical drawing experience, a total of nineteen were discarded; six from Group One, and thirteen from Group Two. This left thirty-three boys in Group One and forty-two in Group Two.

Equating the groups on the factor of age. It was necessary to do the grouping within certain limits of the age factor. It was highly improbable that the groups could be equated in exact age. Therefore, a variation within limits was needed further to equate the groups. An age variation of six months was arbitrarily selected as a reasonable equation limit.

Accordingly, the questionnaires of those pupils now remaining in the experiment were arranged for both groups in ascending order from youngest to the oldest. The ages of

Group One ranged from fourteen years and five months to nineteen years and three months. The ages of Group Two ranged from thirteen years and eleven months to nineteen years and seven months.

From these two sets of pupil questionnaires, the pupils of Group One were matched with the pupils of Group Two with the allowance age of six months difference. There was a cluster of students in Group One at age fifteen years and nine months. Three from Group One of this age had to be discarded because there were not enough pupils of the corresponding age in Group Two.

This equivalent age grouping continued until both groups were equated in terms of age. A tally of the discards indicated that only three from Group One were necessary and twelve were ejected from Group Two. At this point of the equating, there were thirty pupils of each group. Equating the groups in terms of ages reduced the groups to equal members.

<u>Equating the groups on the basis of I. Q.</u> The two sets of pupil questionnaires were now rearranged so that the I. Q. scores were in ascending order. A survey of these remaining questionnaires revealed that the range of I. Q. scores for Group One ranged from seventy-seven to 121. The I. Q. scores for Group Two ranged from eighty-eight to 129.

It was necessary now to determine the variable allowance in I. Q. between group scores. A perfect matching of all pupils would be highly improbable. Because of the small numbers involved in this experiment, an arbitrary allowance of five I. Q. points was accepted as the maximum range of group variation.

When these I. Q. scores of the groups were equalized, only one I. Q. score from each group had to be discarded: the extreme low of Group One and the extreme high of Group Two. However, this grouping based on I. Q. now made it necessary to regroup in terms of age. The regrouping resulted in three more discards from each group.

After this grouping, there was a total of twenty-six pupils left in both groups.

Equating the groups in terms of spatial ability. Here again it was necessary to establish an allowance for variation. A difference of five percentiles was arbitrarily determined for difference in these scores.

The range in percentile scores of the revised *Minnesota Paper Form Board Test* for the remaining pupils of Group One ranged from the twenty-seventh percentile to the ninety-seventh percentile; the range of the corresponding scores of Group Two ranged from the twenty-fifth percentile to the ninety-eighth percentile.

The writer fully expected that the number of pupils left in the experiment, after equating the groups on this factor, would be reduced by two-thirds. However, after rearranging the questionnaires in ascending order of percentile scores, and equating the groups, there were no discards. This was so remarkable that the writer rechecked the original source of data for possible errors. There were no errors in scoring or recording.

III. SUMMARY OF CHAPTER

The concluding test was administered within the established time limits. Two class periods were necessary. The scoring of the tests presented some difficulties as there were no scoring keys, and a problem partially correct was given some credit.

The groups were not equated until the results of the final test were recorded on the pupil questionnaires. The questionnaires of each group were kept separate. The groups were first equated for sex and initial skill. By rearranging the pupil questionnaires, the two groups were equated in terms of age, I. Q., and spatial ability. Twenty-six pupils were left in each group after the final equating was finished.

CHAPTER VI

ANALYSIS OF FINAL TEST RESULTS

With the final test scores recorded, and the pupils equally grouped upon the selected factors, it was now possible to compare the groups. The results of the concluding test gave the basis of comparison as an index to the superiority, if any, of one teaching method over the other. This chapter makes an analysis and a comparison of the final test scores for the equated groups.

I. AN OVERALL PICTURE OF THE TWO EQUATED GROUPS

The age differential of the groups was surprisingly small. Figure 7, page 62, indicates the nearness of the pupils in age between the groups. Only one pupil was included at the maximum age range of six months; three were of no difference in age. The average group difference in ages was only two months.

I. Q. scores also were matched very closely. The limiting range was selected as within five points, plus or minus. Figure 8, page 62, shows the distribution of pupils by I. Q. variation. Five were evenly matched in I. Q. score; only one instance occurred where the maximum of five points was necessary for grouping. The average difference of I. Q. scores for the equated groups was two points. This was as

Number of pupils	0	1	2	3	4	5	6
8		XX					
7		XX					
6		XX	XX				
5		XX	XX				
4		XX	XX		XX		
3	XX	XX	XX	XX	XX		
2	XX	XX	XX	XX	XX		
1	XX	XX	XX	XX	XX	XX	XX

Age difference of groups by months

FIGURE 7

VARIATION OF EQUATED GROUPS BY AGE DISTRIBUTION
IN THIS EXPERIMENT

Number of pupils	0	1	2	3	4	5
7				XX		
6				XX		
5	XX	XX		XX		
4	XX	XX		XX	XX	
3	XX	XX	XX	XX	XX	
2	XX	XX	XX	XX	XX	
1	XX	XX	XX	XX	XX	XX

Difference in I. Q. points

FIGURE 8

GROUP VARIATION OF PUPILS BY I. Q. DIFFERENCE BASED ON
THE OTIS QUICK-SCORING MENTAL ABILITY TEST

close as could be expected.

The two groups were favorably grouped in terms of spatial ability. Figure 9, page 64, indicates the distribution of the pupils on this factor. The variation was greater on this factor. Six instances were of the same percentile and five cases were of the maximum allowance. The average percentile variation was a little over two percentiles.

Because of selective processes at play in equating the groups, the I. Q. distribution of the final equated groups was not a normal distribution. Figure 10, page 64, shows the I. Q. distribution for each group.

II. ANALYSIS AND COMPARISON OF THE FINAL ACHIEVEMENT TEST SCORES

The final test results, in order to be compared, had to be grouped in various manners in order that a definite statistical study could be made from them. The frequency distribution, the averages, the dispersion, and the skewness were statistical concepts upon which the two groups were analyzed, studied, and compared. The inadequacy of group numbers was discovered in this last aspect of the experiment.

The distribution of final test scores. Group One scores ranged from twenty-one to 191; Group Two scores

```
Number
  of
pupils

  7                           XX
  6         XX                XX
  5         XX       XX       XX                          XX
  4         XX       XX       XX                          XX
  3         XX       XX       XX                          XX
  2         XX       XX       XX       XX                 XX
  1         XX       XX       XX       XX       XX        XX
_______________________________________________________________

            0        1        2        3        4         5

               Difference in percentiles
```

FIGURE 9

GROUP VARIATION OF PUPILS BY PERCENTILES BASED UPON SCORES OF THE REVISED MINNESOTA PAPER FORM BOARD TEST

```
Number
  of                                        Legend XX Group One
pupils                                             XX Group Two

  8
  7                      XX      XX
  6                      XX      XXXX
  5                      XX      XXXX
  4                      XXXX    XXXX    XX      XXXX      XX
  3         XX    XX     XXXX    XXXX    XXXX    XXXX      XX
  2         XX    XXXX   XXXX    XXXX    XXXX    XXXX      XX
  1         XX    XXXX   XXXX    XXXX    XXXX    XXXX    XXXX
_______________________________________________________________

         86-    91-    96-     101-    106-    111-    116-
         90     95     100     105     110     115     120

                      I. Q. Scores
```

FIGURE 10

DISTRIBUTION OF I. Q. SCORES OF THE FINAL EQUATED GROUPS ranged from forty-five to 219. The total range of Group One was 170 while that for Group Two was 174. The total range of both was very close. Figure 11 indicates the frequency distribution of the group scores. Note the lack of scores in some of the extreme high intervals for both groups.

<u>The average scores for the two groups</u>. Since the object of an average is to secure a single magnitude which may be considered as characteristic for the whole group, there were several averages computed from the final scores of each group. These averages were computed with the purpose of comparing both groups. Table II, page 66, shows these averages.

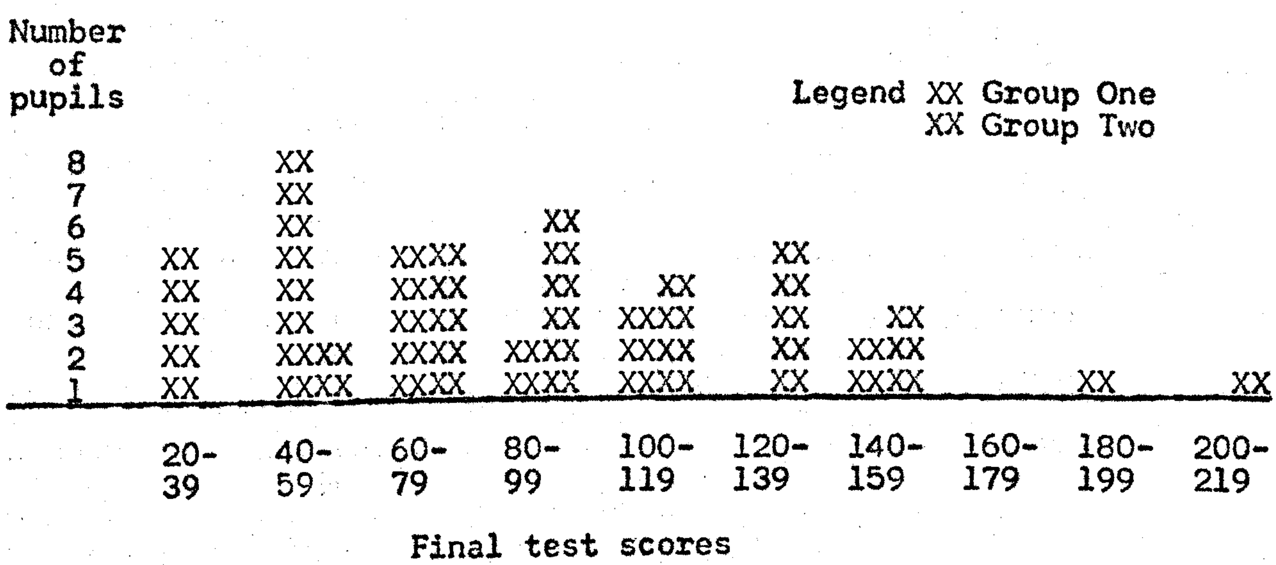


FIGURE 11

DISTRIBUTION OF FINAL SCORES OF THE EQUATED EXPERIMENTAL GROUPS

TABLE II

THE AVERAGES, ARITHMETIC MEANS, MEDIANS, AND MODES OF THE FINAL TEST SCORES OF BOTH EXPERIMENTAL GROUPS

Groups	Mean	Median	Mode
Group One	72.3	60	35
Group Two	103.3	99.5	91.9

Formulas and symbols:

Mean (M) $= \frac{E\ m}{N}$

Median (Md) $= \frac{N + 1}{2}$

Mode (Mo) $= M - 3(M - Md)$

N = Total number of pupils per group
M = Mean
Md = Median
Mo = Mode
E = Sum (Sigma)
m = Value of an individual observation

Referring to Figure 11, page 65, one may note high extremes for both groups. It must be pointed out that these extreme values influence the arithmetic mean. Herein is an inadequacy to the numbers involved in the experiment. The group numbers of the experiment are too insufficient to provide a distribution of scores of every frequency. Perhaps these extremely high scores of both groups are spurious scores. A further study to supplement these scores might well provide a better picture of the distribution. The calculations indicated a mean of 72.3 for Group One and 103.3 for Group Two.

It was quite possible that the extreme high values of both groups unduly affected the mean of the groups. To determine this, the median score for both groups was calculated. A median of 60 for Group One and a median of 99.5 for Group Two was determined. Note, in Table II, page 66, a difference of twelve points between the arithmetic mean and the median of Group One. This may be interpreted that the extreme high values in Group One were influencing the mean. Referring again to Figure 11, page 65, one may note that this indication is borne out. The distribution for Group One is sloping greatly to the right. This too is an indication of inadequate members in the experiment in that a true distribution is probably lacking.

The mode was also determined for each group to determine the grade most frequently received. The mode thus calculated for Group One was 35; for Group Two, 91.9. The mode dropped 37.3 points from the mean in Group One computations. Neither of these modes appeared too applicable to the array of scores as arranged in ascending order. Therefore, the mode seems not too meaningful to this study.

From Table II, page 66, it is evident that the mean, median, and mode of Group Two are grouped quite close together. This is indicative of a normal distribution. On the other hand, these same averages for Group One are widely divergent, which is indicative of a non-uniform distribution.

The appearances of these averages point to a study of their dispersion and skewness.

No comparison of group scores would be complete unless a breakdown of scores was made for each division of the final test. Table III shows these results. Note that Group Two excelled in every division of the final test.

TABLE III

TOTALS AND AVERAGES OF EACH GROUP OF FINAL TEST DIVISIONS

Groups	Final test divisions 1	2	3	4	5	Total score of all test divisions
Group One						
Score	381	347	518.5	230	403.5	1880
Mean	14.7	13.3	19.5	8.8	15.8	72.3
Group Two						
Score	478	456	650	524	577	2685
Mean	18.5	18	25	11	22.3	103.3

Dispersion and skewness of the final scores of the groups. A measure of the scattering, or dispersion, will tell the degree of compactness of a curve of distribution. Another description of a distribution is its skewness.

The measure of the dispersion of a distribution is the range. This is the absolute difference between the lowest and highest score of the series. The range for Group One was 170; for Group Two, 174. Other measures and degrees of the range are the interquartile range, the average, and standard deviations. Table IV summarizes these measures of dispersion used in analyzing the final test results.

TABLE IV

THE RANGE, INTERQUARTILE RANGE, AVERAGE DEVIATION, AND STANDARD DEVIATION OF FINAL ACHIEVEMENT SCORES OF BOTH GROUPS (MEASURES OF ABSOLUTE DISPERSION)

Groups	Range	Quartiles		Quartile deviation	Average deviation	Standard deviation	Number in group
		Q_1	Q_3				
Group One	170	44.5	95	20.25	28.3	42.4	26
Group Two	174	71.75	128.25	28.25	29.2	37.5	26

Formulas and symbols:

$$R = S_F - S_i$$
$$Q_1 = \frac{N}{4}$$
$$Q_3 = \frac{3N}{4}$$
$$Q.\ D. = \frac{Q_3 - Q_1}{2}$$
$$A.\ D. = \frac{E/d/}{N}$$
$$S.\ D.\ \text{or}\ \sigma = \sqrt{\frac{E\ d^2}{N}}$$

/ / = Ignore plus and minus signs
R = Range
S_F = Final score
S_i = Initial score
Q_1 = Quartile One
Q_3 = Quartile Three
N = Total number of pupils per group
Q.D. = Quartile Deviation
A.D. = Average Deviation
d = Deviation of scores from mean
E = Sum (sigma)
S.D. or σ = Standard Deviation

While the table above indicates the absolute dispersion of each group score, there is danger of misinterpretation in comparing group scores. Consequently, these scores are expressed in relative terms so there can be no misinterpretation in comparison of group scores. To provide a basis for comparison, the coefficient of variation was used. Herein, the absolute variation was reduced to a pure relative value by the statistical formula $V = \frac{\sigma}{M} \cdot 100$, where V is the coefficient of variation, σ is the standard deviation, and M is the mean. The number so obtained for Group One was 58.6, and 36.4 was determined for Group Two. From these figures it is seen that Group Two distribution is the more compact of the two by 22.2 per cent. A comparison of the standard deviations from Table IV would not ordinarily give this comparative value in a true perspective.

A further basis of relative variation for comparison, based upon the interquartile range, was used. This is known as the coefficient of dispersion and represented by the formula, $\frac{Q_3 - Q_1}{Q_3 + Q_1}$, when Q refers to the various quartiles. The value for Group One was .287; that of Group Two was .281. This indicates that the groups were comparably distributed between the first and third quartiles. The difference was not great, and, considering the group size, this amount is insignificant.

Another comparison of group scores that was made was the skewness of both group score distributions. This coefficient measures the relative difference between the mean and the mode. Accordingly, a positive number indicates the skewing of the distribution to the right and a negative number is indicative of a skewing to the left.

The formula used to obtain this relative figure was: $SK = \frac{3(\text{mean-median})}{\sigma}$, where SK is the coefficient of skewness, and σ is the standard deviation. Applying this formula to the group scores, it was discovered that both groups were skewed positively. A coefficient of skewness of .87 was obtained for Group One, and .283 was determined for Group Two. The very high figure for Group One is indicative that it tails greatly to the right, or positively skewed. The skewness for Group Two is likewise positive, but the relative skewness is not nearly so high as it is for Group One.

<u>Dispersion of sample means</u>. The groups were considered as two samples not taken from the same universe, because two different teaching methods were used in the experiment. If one teaching method was superior, the difference of the means of the groups would be statistically significant. The critical ratio was employed to determine this significance. To use this ratio the standard error of the mean was determined for each group score with this formula: $M = \sqrt{\frac{\sigma_S}{N - 1}}$, where σ_M is the standard error of the mean, σ_S is the

standard deviation, and N is the number of pupils in the group. After determining this figure for both groups, it was necessary to determine the standard error of the differences between means, which at this point were paired. The formula for this equation is $\sigma_D = \sqrt{\sigma_{M_1}^2 + \sigma_{M_2}^2}$, where σ_D is the standard error of differences of the paired means, and σ_{M_1} and σ_{M_2} are the standard errors of the means for both Groups One and Two, respectively. The critical ratio formula is: $T = \frac{M_1 - M_2}{\sigma_D}$, where T is the critical ratio, M_1 and M_2 are the arithmetic means, and σ_D is the standard error of difference between paired means. The critical ratio, as determined for this experiment, was 2.72σ, which is considerably above the standard 1 per cent level of significance of 2.576σ. With reservations, this may be interpreted that the scores possibly came from a different universe. This in turn implies that there is a significant difference between the group scores. Table V, page 73, summarizes the values of the standard error of the means, the standard error of difference of paired means, and the critical ratio.

Statistical comparison of group scores on the divisions of the final test. Heretofore, the statistical concepts have been applied only to the totals of the test scores. This in no way was a complete comparison of the

TABLE V

STANDARD ERROR OF MEAN, STANDARD ERROR OF DIFFERENCE OF PAIRED MEANS, AND CRITICAL RATIO OF FINAL TEST SCORES OF GROUPS

Groups	Mean	Standard error of mean	Standard error of difference of the paired means	Critical ratio
Group One	72.3	8.48	11.4	2.72
Group Two	103.3	7.5		

Formulas and symbols:

$$\sigma_{M_1} = \frac{\sigma_1}{\sqrt{N - 1}} \quad ; \quad \sigma_{M_2} = \frac{\sigma_2}{\sqrt{N - 1}}$$

$$\sigma_{D_{1-2}} = \sqrt{(\sigma_{M_1})^2 + (\sigma_{M_2})^2}$$

$$T = \frac{M_1 - M_2}{D_{1-2}}$$

σ_{M_1} = Standard error of mean of Group One

σ_{M_2} = Standard error of mean of Group Two

$\sigma_{D_{1-2}}$ = Standard error of difference of paired means

T = Critical ratio

= Standard Deviation

N = Number of pupils per group

M_1 = Mean of Group One

M_2 = Mean of Group Two

final test scores. A statistical comparison of groups between the divisions of the final test was necessary to give a thorough comparison of the groups. Therefore, a statistical analysis was made of these division scores. Table VI, page 74, shows these results. Note that the critical ratio

TABLE VI

A STATISTICAL COMPARISON BETWEEN GROUPS OF FINAL TEST DIVISIONS

	Divisions of final test									
	1		2		3		4		5	
	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
A.D.	7.6	8	6	6	9.9	7.5	6.2	5.4	10.6	11.2
σ	9.4	10.3	8.4	7.1	12.1	9.4	10.2	8.25	12.7	13.1
σ_M	19.2	2	1.7	1.4	2.4	1.9	2	1.65	2.5	2.6
Mo	6.8	11.2	7.9	22	14.95	28.8	3.4	22.25	5.75	11.6
Md	12	16	11.5	18	18.25	26	7	21.75	12.25	19
Q_1	7.5	11.5	8	10.75	10	16.25	3	17	7.4	10.75
M	14.6	18.4	13.3	17.5	19.9	25.2	8.8	21.5	15.5	22.2
Q_3	20.25	23.25	17	22	27	33.25	9.5	24	24.25	32.5
D	.46	.34	.36	.38	.46	.34	.54	.17	.53	.50
V	64	56	63	40.5	60.8	37.3	1.16	.38	.83	.59
Sk.	.83	.7	.64	.63	.43	-.25	.53	-.07	.77	.69
$\sigma_{D_{1-2}}$	2.76		2.2		3.06		2.6		3.61	
T	1.4		1.9		1.7		5		1.9	

NOTE: Symbols and formulas are the same as used in other tables in this chapter.

of Division Four is the only significant difference between scores on divisions of the test, yet the critical ratio for the <u>total test scores</u> is 2.72 σ. This high value of the critical ratio of Division Four seems to have influenced unduly the total critical ratio. This result may be viewed with alarm, especially when the other critical ratios are so closely grouped. Therefore, the critical ratio for the total experiment loses much of its significance.

III. SUMMARY OF CHAPTER

In equating the groups, the limits of the equating factors were closely observed. As a result, the two groups were evenly equated in I. Q., age, and spatial ability. Twenty-six pupils were left in each group after the equating was finished.

These pupils were all too few to apply appropriately statistical measurements. The distribution of the final test scores was too inadequate and too limited. A true idea or conception of the distribution was not ascertainable.

The averages of the two groups were a little more statistically important. The mean of Group One was weighted upward due to the influence of the extreme high scores. The median of Group One varied twelve points from the mean as still another indication of the weight of the high scores. The mode for Group One varied still farther from the mean, a variation of 37.5 points. The variation of the mean, median, and mode of Group Two was slight.

The range for both groups was nearly equal, but Group One scores started considerably below the beginning score of Group Two. The high score of Group Two excelled the top score of Group One. The range of Group One was 170, and for Group Two it was 174. The standard deviation of each group was not equal; 42.4 as compared to 37.5 of Group One and Group Two, respectively.

But there is a great danger of misinterpretation in trying to compare standard deviation with the dispersion. A relative number of dispersion was obtained for each group, and these figures were compared. Group Two was the more uniformly distributed. Another relative comparison of dispersion, using the interquartile range, indicated that Group One was more uniform within this range than was Group Two, but not significantly so.

Another comparison of group distribution was the coefficient of skewness. This was an index as to whether a distribution was greatly skewed and whether it was positive or negative in nature. Both groups were skewed positive. Group One was greatly skewed, and Group Two was only moderately so.

The determination of the critical ratio for the two groups indicated that there was a significant difference between the scores. In an analysis of the group scores on the divisions of the final test, the only significant difference was discovered in Division Four. This significance is so great that its value is unduly affecting the difference of the total score. Hence, there is great doubt cast upon the true significance of the superiority of Group Two over Group One, as determined by the critical ratio, using the totals of the final achievement test.

CHAPTER VII

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. GENERAL SUMMARY

In the course of four years of teaching experience, a problem presented itself to the writer. In his observance of present mechanical drawing teaching methods of other classrooms throughout the Richmond, Virginia, Public Schools and of the State of Virginia, the planes of projection were not widely used in teaching mechanical drawing. Results of experiments on a subjective basis indicated to the author grave doubt as to the superiority of a teaching method not using the planes of projection. This thesis is an objective attempt to answer the question.

In attempting this experiment, the equivalent-group method was decided upon, as this method lent itself very favorably to the conditions of the experimental situation. Some similar factors of Group One and Group Two were kept constant, except the teaching methods, which varied. This variable was to be tested for each group, and the results of the variable should be an index to the success of the teaching variable.

The factors which were to be kept constant and which were to be the basis of grouping the pupils were age, I. Q., spatial ability, sex, and initial skill. Standard tests, the revised Minnesota Paper Form Board Test and the Otis Quick-Scoring Mental Ability Test, were used to establish the factors of spatial ability and I. Q., respectively. The entrance questionnaires were used to establish the factors of age, sex, and initial skill, which included previous geometry and mechanical drawing experiences.

A test was devised by the writer to determine the achievement results of two groups. The items of this test were weighted, as they were arranged in sequence of easy to hard, upon the opinion of five mechanical drawing teachers. This test was given at the end of each experimental semester. It was patterned after one of the better-known reading tests. Time limits were established for each of the five divisions of the test.

The results of this test indicated that Group Two, taught with the planes of projection, scored higher in all divisions of the test, but the difference was not too statistically significant. Therefore, it cannot be said that the teaching for Group Two was superior to Group One. The critical ratio of the final test scores was higher than the 1 per cent level of 2.576 σ, but this figure seemed to be unduly influenced by the high critical ratio of Division Four of the final test.

II. WEAKNESS OF PROJECT

This experiment is not a panacea for the teaching of mechanical drawing, nor is it intended to be. There are many apparent weaknesses which further research should validate or deny. The numbers involved in this experiment should be viewed with more than a casual alarm, even though a few carefully selected cases may give as much validity as thousands of examples. But with these few numbers involved, there is a great chance for bias to enter unnoticed and unfairly affect the results. Further, the few selected may have been the result of factors favorable to the teaching using the planes of projection. Possibly, because so many Thomas Jefferson High School graduates do attend college, these factors subtly influenced the results. More semesters included in the experiment with more pupils of heterogenous groups involved would give added strength to the results.

The numbers involved were too small for significant analysis. The distribution of test scores and the equating factors were lacking in too many intervals. A larger number of students should fill these intervals in the distribution. Analysis of a larger number of scores should be more conclusive.

Another weakness in this experiment is the bias of the author. Bias of some sort probably is present in every human endeavor. Therefore a strict neutrality is quite impossible in this study. An unconscious bias may well have influenced the results because the pupils of Group Two could have been taught better, or the grading may well have been prejudiced. Needless to say, the test was conducted as fairly and honestly as possible. Both groups were taught as well as possible by the experimenter. Grading standards were set up by which the examples were graded to try to avoid bias in grading. Testing instructions and procedures were implicitly followed.

A further bias of the experimenter may have entered in that he has little shop and practical experience. The final test may well have been geared for the theoretical at the expense of the practical aspect of mechanical drawing. The whole experiment, unknowingly, may have been influenced by this factor of teacher bias.

It must be remembered that the method discovered as doubtfully being superior in insignificant test scores is only one method. It is quite possible that a combination of teaching methods with Group One and Group Two could produce a far better effect than either method alone. Further, a scientific study to determine the proper order of presenting mechanical drawing in terms of interest, arrangement of topics, method of presenting the new topics may well reverse the results of this study. The value of the psychological and logical presentment of material to pupils cannot be overlooked.

The writer will not take issue with those who would argue that the content of the first semester of mechanical drawing as outlined in this course is improper, and that other things should be added or deleted, or that the important task of teaching skills of drawing lines, arcs, arrowheads, dimensioning, etc. is overlooked. It may be further argued that the aims and objectives of the work outlined for this one semester are not in accord with educational aims and are therefore psychologically and philosophically unsound. Until these issues are critically examined by research, these topics remain possible areas of weaknesses in the experiment and must be recognized as such.

The test devised by the author likewise may be a weak link in the experiment. The test may not be valid or reliable. It should be examined critically for validity and reliability, and evaluated carefully with a psychological analysis. Because this test has not been so scrutinized, a weakness may exist in this part of the experiment.

The experiment is weak in that no achievement test was given to the groups at the beginning of the study. This was not done as there was no known test available, and it was assumed that both groups knew nothing of mechanical drawing; hence both groups were equal in this factor. It was further weak in that there were no other known experiments of this nature by which the writer could validate his findings and results.

III. FINAL CONCLUSIONS

Because there has been no other similar experiment recorded, or discovered, the author feels justified in making the following conclusions, in spite of the inherent weaknesses in his experiment.

(a) The results of the final achievement test indicate that Group Two scored consistently higher on the test. As Group Two was taught using the planes of projection, it is concluded that this method of teaching was superior but not significantly superior to the teaching method of the non-use of the projection planes. The small number of participants in the experiment did not permit a conclusive finding.

(b) A significant superiority of Group Two over Group One was not clearly established on all counts under observation and study in this experiment. All scores for the averages, mean, median, and quartiles, were nevertheless higher for Group Two. The total range of both groups was equal but the range for Group One started twenty-seven points below that of Group Two. Only Division Four of the final test was statistically significant in favor of Group Two.

The critical ratio was 5 σ for this division. The value of this critical ratio should be viewed with alarm as it is not consistent with the critical ratios of the other divisions. The high value of the critical ratio for Division Four unduly influenced the critical ratio of the total scores.

IV. RECOMMENDATIONS

As this experimental research cannot be accepted as absolute proof of the superiority of Group Two teaching procedures but merely as indicative of certain factors, the following recommendations are forwarded.

(a) Because of the superiority of scores of Group Two pupils over the scores of Group One, it appears desirable that high school pupils be trained in mechanical drawing with the planes of projection. This difference seems to be of great importance and lends value to this study.

(b) Because of the seeming lack of training in the planes of projection in the teachers' professional preparation, it is recommended that the teacher preparation agencies train their products more adequately in this area of mechanical drawing. Only a properly trained person can impart the proper knowledge to others.

(c) As the teacher is the pivot around which this experiment is based, a further recommendation is suggested that the Richmond Public Schools examine very carefully the background of those employed in the future to teach mechanical drawing for training in the planes of projection theory.

(d) The Richmond Public Schools are further advised to undertake a program to verify this experiment in other schools, under other conditions, and under other experimenters, with different pupils, and with large numbers involved, to make a long range project of this study. The project can well be under the supervision of the experimenter or under the Director of Industrial Arts for the City of Richmond. A single experimenter is hampered by the expense, the time element, and the work involved. The teachers of mechanical drawing in the city, working as a group, could easily design an extensive experiment with no more effort than is needed for a single experiment. The numbers of pupils involved in such a study would give further validity to the proposed experiment. The Director of Research of the city schools or the writer could well be in charge of the scientific aspects of the study.

V. FURTHER STUDIES AND RESEARCH NEEDED

This experiment was conducted in a class strictly for mechanical drawing. The universal trend for industrial arts now seems to be in favor of combining the several areas of industrial arts. In an organization of this type, printing, mechanical drawing, metal shop, jewelry, foundry, machine shop, etc. are combined into one room called the general shop. The pupil learns the necessary skills as the pupil needs them. Thus further studies would determine if the planes of projection would be of value to mechanical drawing as it is taught in the general shop, instead of a unit class as it was in this experiment.

As has been noted in the recommendations above, further research is needed for giving greater numbers under varying conditions and situations to determine the value or weakness of this study. This experiment is an isolated study in limited conditions, and needs to be further verified. The varying conditions under which future studies would be made would be in schools where lower and higher percentages of graduates go to college than the 70 per cent of Thomas Jefferson. Experiments need be conducted in schools where the I. Q. curve is more normal than the curve presented in this study. Research should probe and examine this experiment held in situations where the intelligence curve is skewed to the left. (The writer was asked to teach mechanical drawing to a group of exceptional pupils with I. Q.'s of 85 and below. These pupils seemingly did very well in grasping mechanical drawing principles using the planes of projection. This experience was a great factor in arousing the doubt of the value of the present teaching methods of most teachers.)

Future experiments should not be conducted in high schools alone. Teachers in elementary schools, the junior high schools, the vocational schools, the technical schools, the teacher training institutions, the colleges, and the universities, and in adult educational programs should instigate similar studies. Industry likewise has a stake in these studies and could well lend financial support and its educational training facilities for future research.

The problem should be further studied in high school from another angle. For example, do Group Two pupils maintain their superiority in the advanced classes? (The writer offers a subjective observation that they do. The higher and more difficult principles are seemingly easier to teach, and pupils trained in projection planes apparently grasp the new ideas more quickly and easily. Not only in this aspect do the planes of projection seem to be better, but pupils taught as Group One, after having been taught the plane theory, were amazed at their lack of insight into mechanical drawing and often asked, "Why weren't we taught this method before?") The superiority of Group Two may vanish after a time as pupils advance in the mechanical drawing classes. Perhaps this superiority increases in a cumulative fashion.

It is hoped that other mechanical drawing teachers will experiment in this fertile field in order to give validity or to determine more clearly the weaknesses and results of this study. The writer stands ready to co-operate in future research.

VITA

VITA

Arthur Wendell Allison was born in Danville, Illinois, September 30, 1920, of Scotch-Irish descent, the youngest of four children. After graduating from Alvin Community High School, Alvin, Illinois, in June 1938, he entered the University of Illinois, where he received a Bachelor of Arts degree in February, 1943, with a major in sociology and a minor in psychology and economics. He continued in residence at the University of Illinois for two more years, during which time he pursued work in engineering. During the same period and in intervals until June, 1947, he took additional courses in mathematics and education. He has begun work on a program which he hopes will ultimately lead to a Bachelor of Science degree in Elementary Education.

In 1947, he accepted a position as teacher of mechanical drawing in the Richmond, Virginia, Public Schools, where he is still employed. He started work on his Master of Science degree in Education at the University of Richmond in 1948. Requirements for this degree are to be completed in August 1952. He plans to pursue graduate studies leading to a Doctor of Education degree at the University of Virginia.

He was married to Edith Frances Lynch, of Richmond, Virginia, June 11, 1949. They have no children.

He belongs to the Benevolent and Protective Order of the Elks and the University of Illinois Alumni Association. He holds memberships in the following professional organizations: National Education Association, the Virginia Education Association, the Richmond Teachers Association, American Vocational Association, the Virginia Vocational Association, and the Richmond Astronomical Society. The Baptist Church is his religious preference.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

Church, A. E., Descriptive Geometry. New York: American Book Company, 1902.

Edwards, Alan A., Experimental Design in Psychological Research. New York: Rinehart and Company, 1950. 420 pp.

French, Thomas E., Engineering Drawing. New York: McGraw-Hill Book Company, Inc., 1941. 622 pp.

French, Thomas E. and Carl L. Svenson, Mechanical Drawing. New York: McGraw-Hill Book Company, Inc., 1948. 437 pp.

Gavett, G. Irving, A First Course in Statistical Method. New York: McGraw-Hill Book Company, Inc., 1925. 358 pp.

Giesecke, F. E., Alva Mitchell and Henry Cecil Spencer, Technical Drawing. New York: The Macmillan Company, 1940. 676 pp.

Hoelscher, Randolph Philip, The Teaching of Mechanical Drawing. New York: John Wiley & Sons, Inc., 1929. 229 pp.

Jordan, Harvey H. and Randolph P. Hoelscher, Engineering Drawing. New York: John Wiley & Sons, Inc., 1935. 528 pp.

Jordan, Harvey H. and Francis Marion Porter, Descriptive Geometry. Boston: Ginn and Company, 1929. 349 pp.

Sorenson, Herbert, Psychology in Education. New York: McGraw-Hill Book Company, Inc., 1948. 535 pp.

Svenson, Carl Lars, Drafting for Engineers. New York: D. Van Nostrand Company, Inc., 1941. 554 pp.

Whitney, Fredrick Lawson, The Elements of Research. New York: Prentice Hall, Inc., 1950. 539 pp.

B. PERIODICAL ARTICLES

Coover, S. L., "Drawing Can Be Made Interesting," School Shop, X:45-46, April, 1951.

Winslow, W. V., "The Projection Box: Its Use in the Schools," Industrial Arts Magazine, 9:35, May, 1920.

C. PUBLICATIONS OF LEARNED ORGANIZATIONS

Morris, Fred C., "Effective Teaching, A Manual for Engineering Instructors" prepared under the sponsorship of Committee on Teaching Manual American Society for Engineering Education. New York: McGraw-Hill Book Company, Inc., 1950. 86 pp.

Studies in Industrial Education, American Vocational Association Bulletin, No. 4, 1949. Washington: American Vocational Association, Inc., 1949. 160 pp.

D. ENCYCLOPEDIA ARTICLES

French, Thomas E., "Engineering Drawing," Encyclopedia Britannica, 1949, VII, 631-37.

"Gaspard Mongee," Encyclopedia Britannica, 1949, XV, 704.

Longley, William Raymond, "Descriptive Geometry," Encyclopedia Britannica, 1949, VII, 254-57.

APPENDIX A

ENTRANCE QUESTIONNAIRE

DATE____________
GRADE & SECTION____________
HOME ROOM TEACHER____________

NAME____________________________________
Last First Middle

ADDRESS____________________________________ PHONE____________

DATE OF BIRTH____________________________________
Month Day Year

PARENT (OR GUARDIAN'S) NAME________________________

PARENT (OR GUARDIAN'S) ADDRESS________________________

PARENT (OR GUARDIAN'S) OCCUPATION (BE SPECIFIC)____________

____

WHY ARE YOU TAKING THIS COURSE? (ENCIRCLE REASON OR REASONS)

1. I have had it before and I like it.
2. I am taking it for credit.
3. I am taking it to find out what it is about.
4. I am taking it for college entrance.
5. I am taking it to prepare for Engineering, Architecture, etc.
6. I am taking it just because I want to.
7. I am taking it upon the advice of others. Parents?________ Counselors?________ Teachers?________ Friends?________ Others? Who?____________
8. I am taking it because there are no other courses which I like better.
9. Are there other reasons? Please list.____________
____

HAVE YOU TAKEN ANY OF THE FOLLOWING COURSES? ENCIRCLE THOSE THAT YOU'VE HAD.

1. General Math.
2. Arithmetic.
3. Algebra.
4. Plane Geometry.
5. Solid Geometry.
6. Physics.
7. General Shop.
8. Woodwork Shop.
9. Other Shop? ____________
____
____
10. Mechanical Drawing.
How many terms?____________
In what school?____________
The teachers name?____________
Did you like it?____________

YOUR SCHEDULE AT THOMAS JEFFERSON HIGH SCHOOL.

PERIODS	First	Second	Third	Fourth	Fifth	Sixth
SUBJECT						
ROOM						
TEACHER						

In order for you and the teacher to become better acquainted, would you list here your hobbies, or things that you like to do. You may form lasting friendships with other pupils who may have the same likes as you. Or you may become interested in the interests of others.

____
____
____
____
____
____

What do you expect to do in this course? Would you list the things that you would like to do so that we as a group can plan what we want to do in this course.

____
____
____
____
____
____

	GRADE_____&_____ Boys and Girls	AGES_____&_____ Boys and Girls
Revised Minnesota Paper Form Board (score_________)	_____percentile	_____percentile

	I. Q.	AGE NORM
Otis Test (Score______)	________	______to______

	UNWEIGHTED SCORE	WEIGHTED SCORE
Final Achievement Test (Devised by writer)		

APPENDIX B

EXPLANATION OF GRADING IN MECHANICAL DRAWING

To the pupil and parents:

The following system of determining grades will be followed in mechanical drawing courses with Mr. Allison. It is thought to be a simple, fair, and just system. Please consider it carefully.

Note: Notice that each item upon which your grades are determined is dependent upon all the following items. If one of the first items is lacking, the end result will be found lacking also.

There are four (4) items upon which you will be graded. These are: attitude, knowledge, quality, and quantity. These are fully explained below.

1. Attitude: This is the attitude of the student in regards to the teacher, to the classmates, and to the subject. A pupil who learns the most must respect those with whom he is associating, and respect the subject. A pupil must have a positive attitude in that he is to be attentive in class, co-operate with the teacher, and other pupils, and "expect" to learn something about mechanical drawing. If a student does not have these qualities, then his achievement in the next item will be limited.

2. Knowledge: If a pupil has a proper and fitting attitude, he can and will learn something. (With an improper or negative attitude, the amount of knowledge will depend upon item 1.) This is evidenced by the understanding of mechanical drawing principles.

3. Quality: If a pupil has the proper attitude, he can therefore learn something. This knowledge can be placed on paper in the form of mechanical drawing problems correctly solved, which is quality.

Quality includes the neatness, the accuracy, the correctness, and the appearance of the drawing in connection with the promptness in solving the problems.

4. Quantity: Psychological tests have proven that quality and quantity are so closely bound together that one follows the other in most cases.

It follows that if a pupil has, or develops, a proper attitude that he can gain knowledge which insures him of quality in his problems whereby the quantity will follow.

(Each term there will be a required number of drawing problems for each student to work.)

The above concept can be represented by the following:

1. A proper attitude leads to knowledge.

2. A proper attitude plus knowledge leads to quality.

3. A proper attitude plus knowledge plus quality leads to quantity.

A defect in one factor, thereby, limits the success of the subsequent factors.

Would you, as parents, sign below and return this to school. Your remarks concerning the grading of mechanical drawing as hereby represented will be greatly appreciated. You may use the back of the sheet for comments and suggestions which may improve the present grading system.

______________________________Parent

APPENDIX C

MECHANICAL DRAWING ASSIGNMENTS

TEXT: "MECHANICAL DRAWING", by French and Svenson, 4th Edition.

LAYOUT: Layout of sheet to be as shown in Fig. 336, p. 170, except that title panels and their lettering are to be revised as instructed by teacher.

GROUP I: USE OF INSTRUMENTS: Study Chap. II, IX and Art. 223, p. 169:

Sheet No.	Name of Drawing	Scale	Problem No. in Text	Figure No. in Text	Page No. in Text
1	Gage or Templet	F. S. F. S.	2 1	349 343	173 172
2	Tile Pattern or Stencil	F. S. F. S.	4 3	358 350	174 174
3	Brace or Shim	F. S. F. S.	6 5	363 359	177 176
4	Shearing Blank	3" = 1'-0"	8	365	178
5	Cushioning Base	3" = 1'-0"	10	373	180

GROUP II: GEOMETRICAL CONSTRUCTIONS: Study Chap. XIV and Art. 226, p. 181:

Sheet No.	Name of Drawing	Scale	Problem No. in Text	Figure No. in Text	Page No. in Text
6	Geometrical Constructions	F. S.	11, 13, 15, 17		182
7	Geometrical Constructions	F. S.	20, 23, 24, 25		182
8	Geometrical Constructions	F. S.	26, 28, 32, 41	 383	182 183

GROUP III: LETTERING: Study Chap. III and Art. 227, p. 184:

Sheet No.	Name of Drawing	Scale	Problem No. in Text	Figure No. in Text	Page No. in Text
9	Lettering Practice	F. S.	42, 43, 44, 45	384	184
10	Title Strip Lettering	F. S.	See sample sheet on bulletin board		17
1-10	Upon completion of sheet 10, prepare a lettering guide strip as instructed by teacher and letter title strips of sheets 1-10, inclusive.				

GROUP IV: SHAPE DESCRIPTION: Study Chap. IV, V, VIII, IX and Art. 228, p. 188:

Sheet No.	Name of Drawing	Scale	Problem No. in Text	Figure No. in Text	Page No. in Text
11	Shape Description Blocks	F. S. F. S.	59, 60, 61, 62	389	188
12	Adjusting Blocks	F. S.	63, 64, 65, 66	391	188
13	Slide Blocks	F. S.	67, 68, 69, 70	392	188
14	Adjusting Blocks	F. S.	75, 76, 77, 78	394	188
	or Support Blocks	F. S.	71, 72, 73, 74	393	183
15	Angle Blocks	F. S.	79, 80, 81, 82	395	188
	or Angle Blocks	F. S.	83, 84, 85, 86	396	188
16	Links	F. S.	87, 88, 89, 90	397	188
17	Holders	F. S.	91, 92, 93, 94	398	188
18	Shape Description Blocks	None	96 Choose any 4	400	194

APPENDIX D

FINAL ACHIEVEMENT TEST

DIRECTIONS AND INSTRUCTIONS

NAME ____
last, first middle

GRADE ____________ SECTION ______________

On this page, and the following pages, are some problems of Mechanical Drawing very similar to those that you have been working throughout this semester. These problems are a follow-up of the tests given to you at the beginning of the term. The results of this test will not lower your final grade in this course. But a good showing will be refected in your final grade. Moreover, a good showing on this test may well determine your knowledge of Mechanical Drawing principles.

You will be given ample time to solve some problems, but it is doubtful that anyone can finish all questions. Work quickly but do not hurry. Try to be accruate. Work quietly and do not disturb others. You are expected to do your best. Do not spend too much time on any one problem, if you cannot readily solve it, go on to the next problem.

All problems will be done freehand - that is without the use of "T" squares, triangles, scale, etc.. The solutions are to be sketched and completed using only your pencil. Do not guess. If you cannot determine the answer, go on to the next problem. REMEMBER, NO ONE IS EXPECTED TO FINISH ALL OF THE PROBLEMS.

The following questions are divided into five groups - one group only on a page. You are to continue working on each page until you are told to turn to the next page. DO NOT TURN ANY PAGE UNTIL YOU ARE TOLD TO DO SO.

Are there any questions?

Score:

Group 1 ____________

Group 2 ____________

Group 3 ____________

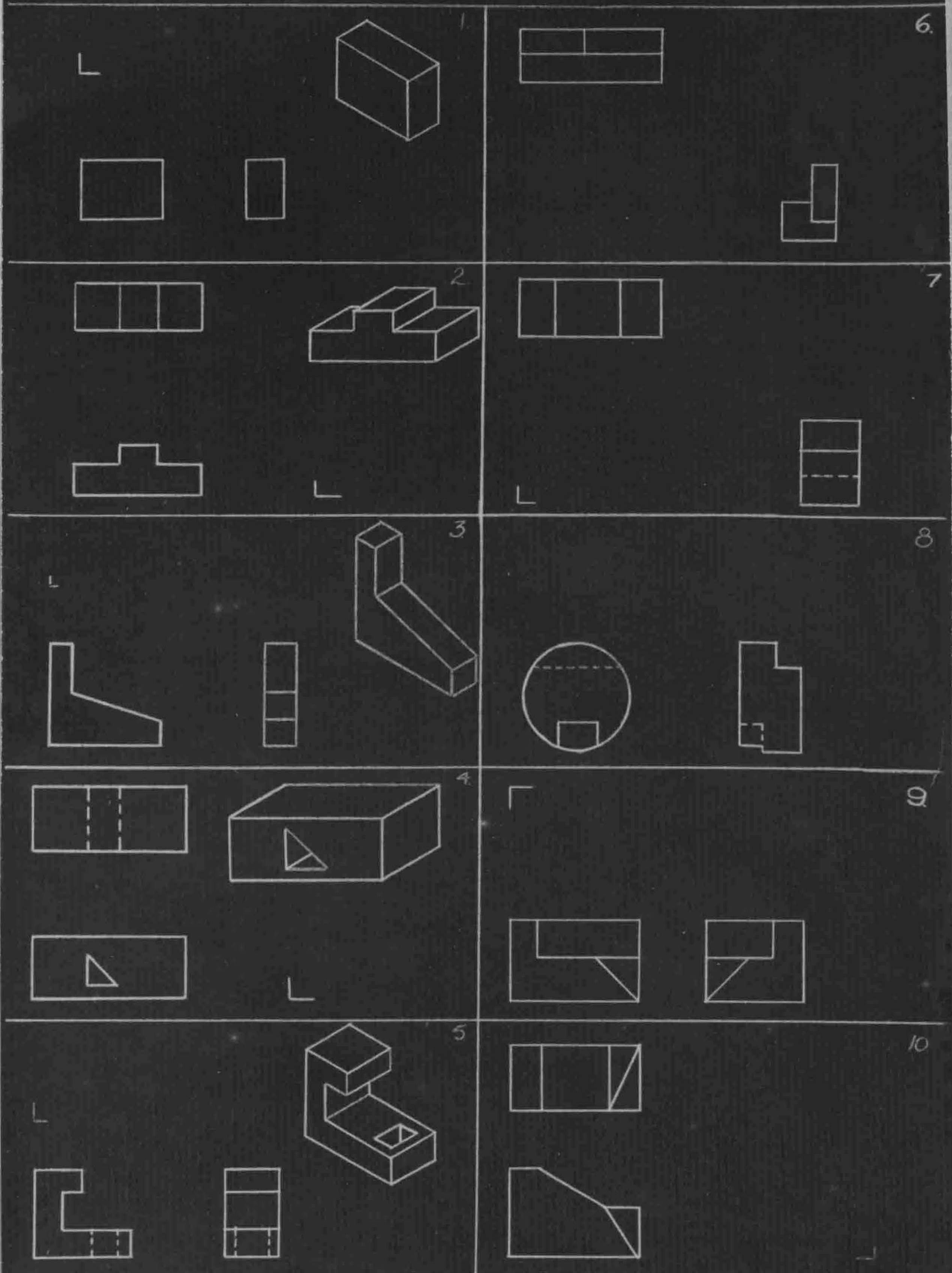
Group 4 ____________

Group 5 ____________

Total ____________

DIVISION ONE

The purpose of this test is to complete the missing view of the object. Two correct views are given. The correct view is to be sketched in its proper position. There are ten problems. Be sure that your sketches are __accurately__ and __correctly__ drawn in the spaces provided.

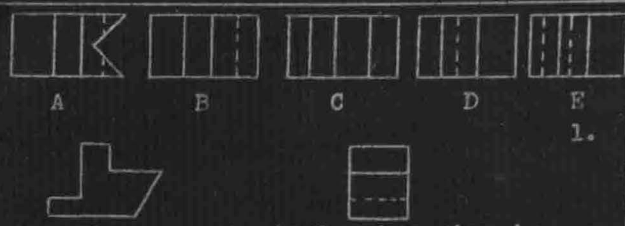


__STOP__. __DO NOT TURN PAGE UNTIL TOLD TO DO SO__. If you have finished, recheck your answers until time is called.

SCORE: ______

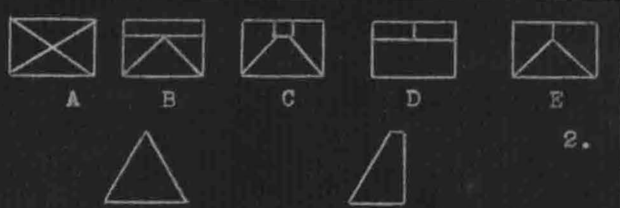
In the following problems are several possibilites of the correct choice for the missing view. You are to choose the letter representing the correct answer and place it in the incomplete sentence. There are ten problems. There is only one answer for each problem.

1.



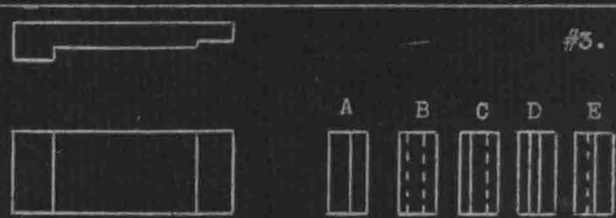
The correct missing top view is ____.

2.



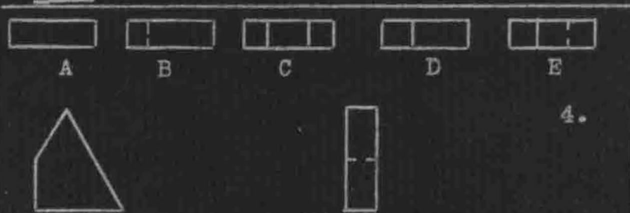
____ is the correct top view.

#3.



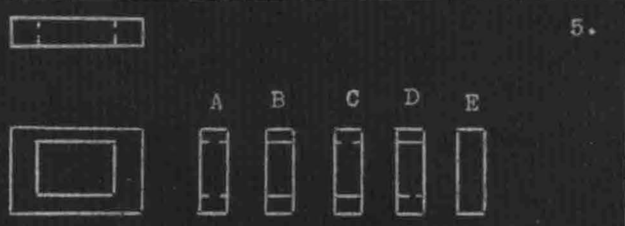
____ is the correct side view.

4.



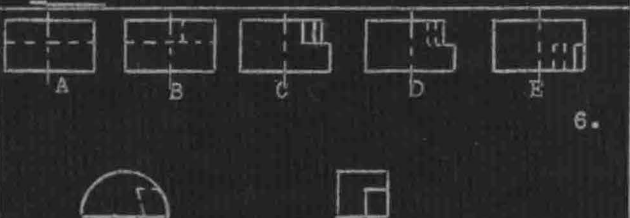
____ IS THE CORRECT TOP VIEW.

5.



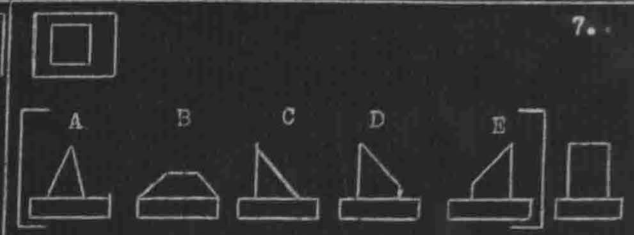
____ is the correct side view.

6.



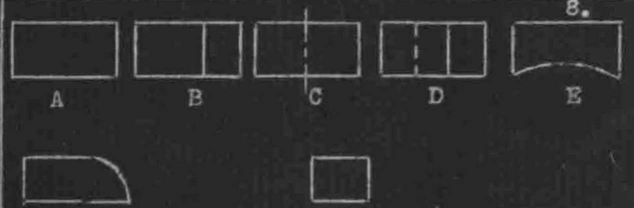
____ is the correct top view.

7.



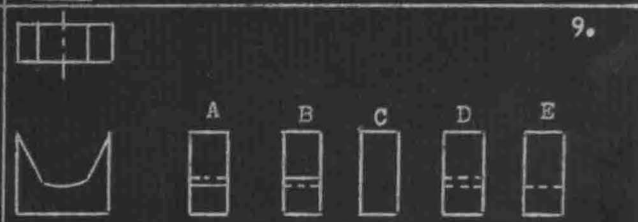
The correct missing front view is ____.

8.



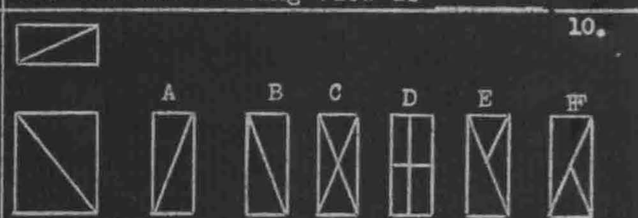
____ is the correct view.

9.



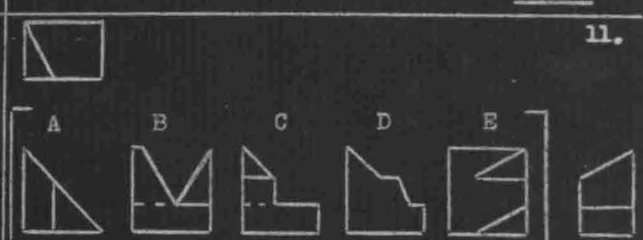
The correct missing view is ____

10.



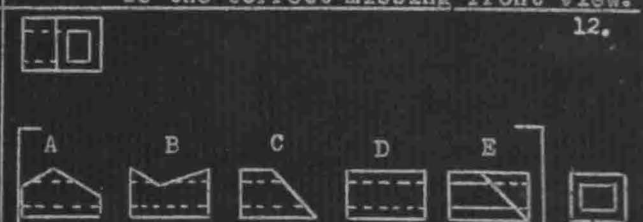
The correct missing side view is ____

11.



is the correct missing front view.

12.



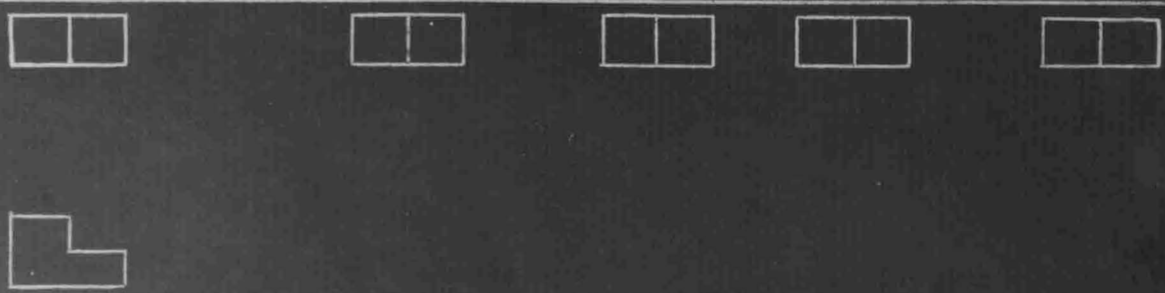
____ is the correct ____ view.

STOP. DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO. If you have finished you may re-check your solutions until time is called.

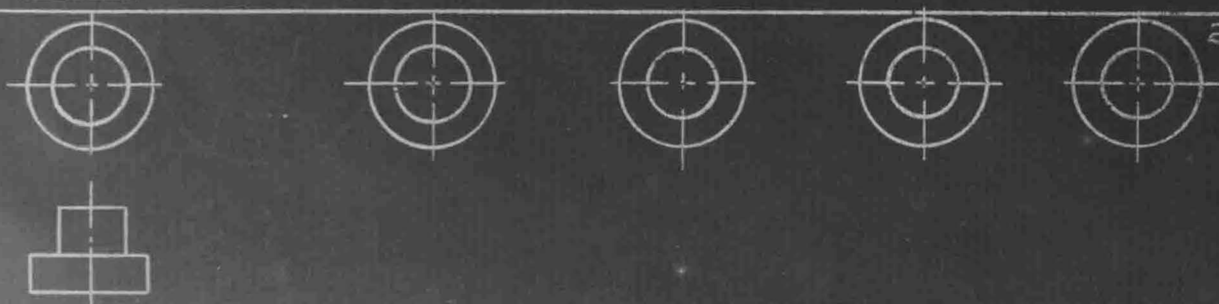
SCORE: ____

In the following spaces are the top views of some simple objects. You are to draw the front views of other objects that will give the same top view as the example. No 2 objects are to be alike. How many objects can you get? Sketch in as many views as you can even if the proper space is not provided. Do not waste time on any one. Go right on to the next problem.

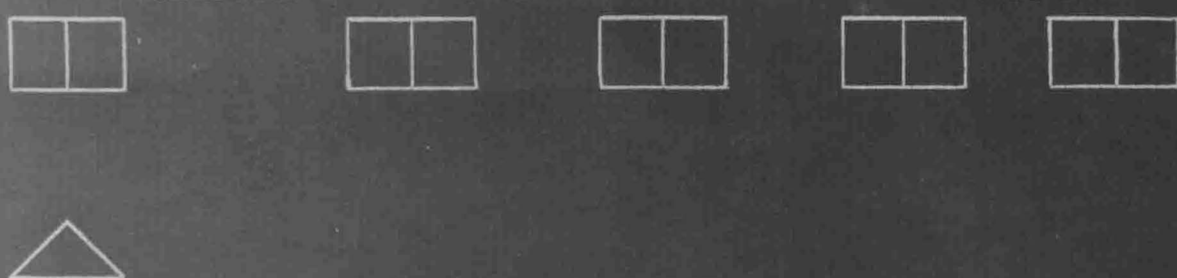
1



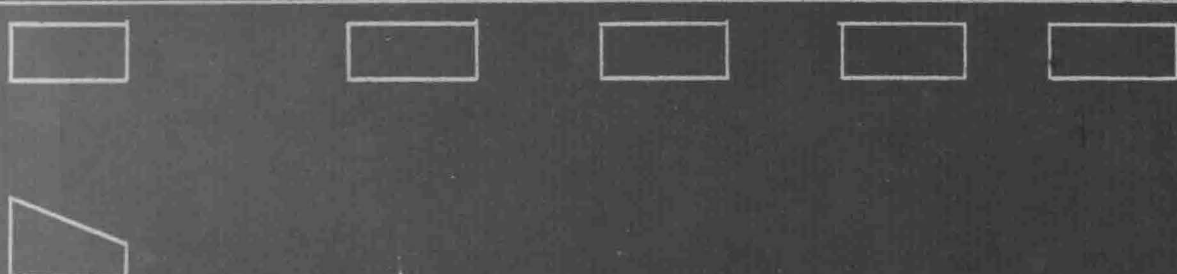
2.



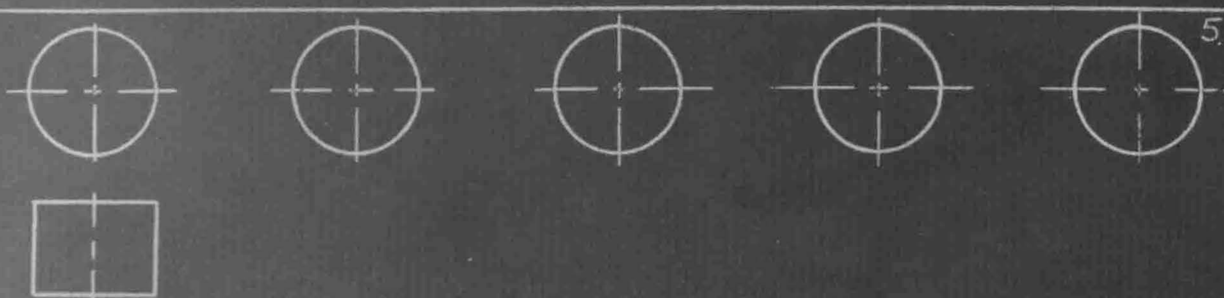
3.



4.



5.

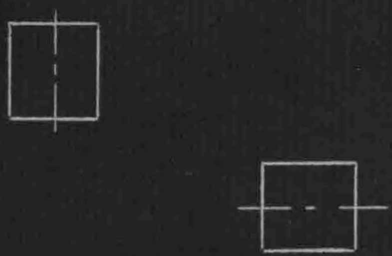


STOP. DO NOT TURN PAGE UNTIL TOLD TO DO SO. Keep at the solutions until time is called.

SCORE:______

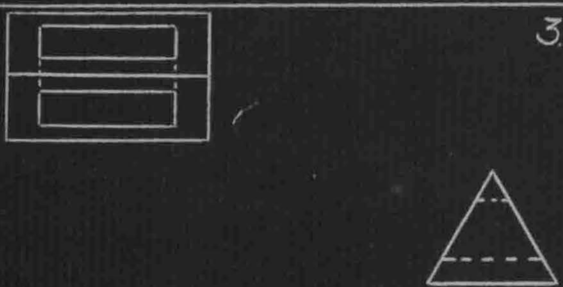
Supply the missing views. Notice that there are no cues or clues to help or aid you in the solutions. You must clearly read the two given views and understand them without doubt before the correct answer is possible. Do not guess. Do not work on any one problem too long. Go on to the next problem. Some are easy; some are hard. You are not expected to answer all of them. Keep busy and do your best. You will be permitted twenty minutes.

1.

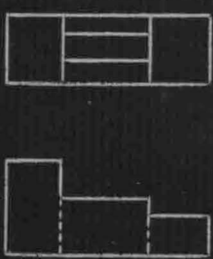


2.

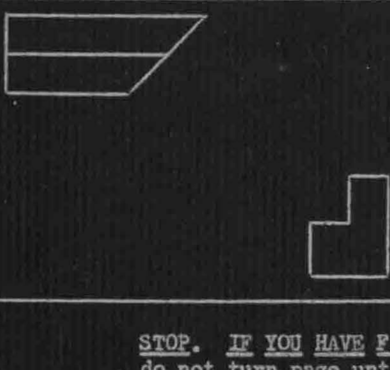
3.



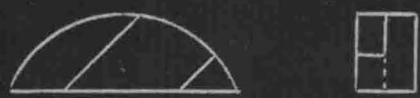
4.



5



6.



7.

8.

9.

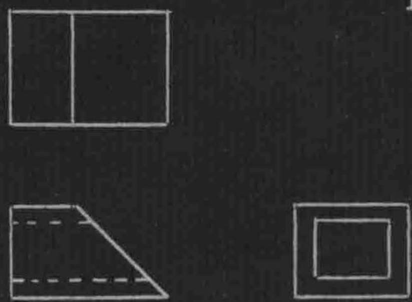
10.

STOP. IF YOU HAVE FINISHED, KEEP WORKING ON PROBLEMS UNTIL TIME IS CALLED. do not turn page until time is called, and you are told to turn to the next page.

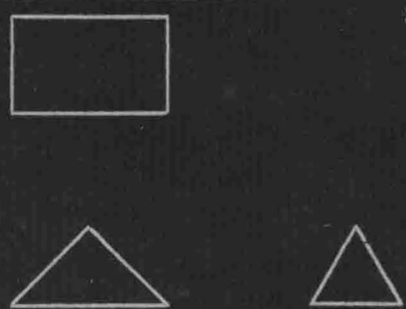
SCORE:______

This a completion serães of problems. One, or more lines have been intentionally omitted in one, two, or three views. You are to carefully study the incomplete, or inaccurate views, and to supply the missing lines with your sketching pencil to make the drawing correct <u>in all views</u>.

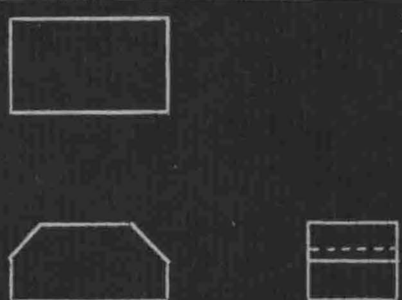
1.



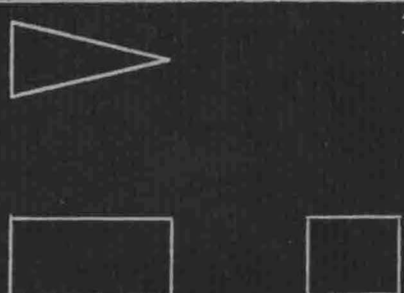
2.



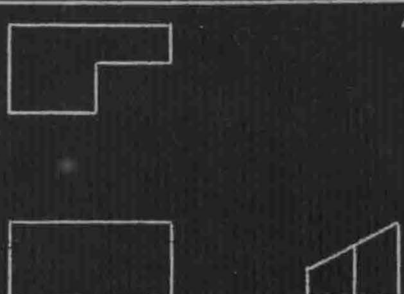
3.



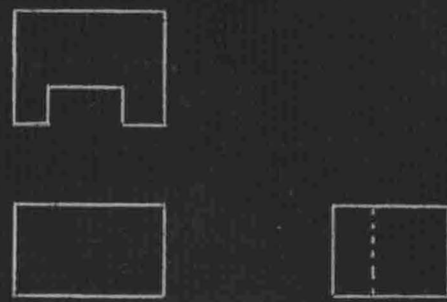
3.



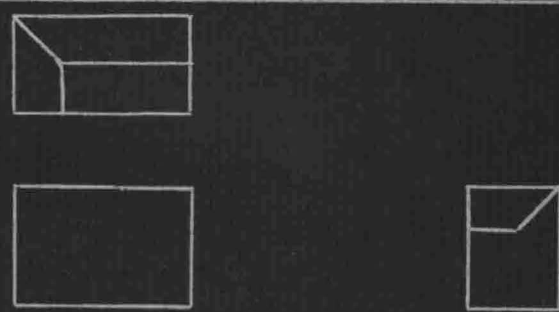
4.



5.

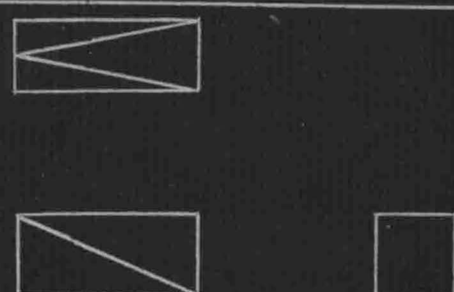


6.

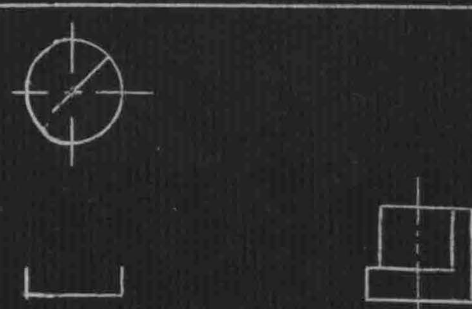


7.

8.



10.



SCORE:_____

SUMMARY SHEET FOR VALUES OF TEST PROBLEMS

Values For Group One

Problem # 1 -	1 point
Problem # 2 -	2 points
Problem # 3 -	2 points
Problem # 4 -	3 points
Problem # 5 -	4 points
Problem # 6 -	7 points
Problem # 7 -	6 points
Problem # 8 -	10 points
Problem # 9 -	10 points
Problem # 10 -	10 points

Values For Group Two

Problem # 1 -	3 points
Problem # 2 -	5 points
Problem # 3 -	2 points
Problem # 4 -	2 points
Problem # 5 -	1 point
Problem # 6 -	6 points
Problem # 7 -	5 points
Problem # 8 -	1 point
Problem # 9 -	3 points
Problem # 10 -	5 points
Problem # 11 -	10 points
Problem # 12 -	7 points

Values For Group Three

As the problems of group three were simple in nature, a value of only two points per solution was assigned to each problem tendered by the student. Many solutions could be offered for any of the five problems listed in this division.

Values For Group Four

Problem #	1 -	2 points
Problem #	2 -	5 points
Problem #	3 -	3 points
Problem #	4 -	4 points
Problem #	5 -	7 points
Problem #	6 -	9 points
Problem #	7 -	8 points
Problem #	8 -	8 points
Problem #	9 -	10 points
Problem #	10 -	10 points

Values For Group Five

Problem #	1 -	3 points
Problem #	2 -	4 points
Problem #	3 -	2 points
Problem #	4 -	2 points
Problem #	5 -	4 points
Problem #	6 -	3 points
Problem #	7 -	7 points
Problem #	8 -	10 points
Problem #	9 -	10 points
Problem #	10 -	10 points