THE DESIGN, CONSTRUCTION, AND USE OF A TRI-COLOR PROJECTION BOX TO BE USED IN THE INSTRUCTION OF ORTHOGRAPHIC PROJECTION

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THE DESIGN, CONSTRUCTION, AND USE OF A TRI-COLOR PROJECTION BOX TO BE USED IN THE INSTRUCTION OF ORTHOGRAPHIC PROJECTION

THESIS

Presented to the Graduate Council of the North Texas State University in Partial Fulfillment of the Requirements

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By

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CHAPTER I

INTRODUCTION

Drafting is called the language of industry, but to many beginning drafting students it is a very abstract and unfamiliar language. Most students in beginning drafting have not had any previous opportunity to have successful experiences in understanding the terminology of industry. This lack of knowledge of industrial phraseology could explain much of the difficulty that teachers in beginning drafting encounter with image representation, transposition of ideas from the abstract to the concrete, and the understanding of two-dimensional surfaces both in textbooks and on drawing paper.

Orthographic drawing is the one most important component of industrial arts and industry.\(^1\) Without a firmly established foundation in orthographic drawing students cannot become proficient in other areas of industrial arts and will have a tremendous limitation placed on future success in other areas of drafting. Orthographic drawing could be called the father

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of drafting, for almost all drafting is derived from orthographic projection. If this is true, then orthographic drawing is the fundamental foundation for drafting and drafting applications. The success attained by students in drafting classes may be dependent upon their understanding of the fundamentals of orthographic projection.

Orthographic drawing is probably the most difficult part of beginning drafting. This will hold true for both the student and the teacher because the teacher has the task of helping the student transpose abstract thoughts into concrete visualizations. It is for the educators to bring about new teaching innovations to help students. Drafting gives an overview of the language of industry to each student in the beginning drafting class. Therefore, conveying ideas becomes an all important process for the draftsman. The draftsman with a thorough orthographic background can transfer ideas and thoughts into working drawings that can easily be understood.

Statement of the Problem

The problem was to study the effectiveness of a tri-color projection box for teaching orthographic projection. More specifically the problem attempted to answer the following questions:
1. Will the tri-color projection box be effective in teaching visualization and image representation?
2. Is the tri-color projection box effective in aiding student retention?
3. Is there any difference in the mean gain of the experimental groups over the control groups?

Purpose of the Study

The purposes of the study were as follows: first, to study the literature in the field of teaching drafting with special reference to the use of instructional aids in presenting orthographic projection concerning the use of a projection box; second, to ascertain the value of the use of a tri-color projection box in teaching orthographic projection to an experimental group of students at the R. L. Turner High School, Carrollton, Texas; and third, to determine if an analysis of these data indicates a justification for the use of this type of an instructional aid in teaching orthographic projection.

Hypotheses

The following hypotheses were tested in order that the effectiveness of the tri-color projection box might be evaluated:
1. The experimental groups will make a greater mean gain on the standardized test given after the orthographic projection unit than will the control groups.
   A. The experimental groups will make a greater mean gain on the two-dimensional spatial relation test than will the control groups.
   B. The experimental groups will make a greater mean gain on the three-dimensional spatial relation test than the control groups.

2. The experimental groups will make greater mean gain on the standardized test given at the end of the first semester of instruction than will the control groups.

Need for the Study

Drafting teachers everywhere need, at various times, visual aids to help in the presentation of subject matter to their students. Teaching aids may be used to simplify instruction and to help the students better understand the subject matter being presented. Because orthographic drawing is the backbone of drawing, any method which can foster a better understanding of the principles of orthographic drawing should be studied. A stronger orthographic drawing unit of instruction should produce stronger drafting classes.
Most of the students in a beginning drafting class will come into contact with engineering drawing for the first time. Therefore, it is the responsibility of the educators to create better and more effective teaching methods to meet the needs of the students.

Since orthographic drawing is the most difficult part of drawing for most beginning students to understand, the instructor may need different instructional aids to help him gain the student's understanding of the problem. Because of this difficulty in understanding the drafting language, the instructor needs those aids which help the students in the transfer of knowledge. "The instructor's problem, then, is to provide a basic understanding of this foreign language."²

Many aids may provide some understanding for the student, but there may be two or three which would provide a more complete and basic understanding of drafting. Textbook, chalk board, lecture, demonstration, films, overhead projector, and models were used to convey the information on orthographic projection to the students in the control group; the experimental group used the same materials, supplemented by the tri-color projection box, to explain orthographic projection

principles and how these principles related to the student's drawings.

If the hypotheses are sustained then this study is significant in that it will give the instructor a better way of presenting abstract material in orthographic drawing and the directions for the construction and the uses of the tri-color projection box.

Definition of Terms

1. **Tri-color projection box.**—A projection box that has three colors representing the three principal planes. Blue represents the profile plane, yellow the frontal plane, and green the horizontal plane. The projection box is used to demonstrate the three principal planes and their relationship to their counterparts on drawing paper and orthographic principles with the different planes. Applications for representation of points, lines, and oblique planes may also be accomplished.

2. **Control group.**—Group in which a method of teaching orthographic projection using textbooks, chalk board, lectures, demonstrations, films, overhead projector, and models are employed by the instructor.
3. **Experimental group.**—Group in which the method of teaching orthographic projection using the same methods as in the control group with the addition of the tri-color projection box are employed by the instructor.

4. **Visualization.**—The ability to form a mental picture; perception of any object which can be drawn or sketched on paper.

5. **Achievement.**—The degree to which each student has developed his ability of visualization with respect to orthographic drawing principles and practices.

6. **Orthographic projection.**—The type of drawing in which the observer "moves straight back from the picture plane until he is an infinite distance from it; the projection lines from the eye to the object then become parallel to each other and perpendicular to the picture plane. The resulting projection will be the same shape and size as the front surface of the object."[^3]

7. **Retention.**—The faculty of continuing possession of past impressions or ideas from previously learned tasks.

8. Matched groups.—Groups that are alike within some measure; equal groups are not necessarily of the same size.

9. Unit test.—A standardized test; The Multiple Aptitude Test, 1959 Edition, Factor IV, Spatial Visualization.¹

Limitations of the Study

This study was limited to 104 male students at R. L. Turner High School, Carrollton, Texas. The students were enrolled in four classes of beginning engineering drawing; each class met for a fifty-five minute period Monday through Friday. The distribution of freshmen, sophomores, juniors, and seniors and the total number of students in each group is shown in Table I.

TABLE I

CLASSIFICATION AND TOTAL OF STUDENTS

<table>
<thead>
<tr>
<th>Group</th>
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<tr>
<td>Experimental II</td>
<td>9</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>23</td>
</tr>
<tr>
<td>Control I</td>
<td>8</td>
<td>14</td>
<td>4</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Control II</td>
<td>7</td>
<td>12</td>
<td>7</td>
<td>4</td>
<td>30</td>
</tr>
</tbody>
</table>

Related Studies

Everett Glazener in his research to determine the value of selected visual aids found that distinctive colors on different views of both two-dimensional and three-dimensional drawing aids were of value for clearly presenting information to the students in the classes. Data were collected from fourteen classes in mechanical drawing; these classes consisted of 217 boys enrolled in four junior high schools. Students had not received any previous instruction in mechanical drawing.

The primary purpose of this study was to determine the relative effectiveness of scale models and pictorial drawings to help beginning mechanical drawing students to learn the principles of orthographic projection. An experiment was conducted in which discriminations involving orthographic projection were solved by subjects under three experimental treatments in learning task followed by a transfer task which was the same for all students.

Students in the model group were shown full size models as drawing aids; isometric drawings were shown with problems

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to students in the pictorial group as their visual aid. The third group used no visual aids to help solve drawing problems. Both the model and the pictorial groups solved problems in the task with fewer responses than the other group. It was concluded that pictorial drawings were more effective than scale models or no aids in helping the beginning student to learn some principles of orthographic projection.

In the research study of Shaw the aims were to develop a means whereby the student would be aided in studying many of the basic principles in several difficult areas of orthographic projection drawing. This study was carried out by contacting teachers and from past research to determine an effective and reasonable aid to help students visualize the principles of orthographic projection. As a result of the study a universal projection drawing device was developed to illustrate the planes of projection.

McSpadden studied the effectiveness of two different methods of teaching mechanical drawing. The students were


divided into two groups; one group was the block group and the other was the problem book group. There was no great difference between the two methods of teaching mechanical drawing, but there was a significant difference between the visualization level achieved by the two groups. The group using blocks achieved more visualization than the problem book group.

Bjorkquist in his study on transfer from scaled models to learning orthographic projection demonstrated the effectiveness of scale models in helping beginning drawing students to learn general drafting principles. It was also determined that the experimental group required fewer responses to learn the assignments.

Donovan Mitchell, using a partially wood and partially transparent projection box for descriptive geometry, found that the experimental group scored higher on the achievement tests than did the control group. Mitchell also found that shorter lecture sessions were required to present space.

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relation problems with the use of a transparent projection box. The projection box was used to set up problems and assist in solving those problems.

Frank Sullivan\textsuperscript{10} conducted a study to determine the effectiveness of two methods of teaching orthographic projection. One method was termed traditional, utilizing instruction in multi-view orthographic projection, and the other method was termed the correlation of isometric drawings and both two and three multi-view projections. Instruction was the same in both groups. The results of the study indicated a statistically significant difference between the control group and the experimental group in understanding the principles of orthographic projection.

Methods of Procedure

This experiment was conducted with ninth through twelfth grade beginning drafting students at R. L. Turner High School, Carrollton, Texas. Each level of student classification was represented in each of the four groups. The experiment with the tri-color projection box was conducted only during the orthographic projection unit of instruction. The projection

box was used only in the experimental group; both groups were taught by regular instructional methods previously mentioned.

At the beginning of the year a standardized test, the Multiple Aptitude Test, was given before any instruction began. At the end of the orthographic projection drawing unit a post-test was given. During the last week of the semester the standardized test was given again as a re-test to determine retention.

All four groups covered identical material in the same sequence with the same assignments. In the control groups lesson plans covering abstract parts of orthographic projection were used, while the projection box was used in the experimental groups for the same purpose.

The Multiple Aptitude Test

The Multiple Aptitude Test is divided into nine different parts; the battery of tests will yield data from nine areas as covered by the test. In this study only Parts Eight and Nine were used.

Test Eight, Spatial Relations—Two Dimensions, consists of a row of five figures; the example figure is given on the right with four groups of parts on the left. The student chooses the group of parts that, when fitted together, will yield the example figure. Test Nine, Spatial Relations—Three
Dimensions, is the same as Test Eight except that the figures are three dimensional rather than two dimensional. There was a time limit placed on each part of the test; for Test Eight the time limit was eight minutes and for Test Nine the time limit was twelve minutes.

Treatment of Data

Data used in making comparisons between the two methods of teaching orthographic projection were obtained from the Multiple Aptitude Test which was administered to each student in the study. By determining the mean score of each group, by determining the standard deviation and setting up letter grades to compare the two groups, and by using tables in the instructional manual of the Multiple Aptitude Test to determine percentile rank on the pre-test three comparisons were made of the control and experimental groups.

Mean scores for each group were computed by standard statistical means to determine if there was any difference between the mean scores of the groups. Calculations of the mean scores, using data collected from the raw scores made on the Multiple Aptitude Test, were grouped into a frequency distribution. The mean was then calculated by using the following assumed mean formula:  

\[ \text{Mean} = \frac{\sum \text{scores}}{n} \]

\[ M = AM + \left( \frac{\sum fX}{N} \right)i \]

\[ \text{M = MEAN} \]

\[ \text{AM = ASSUMED MEAN} \]

\[ N = \text{NUMBER OF SCORES} \]

\[ i = \text{INTERVAL} \]

\[ \sum = \text{MEANS "SUMMATION OF"} \]

\[ f = \text{THE FREQUENCY WITH WHICH SCORES OCCURED WITHIN AN INTERVAL} \]

\[ X = \text{A RAW SCORE} \]

In order to set up the normal probability curve and to compare the two methods of teaching orthographic projection in another way, calculation of the standard deviation was made using the following formula: \(^{12}\)

\[ SD = i \sqrt{\frac{\sum fX'^2}{N} - C^2} \]

\[ \text{SD = STANDARD DEVIATION} \]

\(^{12}\text{Ibid., p. 53.}\)
\[ i = \text{INTERVAL} \]
\[ \Sigma = \text{MEANS}''\text{SUMMATION}'' \text{OF} \]
\[ N = \text{NUMBER OF SCORES} \]
\[ fX = \text{THE FREQUENCY WITH WHICH SCORES OCCURRED WITHIN AN INTERVAL SQUARED} \]
\[ C^2 = \left( \frac{\Sigma fX}{N} \right) \]

After finding the standard deviation and the normal probability curve, a comparison between the experimental and control groups can be made as to the letter grades, such as A, B, C, D, and F.

The third comparison between the scores of the two groups was based on percentile rank. This comparison was made to determine if the groups were low, average, or high according to national norms. In the instruction manual for the Multiple Aptitude Test tables indicate the percentile rank for the corresponding raw scores according to grade level. The percentile may be described as a point on a one hundred point scale which gives the percentage of students falling below that particular percentile.
CHAPTER II

DESIGN AND CONSTRUCTION OF A TRI-COLOR PROJECTION BOX

One of the first problems was the design of a projection box that would provide as much clarity as possible for beginning drafting students. In surveying the literature on drafting, particularly orthographic projection, most of the visual aids left much to the imagination of the student and gave very little concrete evidence. Many of the aids discovered through research left many questions unanswered. Feeling that a projection box could provide substance to other aids and provide the beginning drafting student with a more concrete foundation in orthographic projection, it was found, in surveying aids for orthographic projection, that there were several aids specifically designed for teaching orthographic projection.

Many aids dealt with solid objects which had the surfaces painted; one visual aid had painted cardboard which could be removed from each surface of a three dimensional block.¹

¹Val F. Creary, "Orthographic Projection Teaching Aid," Industrial Arts and Vocational Education, LV (September, 1966), 52.
In the representation of different planes and corresponding views, each of the surfaces was painted a different color. Studies valued the use of objects in the teaching of orthographic projection; in these studies both colored and uncolored objects were used. Taking various studies and articles into consideration and incorporating various ideas, the tri-color projection box was originated.

To utilize color for the planes of the projection box required the use of Plexiglas. The use of colored Plexiglas required some investigation into what colors were the most desirable. It was decided that light yellow, light blue, and light green allowed an object to be seen more clearly than any other of the available colors, although any other three colors with equal transparency could have been used. The back plane was made of clear Plexiglas to allow more light on the object in the projection box. The object inside the box appears to have colored surfaces because of the vari-colored planes.

Some Initial Considerations

One of the most important considerations in the design of the projection box was that of size. Remembering that the box should be large enough to be seen clearly in the rear of a normal size classroom, yet small enough to be
portable, through experimentation in the classroom the dis-
tance at which certain objects were visible was decided, and
a twelve inch square projection box was found suitable.

Another consideration was to make the projection box as
transparent as possible. This meant that the entire projec-
tion box, with the exception of the platform and base, would
have to be constructed of a transparent Plexiglas material.
Further research was required on Plexiglas and methods in
its use. If the projection box was to be as transparent as
possible, some type of transparent hinge would have to be
constructed. These hinges would have to support the planes
to which they were attached; the hinges were also constructed
of Plexiglas. Adaptations for teaching drafting units other
than orthographic projection were built into the projection
box.

Construction of the Tri-color
Projection Box

In making a projection box such as the one used in this
study a variety of materials and plans for its construction
was necessary. This chapter gives instructions and detailed
drawings for the construction of the tri-color projection
box used in this study.
Shown in Figure 1 is a pictorial drawing of the completed projection box. This drawing shows only the completed projection box and the exact location of each part may be difficult to determine. To clarify Figure 1, Figure 2 is an exploded pictorial drawing that distinguishes between the parts and indicates the location of each. A drafting teacher may consider changing some dimensions or material due to personal preference. Dimensions should be considered critical because one change would affect all the other parts.

The platform of the projection box, as shown in Figure 3, is made of one and one-quarter inch walnut wood. Several milling operations were necessary to complete the platform on which most of the planes rest. Special attention was given to the routed grooves in the platform because these grooves had to match the width of the planes which fit into them. One hundred and twenty-one holes one inch apart were drilled into the bottom of the platform for the positioning of planes other than the three principal planes making up the outer shell of the projection box. A small wooden rail was placed at the front right end of the platform as a stop for the right profile plane when it is folded out. After all milling operations and a thorough sanding, a suitable stain and lacquer was applied. Under the platform is a base
Fig. 1—Pictorial of tri-color projection box
Fig. 2—Exploded pictorial of tri-color projection box
MATERIAL - WALNUT
FINISH - CLEAR LACQUER

Fig. 3 - Platform of tri-color projection box

- ROUT 1/2" X 1" DEEP
- DRILL 1/4" DIA. 1" ON CTR. III PLACES
- ROUT 3/16" X 1" DEEP
- 3/8" X 1/2" STOP
- 27"
on which the entire projection box rests. Figure 4 shows the base and its dimensions. One factor concerning the base of significance was that of weight distribution. Since the major portion of the weight of the projection box rested on the left end of the platform, the base had to be off centered under the platform to compensate for the weight difference.

Between the base and the platform was placed a lazy susan type bearing plate. The bearing plate, shown in Figure 5, allowed the platform to rotate on a horizontal plane 360 degrees for showing inclined planes and other views. The bearing plate used on the projection box in this study was attached to both the base and the platform to insure stability.

Using Plexiglas for planes, hinges, plane holders, and object holders, required some knowledge of how to work with Plexiglas. Some of the questions that had to be answered before attempting to work with Plexiglas were the following:

1. How to cut Plexiglas?
2. How to finish the edges of Plexiglas?
3. How to bond Plexiglas?
4. How Plexiglas reacts to heat?
5. How to form Plexiglas?
6. How to drill Plexiglas?
NOTE:
PLACEMENT OF 1/2" DIA. HOLES ARE FOR 6" LAZY SUSAN BEARING ONLY

MATERIAL - WALNUT
FINISH - CLEAR LACQUER

Fig. 4 -- Base of tri-color projection box

BASE

DRILL THROUGH 1/2" 4 PLACES
Fig. 5—Lazy susan bearing
Polymethyl methacrylate is the chemical name for Plexiglas, which is an acrylic plastic. Working with acrylic plastics requires a thorough knowledge of what can and cannot be done. Cutting or sawing acrylic plastic may be accomplished with either woodworking or metalworking tools. The protective paper coating on the Plexiglas was not removed until all laying out, cutting, and polishing and sanding of the edges was accomplished.

If we remember that acrylic plastic is thermoplastic, affected by heat, we can be guided in our selection of cutting tools, cutting speeds, etc. When a saw or tool turns fast enough to melt the plastic, the tool will gum up and a poor job will result. This is particularly true with the thicker material. Plastic is a very poor conductor of heat, so heat generated by a cutting tool remains largely at the point of cutting, causing the plastic to soften.

Circular saw blades used in cutting plastics should be hollow ground or the teeth should have a slight set... The saw should be set so that the blade extends through the sheet about one-fourth inch... Since there was some drilling to be done, it was necessary to secure information on how to drill acrylic plastic.

Bits for drilling acrylic plastic should be carefully ground. It is especially important that the cutting edge of the drill be ground off to a "zero" rake angle. In other words, the cutting edge should be perpendicular to the face of the material to be drilled. The drill should preferably have a "slow" spiral, and the flutes should be highly polished, so that the chips will be removed rapidly and efficiently.²

²Dwight Cope, Cope's Plastics Book (Chicago, 1957), p. 34.
³Ibid., p. 38.
It was undesirable to leave raw edges on the planes after they had been sawn to size. These raw rough edges detract greatly from the appearance of the planes of the projection box. There were minor scratches that had to be removed.

Ordinarily, with shallow scratches, or with an edge that has been sawed, milled or scraped, a mild sanding process, followed by buffing and polishing, will restore the beautiful lustre of the original material.

This is done by first "rough" sanding the material. For this operation we use abrasive paper (garnet or aluminum oxide) with a grit rated No. 80-150, if much stock is to be removed, or if the edge or face is quite rough. If hand sanding is to be done, the abrasive paper or cloth should be wrapped around a small block of wood to assure a square edge.

An intermediate grade grit should be used next, with grit-size 180-220. With a power sander this step may often be skipped, and the sanding job finished by using a wet-sanding belt with a grit ranging from 320 to 400.\(^4\)

In completing the process of finishing mars, scratches, and scrapes, after the sanding was completed, it was necessary to polish and buff these areas.

Polishing is usually done in a two stage operation using motor-driven cloth buffing wheels. The experimenter must remember that the heat generated by friction, if the work is held too hard against the revolving buffing wheel, will cause the plastic material to overheat. This will result in "burning" or disfiguring the surface that has been so painstakingly brought to this stage of near perfection.

\(^4\)Ibid., p. 40.
The buffing wheel should be of the stitched-cloth type. It has been found that for ordinary shop use, the best practice is to mount two one-inch stitched muslin wheels together. This gives a large enough surface to be practical and does not require too much power to turn it. This wheel should run at about 2,000 surface-feet-per-minute—that is, a 6-inch wheel should turn about 1,300 revolutions per minute.

A polishing material with a slight abrasive action is first applied to the wheel. This is usually supplied in the form of a stick which is made largely of tallow into which some tripoli has been mixed. Tripoli is a soft, powder-like material of rocky (silica) origin with light abrasive action. Sometimes tripoli is known as powdered rottenstone, diatomite, or kieselguhr.

The final polish, which brings out the optical clarity of the acrylic surface, is done on a second wheel. It is recommended that this second or buffing wheel consist of two conventional one-inch buffing wheels mounted on the shaft together. A buffing wheel consists of stitched layers of cotton flannel, and is softer than a polishing wheel. . . . The piece should be moved rapidly back and forth during the polishing operation, and under no circumstances should the work ever be held still while in contact with the buffing wheel.5

Because acrylic plastic is directly affected by heat, it becomes soft and easily bends into any desired shape.

The best temperature to use will depend on several factors, including the thickness of the material, the method of doing the forming operation, and the shape to which the material is being bent. . . . A piece 0.250 (one-fourth inch) thick heated to 250°F., will still be slightly flexible after three minutes at room temperature.6

5Ibid., pp. 41-42.
6Ibid., p. 43.
Although acrylic plastic is readily suitable for forming, there was one big problem. If acrylic is overheated small bubbles will occur throughout the sheet of plastic. Extreme care was taken to see that a reasonably constant temperature was sustained.

A major step in the construction of the projection box was that of bonding several pieces of plexiglas.

The manufacturers of Plexiglas list six different formulations of cement, suitable for different purposes. There are three principal organic solvents known by their chemical names as "methylene dichloride" (M.D.C.), "ethylene dichloride" (E.D.C.), and "vinyl trichloride" (or more properly 1,1,2-trichlorethane, and sometimes abbreviated V.T.C.).

Hinges on which the planes swing and the jig used to form these hinges are shown in Figure 6. One-quarter inch Plexiglas rods were used for center pins to connect both hinges. To form hinges the hinge material was cut to the correct size and then placed on a metal sheet in a preheated oven at 250 degrees Fahrenheit.

Special care was taken in forming the hinges. Only when the Plexiglas reached the flexible state were the hinges formed on the jig. After the stock had become flexible enough, it was removed from the oven and each piece was rolled around the jig. The hinges were held in place until

\[7\text{Ibid.}, \text{ pp. 46-47.}\]
Fig. 6—Hinge and hinge jig
enough heat had dissipated from the hinge that it held its shape. If a hinge was not well formed, it was replaced in the oven. The hinge returned to its original shape and was then reformed. Ethylene dichloride was used in attaching the hinges to the planes. A reaction between the two pieces of Plexiglas resulted in the formation of a chemical bonding of the two pieces.

The placement of the hinges on the light yellow transparent Plexiglas for the frontal plane is shown in Figure 7, and required careful aligning of the hinges with those on the other planes. The frontal plane was attached to the left profile plane by bonding the edge of the profile plane to the flat three-sixteenth inch edge surface at the end of the frontal plane. After being bonded, both the frontal and left profile planes were placed into the grooves in the platform. In Figure 8 a detailed drawing of the left profile plane, which was bonded to the frontal plane, is shown. The height of the left profile plane and frontal plane were checked to be sure that they were the same.

The horizontal plane, as shown in Figure 9, was made of light green transparent Plexiglas. Placement of the hinges on the horizontal plane was also of great importance because the hinges should not bind and should allow the plane to be
Fig. 7—Frontal plane of tri-color projection box

MATERIAL
LIGHT YELLOW TRANSPARENT PLEXIGLAS

3/16" AREA WHICH GOES INTO ROUT IN PLATFORM

3/4" SURFACE TO WHICH THE LEFT PROFILE PLANE IS TO BE BONDED

AREA OF HINGE PLACEMENT
Fig. 8—Left profile plane of tri-color projection box
Fig. 9—Horizontal plane of tricolor projection box

MATERIAL
LIGHT GREEN TRANSPARENT PLEXIGLAS

AREA OF HINGE PLACEMENT
revolved to a vertical position easily. The right profile plane, made of light blue transparent Plexiglas, is shown in Figure 10. To keep the hinges from binding and to keep the right profile plane from dragging on the platform a careful check of the measurements was required before the bonding.

The back plane, shown in Figure 11, was made of one-half inch Plexiglas; this plane also was designed to serve as the receptor of the one-quarter inch Plexiglas rod that holds various objects displayed in the projection box. A routed groove located in the back of the platform allowed the back plane to be easily withdrawn.

To add to the uses of the projection box and the three principal planes, an interior plane and its holder are shown in Figure 12. By utilizing the holes in the bottom of the platform, the interior plane may be used to demonstrate positioning of the three inclining planes, orthofrontal, orthoprofile, and vertical.

The primary purpose of the tri-color projection box was its use as a teaching aid for orthographic projection to beginning drafting students. The projection box may be used as an aid in teaching other units of drafting and may be used in teaching descriptive geometry.
Fig. 10—Right profile plane of tri-color projection box
Fig. 11—Back plane of tri-color projection box
Fig. 12—Interior plane and plane holders
CHAPTER III

EXPERIMENTAL USE OF THE TRI-COLOR

PROJECTION BOX

The purpose of Chapter III is to show the ways in which the tri-color projection box was used in this study. The purposes of using the projection box as a teaching aid were to clarify visualization and representation and to aid students' retention of principles taught. The study was conducted during the first semester of beginning drafting classes at R. L. Turner High School, Carrollton, Texas. There were four classes involved in the study—two control and two experimental groups. All classes were taught the same material in the same manner. The projection box was the only variable in the experimental groups; it was used to see if the students' understanding of the abstract material of orthographic projection was increased.

Teaching students the theory and principles of orthographic projection is the responsibility of the instructor and applying these theories and principles to the drawing problem is the responsibility of the student. In using the projection box as the variable in the experimental
groups, the instructor, in conjunction with lecture, explained the applications, theory, and principles to the students. In the experimental groups the projection box was used to supplement instruction, to clarify material, to explain abstract principles, and to give the beginning student a more concrete foundation in drafting.

Experimental Use of the Projection Box

In any beginning drafting class the instructor has the problem of communicating orthographic principles and theory to his students. The shape of an object is shown by projection, a process of forming an object or image by the lines of sight; the lines of sight are projected perpendicularly onto a picture plane. Figure 13 shows the theory of projection. A styrofoam object was placed inside the projection box to represent the image being projected to the picture plane.

Shown in Figure 14 are orthographic views of the tri-color projection box and the three principal planes that it represents. Because the projection box is a three dimensional aid, the students can actually see the three dimensional material about which the instructor is lecturing. The frontal plane is represented by the light yellow plane; the horizontal
Projection is a process of causing an image to be formed by rays of sight, a process of forming this image on a picture plane through the lines of sight perpendicular to the picture plane.

Fig. 13—Picture plane with object projected onto it
The three principal planes are represented as yellow for the frontal plane, green for the horizontal plane and blue for the profile plane.
The frontal plane, horizontal plane, and the profile plane, shown in Figure 15, are mutually perpendicular to each other. This principle confuses many beginning drafting students because the drawings to be done in orthographic projection are represented in two dimensions on drawing paper and the planes do not appear to be mutually perpendicular in two dimensions.

Revolving the horizontal and profile planes forward on the projection box to the position of the frontal plane will make it possible to draw objects on what appears to be one plane; this single plane then represents the drawing paper. When the horizontal and profile planes are rotated into the same plane as the frontal plane, a single plane represents all three principal planes. This rotation is shown in Figure 16.

Figure 17 shows the planes and corresponding views. The frontal plane has the front view projected to it; the horizontal plane has the top view projected to it; and the profile plane has the right-side view projected to it. The representation of the views projected to the three principal planes
Fig. 15—The frontal, profile and horizontal planes shown to be mutually perpendicular.
The horizontal and profile planes are rotated into the same plane as the frontal plane. This makes it possible for all three planes to be represented on drawing paper.
The three principal planes of projection: frontal, horizontal, and profile and their corresponding views which are projected onto them.
Each line and surface has a classification. "Any object, depending upon its shape and space position, may or may not have some surface parallel or perpendicular to the planes of projection. Surfaces are classified according to their space relationship with the planes of projection."\(^1\) Classification of surfaces and lines through the use of the projection box as demonstrated in the classroom is shown in Figure 18. The frontal, horizontal, and profile surfaces were shown on the object inside the projection box. The surfaces on the object match those planes parallel to the projection box.

"An edge view of a plane is one for which the direction of sight is parallel to some line of the plane."\(^2\) This rule is shown in Figure 19 with the use of the projection box.

There are three types of lines which may be drawn on the three principal planes. "A horizontal line is a level line. An infinite number of horizontal lines may be drawn in a horizontal plane through any point in the plane."\(^3\) "A frontal line is a line which is perpendicular to the direction of


\(^3\)Ibid., p. 15.
Surfaces parallel to the three principal planes on the object are classified according to their space relation with the plane of projection.
When the direction of sight is parallel to the plane, you see the edge of that plane.

1. Line of sight parallel to the horizontal plane
2. Line of sight parallel to the profile plane
3. Line of sight parallel to the frontal plane
sight for the front view. An infinite number of frontal lines may be drawn in a frontal plane through any point in the plane. "A profile line is a line which is perpendicular to the direction of sight for the side view. An infinite number of profile lines may be drawn in a profile plane through any point in the plane." The preceding rules on lines are shown in Figure 20.

All material objects, either simple or complex, are measurable by three distinct limitations, height, width, and depth. Height, width, or depth may be determined by measuring the distance between two points. Depth is the distance between two points from the front to the rear. Width is the distance between two points from the left to the right. Height is the measurement of the difference in the elevation of two points. Figure 21 shows these measurements as related to the projection box and orthographic drawing.

In Figure 22 is shown the relationship between space dimensions and the plane of projection. View directions are perpendicular to their respective planes of projection. Width is parallel to the frontal and horizontal planes; height is parallel to the frontal and profile planes; and depth is parallel to the profile and horizontal planes.

Frontal, horizontal, and profile lines as they appear on their respective planes. An infinite number of frontal, horizontal, and profile lines may appear on their plane.
Fig. 21--Three Space dimensions

Shown in the above figure are the three space dimensions: height, width, and depth.
and their planes of projection.

Fig. 22—The relationship between space dimensions and their planes of projection.

1. Width is parallel to the frontal and horizontal planes

2. Depth is parallel to the horizontal and profile plane

3. Height is parallel to the frontal and profile planes
Hidden lines are an essential part of describing objects in orthographic drawing. The hidden surface not seen in one view is located by a line if the line of sight is parallel with that hidden surface. Hidden lines and surfaces are shown in Figure 23.

As a teaching aid the projection box is a highly versatile piece of equipment and is not limited to use in orthographic projection instruction. There are many other areas of drafting in which an instructor could use the projection box as an unlimited aid to assist him in helping his students understand the many aspects of drafting, but the instructor should not use the aid to the extent that it becomes a crutch. An aid such as the projection box should be used to help clarify abstract material for drafting students.

Summary

Through Chapter III the experimental uses of the projection box have been illustrated to explain the methods used in the experimental groups. Each pictorial drawing illustrates the techniques used to convey to students difficult material in the more understandable language of a three-dimensional teaching aid. Most of the orthographic projection abstractions, which are the most difficult to almost every student in the beginning drafting class, were shown in this chapter.
Fig. 23—Object with a hidden line

Hidden lines help explain views and complete the subject. By using the projection box one can rotate the object and show where the hidden line is located.
CHAPTER IV

PRESENTATION OF DATA

Data for this study were gathered from raw scores made on the Multiple Aptitude Test, administered to 104 beginning drafting students in four classes at R. L. Turner High School, Carrollton, Texas. Each group of students, two experimental and two control, was given the Multiple Aptitude Test three different times during the first semester. At the beginning of the school year each student involved in this study was given the test before any instruction began. This pre-test was given to establish a point from which each group could be evaluated in terms of its progress in the principles of orthographic projection. A second reason for giving the pre-test was to establish how the students ranked in relation to the national norms on Part Eight and Part Nine of the Multiple Aptitude Test.

As the semester progressed and the unit on orthographic projection was taught in all four classes, the only variable, the projection box, was used in the experimental groups. Immediately following the last lesson and completion of the last drawing plate in the orthographic projection unit a
post-test was given to each student in this study. Data gathered from the post-test were compared with the pre-test to evaluate the effectiveness of the projection box.

A third test was given in the form of a re-test for evaluating loss or gain at the end of the first semester. A comparison of the re-test data with the post-test data was used for evaluating each group's retention of the principles of orthographic projection.

Raw scores alone do not give any information on one group in relation to another. Because each group was accepted without matching or any other grouping process, the gain in mean scores was used for comparison. In Chapter IV, various methods were used to determine the differences between the experimental and control groups.

To determine the national standings of each group a percentile rank was used. The Multiple Aptitude Test has tables in the test manual that give percentile rank for each part of the test. Norms for percentile rank were determined according to the grade level of the student and the raw test scores made by that student. Table II shows the percentile rank made on Part Eight and Part Nine of the pre-test by each student. This comparison was made to determine if the groups were low, average, or above average according to national
### TABLE II

PERCENTILE RANK\(^1\) OF INDIVIDUAL STUDENTS ON THE PRE-TEST

<table>
<thead>
<tr>
<th>Student</th>
<th>Experimental I</th>
<th>Experimental II</th>
<th>Control I</th>
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norms on the **Multiple Aptitude Test**. Each student's percentile rank is representative of points on a one hundred point scale which gives the percentage of students falling below that particular percentile.

Individual percentile rank shown in Table II are too numerous to evaluate by themselves. The percentile ranks, shown in Table III, was determined for each group on Part Eight and Part Nine from the mean scores to determine the relationship of each group to national norms on the pre-test.

### TABLE III

**PERCENTILE RANK**\(^2\) **COMPUTED FROM MEAN SCORES FOR EACH GROUP ON THE PRE-TEST**

<table>
<thead>
<tr>
<th>Group</th>
<th>Part 8</th>
<th>Part 9</th>
<th>Part 8</th>
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The average rank of each group on the pre-test was about average with that of national norms on the **Multiple Aptitude Test**. Each group ranged from slightly below average to slightly above average.

Raw scores made by individual students on the pre-test Part Eight and Part Nine are shown in Table IV. The possible

\(^2\)Ibid.
<table>
<thead>
<tr>
<th>Student</th>
<th>Part 8</th>
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range of scores on Part Eight and Part Nine of the Multiple Aptitude Test is from a negative eight to a positive twenty-five. The raw scores for both parts of the test were computed by subtracting one-third of the wrong answers from the total number of right answers.

Individual scores made by each student as shown in Table IV were arranged in a frequency distribution. By using the assumed mean method, the mean scores were calculated for each part of the pre-test as shown in Table V.

**TABLE V**

**PRE-TEST MEAN SCORES**

<table>
<thead>
<tr>
<th>Group</th>
<th>Part 8</th>
<th>Part 9</th>
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<tbody>
<tr>
<td>Experimental I</td>
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<td>14.17</td>
</tr>
<tr>
<td>Experimental II</td>
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<td>10.72</td>
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<tr>
<td>Control I</td>
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<td>13.60</td>
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<tr>
<td>Control II</td>
<td>15.36</td>
<td>14.70</td>
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</table>

The mean scores shown in Table V are fairly homogeneous. The mean score of Experimental Group II was somewhat lower than the rest of the groups' mean scores. On Part Eight of the pre-test the mean score of Experimental Group II was 2.12 points lower than the mean scores of the other groups.
on the same test. The mean score of Experimental Group II on Part Nine of the pre-test was 2.34 points lower than the mean scores of the other groups on the same test.

The pre-test mean scores shown in Table V indicate that the groups participating in the study were within the average range in percentile rank of national norms. These percentile ranks were shown in Table III. These mean scores, then, would indicate that the groups in this study would be easier to work with than groups higher than average or lower than average.

Mean scores in Table V show in each group lower scores on Part Nine than on Part Eight. This could be attributed to the test, in that Part Eight deals with two dimensional space relations which are easier than that of Part Nine which deals with a more difficult three dimensional space relations. The projection box used in this study dealt more specifically with the three dimensional space relations.

A post-test was given at the end of the orthographic-projection unit for the purpose of evaluating the progress of the four groups in visualization and image representation of orthographic principles. Scores made by individual students on the post-test are shown in Table VI.
<table>
<thead>
<tr>
<th>Student</th>
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<th>Control I</th>
<th>Control II</th>
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</tbody>
</table>
To compare the post-test to the pre-test computation of the mean score for each group was necessary. Mean scores for Part Eight and Part Nine were computed using the assumed mean formula. Mean scores for Part Eight and Part Nine of the post-test are shown in Table VII.

TABLE VII
POST-TEST MEAN SCORES

<table>
<thead>
<tr>
<th>Group</th>
<th>Part 8</th>
<th>Part 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental I</td>
<td>19.25</td>
<td>16.17</td>
</tr>
<tr>
<td>Experimental II</td>
<td>16.34</td>
<td>14.02</td>
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<td>Control I</td>
<td>13.56</td>
<td>13.72</td>
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<tr>
<td>Control II</td>
<td>17.70</td>
<td>15.30</td>
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</tbody>
</table>

Mean scores made on the post-test would seem to indicate that each group in this study made an improvement; the scores seem to indicate that the experimental group had a greater mean gain than the control groups on Part Eight and Part Nine of the Multiple Aptitude Test. Table VIII shows the differences in the mean scores of each group on Part Eight and Part Nine of the pre-test and the post-test.
As shown in Table VIII, both experimental groups made greater gains in mean scores between the pre-test and the post-test than did the control groups. The gains in mean scores on Part Eight of the post-test were: 3.59, 3.60, 1.92 and 2.34; the size of the gain for the experimental groups was larger than the control groups. The gain on Part Nine of the post-test was fairly large; Experimental Group II indicated more improvement than either of the control groups. Experimental Group I also indicated more improvement than either of the control groups, but not as much improvement as Experimental Group II.

A re-test was given at the end of the first semester; eleven weeks had elapsed between the post-test and the re-test. The purpose of the re-test was to check student retention. Raw scores made on the re-test are shown in Table IX.
<table>
<thead>
<tr>
<th>Student</th>
<th>Experimental I</th>
<th>Experimental II</th>
<th>Control I</th>
<th>Control II</th>
<th>Experimental I</th>
<th>Experimental II</th>
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<th>Control II</th>
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</tbody>
</table>
Raw scores from Table IX were placed into a frequency distribution and a mean score for all groups was computed. These mean scores, shown in Table X, were used to evaluate any gain or loss from the time the post-test was administered.

**TABLE X**

**RE-TEST MEAN SCORES**

<table>
<thead>
<tr>
<th>Group</th>
<th>Part 8</th>
<th>Part 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental I</td>
<td>20.00</td>
<td>17.17</td>
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<tr>
<td>Experimental II</td>
<td>17.80</td>
<td>14.76</td>
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<tr>
<td>Control I</td>
<td>13.94</td>
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<tr>
<td>Control II</td>
<td>18.10</td>
<td>14.90</td>
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</table>

To determine if the mean scores on the re-test were better than the post-test, it was necessary to compute the mean of the re-test and then determine the differences between the mean score of the post-test and the mean score of the re-test. The differences in the mean scores of the two tests are shown in Table XI. This table should indicate if there was any gain or loss of orthographic principles from the post-test to the re-test, given at the end of the first semester of beginning drafting to all four groups.
TABLE XI
DIFFERENCE BETWEEN THE MEAN SCORES ON THE POST-TEST AND THE RE-TEST

<table>
<thead>
<tr>
<th>Group</th>
<th>Part 8</th>
<th>Part 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental I</td>
<td>0.75</td>
<td>1.00</td>
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<tr>
<td>Experimental II</td>
<td>0.96</td>
<td>0.74</td>
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<tr>
<td>Control I</td>
<td>0.38</td>
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</tr>
<tr>
<td>Control II</td>
<td>0.40</td>
<td>-0.40</td>
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</tbody>
</table>

On the re-test the mean scores on Part Eight increased only slightly. Each experimental group increased its mean score on Part Nine, but the mean scores of the control groups on Part Nine decreased. On both parts of the test the experimental groups had greater mean gains than did the control groups. The experimental groups' greater gain could be the result of the orthographic projection unit being followed by a related unit, auxiliary views. In the auxiliary views unit, the experimental group could have been making use of the material studied with the aid of the projection box.

Table XII shows the total difference between the pre-test and the re-test for each group. The mean gains for Part Eight and Part Nine are presented to indicate which groups had the greatest overall mean gains. This test was
given at the end of the first semester, eleven weeks after the post-test was administered.

TABLE XII

DIFFERENCE BETWEEN THE MEAN SCORES ON THE PRE-TEST AND THE RE-TEST

<table>
<thead>
<tr>
<th>Group</th>
<th>Part 8</th>
<th>Part 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental I</td>
<td>4.34</td>
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</tr>
<tr>
<td>Experimental II</td>
<td>4.56</td>
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</tr>
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<td>Control I</td>
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</tr>
<tr>
<td>Control II</td>
<td>2.64</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Data presented in Table XII indicate the group that was lowest on both parts of the pre-test was the group that made the greatest mean gain. Both experimental groups made a greater mean gain than the control groups on both Part Eight and Part Nine of the Multiple Aptitude Test. The largest mean gains in the study were made on Part Nine, Three Dimensional Space Relations, which is the most closely related to the abstract material which was presented with the projection box in the experimental group.

Distributions of Experimental Group I

A bi-modal distribution of scores made by Experimental Group I with a mean of 15.66 from the pre-test, Part Eight,
is shown in Figure 24. In this distribution two different portions of the class are shown, one low to the left of the mean and the other high to the right of the mean. On the post-test, Part Eight, there was a slightly skewed negative distribution with a mean of 19.22; this is shown in Figure 25. A distribution of scores made on the re-test, Part Eight, was a highly skewed curve with a mean of 20.00 and is shown in Figure 26.

These data seem to indicate that there was a definite improvement in the performance of Experimental Group I. It would also seem to indicate that most students low on the pre-test increased their scores as did those who scored well on the first test. Mean scores made by the experimental groups for the pre-test, post-test, and the re-test were 15.66, 19.22, and 20.00, respectively.

The scores made on the pre-test, Part Nine, by Experimental Group I, was a relatively normal distribution and is shown in Figure 27. This distribution had more students below the mean than above the mean. Figure 28 shows a slightly skewed distribution of scores made on the post-test, Part Nine, with a mean of 16.17. On the post-test, Part Nine, more students scored above the mean than below the mean. A negatively skewed distribution of scores from the re-test, Part Nine, is shown in Figure 29 with a mean score of 17.17.
Fig. 24—Pre-test scores made by Experimental Group I on Part 8 of Multiple Aptitude Test.

Fig. 25—Post-test scores made by Experimental Group I on Part 8 of Multiple Aptitude Test.

Fig. 26—Re-test scores made by Experimental Group I on Part 8 of Multiple Aptitude Test.
Fig. 27—Pre-test scores made by Experimental Group I on Part 9 of Multiple Aptitude Test.

Fig. 28—Post-test scores made by Experimental Group I on Part 9 of Multiple Aptitude Test.

Fig. 29—Re-test scores made by Experimental Group I on Part 9 of Multiple Aptitude Test.
Scores made on Part Nine of the pre-test, post-test, and re-test seem to indicate an improvement in the group's performance. There was a total mean gain of 3.33 from the pre-test to the re-test. The re-test, given to check retention, showed that this group had a total mean gain of 1.00; this may indicate retention and application of orthographic principles.

Distributions for Experimental Group II

Scores made on Part Eight of the pre-test by Experimental Group II, shown in Figure 30, are very slightly skewed with a mean score of 13.24. Figure 31 shows a skewed distribution of scores with a mean of 16.84 from the post-test, Part Eight; most of the students scored above the mean on this test. On the re-test, Part Eight, shown in Figure 32, the distribution of scores was also skewed in a negative direction; the mean score on the re-test was 17.80.

Data from the pre-test, post-test, and the re-test indicate an improvement by the Experimental Group II on both the post-test and the re-test. As shown in Figure 31 and Figure 32, most of the students in this group scored above the mean. There was a total mean gain from the pre-test to the re-test of 4.58 on Part Eight of the Multiple Aptitude Test.
Fig. 30--Pre-test scores made by Experimental Group II on Part 8 of Multiple Aptitude Test.

Fig. 31--Post-test scores made by Experimental Group II on Part 8 of Multiple Aptitude Test.

Fig. 32--Re-test scores made by Experimental Group II on Part 8 of Multiple Aptitude Test.
As shown in Figure 33, there is an almost normal distribution of scores made on Part Nine of the pre-test by Experimental Group II with a mean score of 10.72. On the post-test, Part Nine, there was a very slightly skewed distribution with a mean score of 16.12 and is shown in Figure 34. This distribution was skewed in a negative direction. The re-test scores on Part Nine, shown in Figure 35, had a mean of 14.79 and was negatively skewed. Part Nine of the post-test showed an improvement of 3.30 in mean scores from the pre-test to the post-test. Although the distributions shown in Figure 34 and Figure 35 are almost identical, there was a mean gain of 0.96 by the group. The data on Part 9 of the pre-test and re-test indicate improvement with a mean gain of 4.04.

These data would indicate that there was a definite improvement in the performance of Experimental Group II on Part Nine of the Multiple Aptitude Test. Data indicate that this group did understand the two dimensional and three dimensional space relations and retained this knowledge.

Distributions of Control Group I

Data presented in Figure 36 show a very slightly negatively skewed distribution of scores made by Control Group I on Part Eight of the pre-test with a mean of 16.44. On Part Eight of the post-test a slightly skewed curve resulted
Fig. 33--Pre-test scores made by Experimental Group II on Part 9 of Multiple Aptitude Test.

Fig. 34--Post-test scores made by Experimental Group II on Part 9 of Multiple Aptitude Test.

Fig. 35--Re-test scores made by Experimental Group II on Part 9 of Multiple Aptitude Test.
Fig. 36—Pre-test scores made by Control Group I on Part 8 of Multiple Aptitude Test.

Fig. 37—Post-test scores made by Control Group I on Part 8 of Multiple Aptitude Test.

Fig. 38—Re-test scores made by Control Group I on Part 8 of Multiple Aptitude Test.
and is shown in Figure 37. In Figure 38, the distribution of scores on Part Eight of the re-test showed a negative skewness with a mean of 18.94.

Data on the distributions of scores made on the pre-test and re-test by Control Group I would indicate that the group did improve. Although there were more students who scored below the mean on Part Eight of both the post-test and the re-test, there was a total mean gain of 1.92 for this group on Part Eight of the Multiple Aptitude Test.

Scores made by Control Group I on Part Nine of the pre-test was relatively close to a normal probability curve and is shown in Figure 39. This distribution shows most of the students scoring above the mean. In Figure 40, there were two peaks in the distribution of scores made by Control Group I. Although there was a mean score of 13.72 on Part Nine of the post-test, few students scored near the mean. Scores on Part Nine of the re-test, shown in Figure 41, had a mean of 13.60 and was negatively skewed. These data would indicate that there was an improvement; there was a mean gain of 0.56 from the pre-test to the re-test. From the post-test to the re-test there was a mean loss of -0.12. The group had a total mean gain of 0.44 from the pre-test to the re-test.
Fig. 39—Pre-test scores made by Control Group I on Part 9 of Multiple Aptitude Test.

Fig. 40—Post-test scores made by Control Group I on Part 9 of Multiple Aptitude Test.

Fig. 41—Re-test scores made by Control Group I on Part 9 of Multiple Aptitude Test.
Distributions of Control Group II

The distribution of scores made on Part Eight of the pre-test by Control Group II is shown in Figure 42 with a mean of 15.36. Skewness in this distribution was negative. Figure 43 shows the distribution of scores on Part Eight of the post-test by the same group to be highly skewed. This distribution had a mean score of 17.70 and negative skewness. The distribution of scores on Part Eight of the re-test, shown in Figure 44, was slightly negatively skewed and had a mean of 18.10.

Data on these tests indicate a mean gain of 2.34 from the pre-test to the post-test and a mean gain of 0.40 from the post-test to the re-test. The net gain of this group from the pre-test to the re-test on Part Eight was 2.64.

Data in Figure 45 show an almost normal distribution of scores on Part Nine of the pre-test with a mean of 14.70. The distribution of scores on Part Nine of the post-test is shown in Figure 46 and is bi-modal with a mean of 15.30. Scores on Part Nine of the re-test, shown in Figure 47, is almost a normal curve with a mean of 14.90.

These data would indicate that there was definite improvement of Control Group II from the pre-test to the post-test on Part Nine, and that there was an increase of 0.60
Fig. 42—Pre-test scores made by Control Group II on Part 8 of Multiple Aptitude Test.

Fig. 43—Post-test scores made by Control Group II on Part 8 of Multiple Aptitude Test.

Fig. 44—Re-test scores made by Control Group II on Part 8 of Multiple Aptitude Test.
Fig. 45--Pre-test scores made by Control Group II on Part 9 of Multiple Aptitude Test.

Fig. 46--Post-test scores made by Control Group II on Part 9 of Multiple Aptitude Test.

Fig. 47--Re-test scores made by Control Group II on Part 9 of Multiple Aptitude Test.
from the pre-test to the post-test and a decrease of -0.40 from the post-test to the re-test. There was a total gain of 0.20 in the mean score of this group.

Comparison of the Distribution of the Experimental and Control Groups

The preceding data would indicate that there was improvement in each group involved in this study. Individual distributions for each part of the Multiple Aptitude Test indicated that the control groups did not make as much progress as did the experimental groups on Part Eight of the post-test and the re-test. The control groups did not make as much progress on Part Nine of the post-test and re-test as did the experimental groups. The control groups' performance on the re-test, Part Nine, showed a decrease in mean scores. This may indicate that the students did not retain the principles of orthographic projection as well as the students in the experimental groups.

Part Nine of the Multiple Aptitude Test deals specifically with three dimensional space relations; the projection box, as a variable, was used primarily to make abstract principles of orthographic projection more concrete for the students in the experimental groups. In the data previously presented, the experimental groups made a greater mean gain
on Part Nine from the post-test to the re-test than the control groups. This may indicate a greater retention of orthographic principles, especially in three-dimensional spatial relations by the experimental group.

Grades Based on the Normal Probability Curve

The statistics from the normal distribution curves were used to compute the percentage of students that would be assigned letter grades of A, B, C, D, and F. Table XIII shows the percentage of letter grades assigned.

**TABLE XIII**  
**GRADES ON THE RE-TEST, PART EIGHT AND PART NINE**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Experimental Groups</th>
<th>Control Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Part 8</td>
<td>Part 9</td>
</tr>
<tr>
<td>A</td>
<td>6%</td>
<td>11%</td>
</tr>
<tr>
<td>B</td>
<td>40</td>
<td>34</td>
</tr>
<tr>
<td>C</td>
<td>42</td>
<td>33</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>F</td>
<td>8%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Table XIII shows that the experimental groups had a greater percentage of C and higher grades than did the control groups.
Summary

In Chapter IV data have been presented on all four groups for evaluating these groups and the effectiveness of the projection box. The data presented were gathered from results of the Multiple Aptitude Test. Mean and distributions for each group's test results on the pre-test, post-test, and re-test indicate that the experimental group's mean gains were larger and their retention of three-dimension space relations was more than that of the control groups in this study.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This study was concerned with the design, construction, and use of a tri-color projection box as a teaching aid to supplement teaching orthographic projection. The purpose of this study was to evaluate the effectiveness of the use of the projection box in teaching orthographic projection to two experimental groups as compared with two control groups where the projection box was not used.

A second concern of this study was to survey the literature in the field of drafting. Particular emphasis was placed on the use of visual aids in teaching orthographic projection. Special emphasis was placed on literature that related to the use of a projection box.

This study was divided into five parts. Chapter I contains the introduction, statement of the problem, hypotheses, need for the study, related studies, methods of procedure, the Multiple Aptitude Test, and treatment of data. Contained in Chapter II are the design and the construction of the tri-color projection box. Information needed for the construction
of a projection box, such as the one used in this study, is
contained in Chapter II. A number of figures are included
that give methods of construction. Chapter III indicates
the ways in which the projection box was used in this study.
The results of the Multiple Aptitude Test are presented in
Chapter IV. In Chapter V the summary, findings, conclusions,
and recommendations are presented.

Summary

This study was limited to 104 male students at R. L.
Turner High School, Carrollton, Texas. Each student in this
study was enrolled in one of four beginning drafting classes.
There was no grouping process used to place students. These
students were tested at the beginning of the year before any
instruction began; the Multiple Aptitude Test, Parts Eight
and Nine were used. This pre-test was to establish a point
of reference for evaluation of student progress.

At the end of the unit on orthographic projection a
post-test was given. A re-test was administered at the end
of the first semester.

Data in this study were compiled from the test results
of each group. Presented in Chapter IV, these data represent
raw test scores and mean scores. The mean score of each
group was compared to the mean score of that group on the
post-test and the re-test. The mean gain and the distribution of each group was computed. Most of the distributions were skewed.

Findings

The following are the findings of this study:

1. The four groups of students in this study were about average in relation to the national norms for the Multiple Aptitude Test.

2. The experimental groups made greater mean gains on Parts Eight and Nine of the Multiple Aptitude Test when administered as a post-test than did the control groups.

3. The experimental groups had greater mean gains from the post-test to the re-test, Part Eight, than did the control groups. On Part Nine the experimental groups had mean gains while the control groups had mean losses.

4. The experimental group had greater mean gains from the pre-test to the re-test than did the control groups.

5. A greater percentage of students in the experimental groups made higher course grades than did the control groups.

Conclusions

To the extent that the materials presented in this study are accurate, the following conclusions may be drawn:
1. The projection box is an effective and efficient means in aiding retention of the subject matter of orthographic projection.

2. Students taught orthographic projection by means of a projection box retained knowledge of three dimensional space relations.

3. The projection box communicated the abstract material in orthographic projection to the students. This is especially true for students who are below average.

Recommendations

In view of the findings and conclusions of this study, the following recommendations appear to be warranted:

1. The projection box is adaptable to areas of drafting other than orthographic projection. Further study and research should be conducted to determine the effectiveness of the projection box in such areas as auxiliaries and descriptive geometry.

2. Since the projection box used in the experimental groups in this study was tri-color, a clear projection box should be used to determine the correlation of color and effectiveness of the projection box.

3. Further study and research in the area of orthographic projection should be conducted to produce more
effective teaching in the orthographic projection area of drafting. The various types of orthographic projection devices need to be evaluated on the basis of their relative effectiveness in the classroom situation.
APPENDIX A

LESSON PLANS USED FOR CONTROL
AND EXPERIMENTAL GROUPS
ORTHOGRAPHIC PROJECTION UNIT

I. Principal Planes
   A. Theory of orthographic projection
   B. Orthographic views
   C. Six principal views

II. Three Space Dimensions and Reference Planes
   A. Height
   B. Width
   C. Depth

III. Classification of Surfaces and Lines
   A. Three principal surfaces
   B. Three principal lines

IV. Relationship of Planes, Views, Directions, and Space Dimensions
   A. Mutually perpendicular planes
   B. Perpendicular projection
   C. Dimensions and connections

V. Hidden Surfaces and Lines
   A. Surfaces
   B. Lines
   C. Center lines
VI. Dimensioning, Notes, and Symbols

A. Lines and symbols

B. Dimension placement

C. Notes
LESSON PLAN NUMBER 1

Lesson—Principal Planes

Type—Lecture and Demonstration

Instructional Media—Textbook, Chalkboard, Overhead projector, and Overlays


Student Equipment—Textbook, Pencils, Tape, Lecture Notes, drawing paper, T-square, triangles, and other drafting instruments.

Assignment—Page 130, Problem 5.1.1.-B
PRINCIPAL PLANES

I. Presentation (Lecture and Demonstration)

A. Objectives

1. To help students clarify the planes and their position
2. To help students identify each plane
3. To help students understand the two-dimensional drawings and the planes on which they appear
4. To help students understand the direction of sight in relation to the picture plane
5. To help students understand the planes that appear on drawing paper
6. To help students relate views and planes

B. Lecture and Demonstration

1. Explanation of orthographic projection and the theory of planes
2. Explanation of the three principal planes
3. Demonstration of the frontal, horizontal, and profile planes on chalkboard
4. Demonstration that the three principal planes are mutually perpendicular on chalkboard
5. Explanation of the relationship of the planes and corresponding views on the overhead projector
6. Explanation of the six possible views
II. Review
A. Review each plane
B. Review orthographic projection views and planes
C. Review the six possible views
D. Quickly summarize the lesson on orthographic projection

III. Questions
A. What three views are represented in this drawing on the overhead projector?
   Answer—front, top, and right side view
B. What three planes are represented on your drawing paper?
   Answer—Frontal, horizontal, and profile planes
C. Are the three principal planes mutually perpendicular?
   Answer—Yes
LESSON PLAN NUMBER 2

Lesson—Three Space Dimensions and Reference Planes

Type—Lecture and Demonstration

Instructional Media—Textbook, Chalkboard, Overhead projector, and Overlays


Student Equipment—Textbook, Pencils, Tape, Lecture notes, Drawing paper, T-square, Triangles, and Other drafting instruments

Assignment—Page 130, Problem 5.1.3.-A
THREE SPACE DIMENSIONS AND REFERENCE PLANES

I. Presentation (Lecture and Demonstration)

A. Objectives

1. To teach students to identify a reference plane

2. To teach students the three space dimensions—height, width, and depth

3. To teach students how to determine height, width, and depth

B. Lecture and Demonstration

1. Explanation of the three space dimensions on the chalkboard

2. Explanation of the relationship of planes to views and three space dimensions on overhead projector

3. Demonstration of measuring views with engineer's scale

II. Review

1. Review of three space dimensions

2. Review of reference planes

3. Review measuring and measurement of views

4. Quickly summarize the lesson

III. Questions

A. What two dimensions can be determined from the front view on the frontal plane?

Answer—Height and width
B. What two dimensions can be determined from the top view on the horizontal plane?

Answer—Width and depth

C. What two dimensions can be determined from the right side view on the profile plane?

Answer—Height and depth

D. What does one use to transfer measurements from one drawing to another?

Answer—Engineer's scale
LESSON PLAN NUMBER 3

Lesson—Classification of Lines and Surfaces

Type—Lecture and Demonstration

Instructional Media—Textbook, Chalkboard, Overhead projector, and Overlays


Student Equipment—Textbook, Pencils, Tape, Lecture notes, Drawing paper, and Drafting equipment

Assignment—Page 131, Problem 6.1.2-B
CLASSIFICATION OF LINES AND SURFACES

I. Presentation (Lecture and Demonstration)

A. Objectives

1. To teach students how to classify surfaces according to their space relations

2. To teach students the classification of lines

3. To teach students that the line of sight must be perpendicular to any plane, surface, or line before the true size, shape, and length of any plane, surface, or line can be determined

B. Lecture and Demonstration

1. How to recognize surfaces demonstrated on the chalkboard

2. Explanation of how planes involve and that when the edge of a plane is seen that plane is perpendicular to another plane

3. Explain that horizontal, frontal, and profile lines appear on their respective planes

4. Explain that an edge appears in true length when it is parallel to the plane of projection

II. Review

A. Review surfaces

B. Review edge views

C. Review classification of lines

D. Quickly summarize the lesson
III. Questions

A. What is the name of a surface parallel to the front view?

Answer—Frontal

B. What is the name of a line which appears parallel to the horizontal plane?

Answer—Perpendicular

C. What is the name of a line which appears parallel to the frontal plane?

Answer—Frontal line

D. How must one look at a surface to see that surface in its true size and shape?

Answer—Perpendicular
LESSON PLAN NUMBER 4

Lesson—The Relationship of Planes, Views, Directions, and Space Dimensions

Type—Lecture and Demonstration

Instructional Media—Textbook, Chalkboard, Overhead projector, and Overlays


Student Equipment—Textbook, Pencil, Tape, Lecture Notes, Drawing paper, and Drafting instruments

Assignment—Handout sheet
THE RELATIONSHIP OF PLANES, VIEWS, DIRECTIONS, AND SPACE DIMENSIONS

I. Presentation (Lecture and Demonstration)

A. Objectives

1. To show how the actual views are projected onto a related plane

2. To teach students the relationship between space directions and the planes of projection

3. To teach dimension relations to planes views

4. To teach space dimension difference between two points

B. Lecture and Demonstration

1. Demonstration of the spaces between views and the relationship of views being projected on planes on the overhead projector

2. Explanation of the space between any two points in space

3. Explanation of the direction of each dimension according to third-angle projection

II. Review

A. Review space between views

B. Review directions of dimensions

C. Review of surfaces and plane projection

III. Questions

A. What is the difference between two frontal planes?

   Answer—Space dimension of depth
B. The height of the frontal plane where the object is projected is the same height of what two views?

   Answer—Front and right side views

C. Are the two space dimensions for a view parallel to the plane that view?

   Answer—Yes

D. The depth direction is parallel to what planes and views?

   Answer—Profile plane, right side view, horizontal top view
Lesson Plan Number 5

Lesson—Hidden Surfaces and Lines

Type—Lecture and Demonstration

Instructional Media—Textbook, Chalkboard, Overhead projector, and Overlays


Student Equipment—Textbook, Pencil, Tape, Lecture notes, Drawing paper, and Drafting instruments

Assignment—Page 131, Problem 6.3.1.-A
HIDDEN SURFACES AND LINES

I. Presentation (Lecture and Demonstration)

A. Objectives

1. To teach students about hidden lines
2. To teach students about hidden surfaces
3. To teach students about intersecting surfaces which are hidden

B. Lecture and Demonstration

1. Explanation of hidden lines
2. Explanation of hidden surfaces
3. Explain how hidden lines describe an object

II. Review

A. Review hidden lines of objects
B. Review hidden surfaces on objects

III. Questions

A. What are hidden lines used for?

Answer—To help explain an object
LESSON PLAN NUMBER 6

Lesson—Dimensions, Notes, and Symbols

Type—Lecture and Demonstration

Instructional Media—Textbook, Chalkboard, Overhead projector, and Overlays


Student Equipment—Textbook, Pencils, Tape, Lecture notes, Drawing paper, and Drafting instruments

Assignment—Page 131, Problem 6.3.3-C
DIMENSIONING, NOTES, AND SYMBOLS

I. Presentation (Lecture and Demonstration)

A. Objectives

1. To teach the basic factors of dimensioning
2. To help students understand symbols used for shortening notes
3. To teach students how, when, and where to use notes
4. To teach students the best procedure for dimensioning

B. Lecture and Demonstration

1. Demonstration of size, position, and selection of dimensions
2. Explanation of the correlation of dimensions
3. Explanation of maximum and minimum sizes
4. Explanation of symbols and their uses
5. Explanation of the specific areas for notes
6. Explanation of preference of notes to symbols in certain situations
7. Explanation of dimensions—Aligned and unaligned

II. Review

A. Summary of dimensions and their positions
B. Review of Symbols
C. Review of notes and lessons
III. Questions

A. What are the two types of dimensions?
   Answer—Aligned and unaligned

B. What should be the height of the numbers used for dimensions?
   Answer—1/8"

C. Should the angular dimensions align themselves with the surface to be dimensioned?
   Answer—Yes

D. Preferably where should notes be placed on the drawing?
   Answer—One of the four corners
APPENDIX B

SUPPLEMENTARY LESSON PLANS USED IN THE EXPERIMENTAL GROUPS ONLY
SUPPLEMENT TO LESSON PLAN NUMBER ONE

Principal Planes

I. Presentation by lecture and demonstration

A. Objectives

1. The student will be able to identify the planes and their relative positions.

2. The student will be able to identify each plane by its color.

3. The student will be able to understand the two dimensional drawings of a projection box in the book.

4. The student will be able to understand the planes as they appear on drawing paper.

5. The student will be able to understand the direction of sight in relation to the picture plane.

6. The student will be able to relate views to planes.

B. Demonstration with the projection box

1. Explanation of orthographic projection and the theory of planes with the projection box.

2. Explanation of the name of each plane and that yellow is the frontal plane, green is the horizontal plane, and blue is the profile plane on the projection box.

3. Demonstration of how the planes are mutually perpendicular using the projection box.

4. Explanation of how, when unfolded, the horizontal and profile planes appear the same as on drawing paper.
5. Explanation of the relationship of the planes and corresponding views (orthographic views).

II. Review

A. Quickly summarize the lesson on the projection box
   1. Review the planes and the color of the planes
   2. Review orthographic view and planes
   3. Review the position of the planes
   4. Review the folding of the planes

III. Questions

A. What is the name of this plane and the orthographic view that appears on it?
   Answer—Frontal; front view

B. What is the name of this view and the orthographic view that appears on it?
   Answer—Profile; right side view

C. What is the name of this view and the orthographic view that appears on it?
   Answer—Horizontal; top view

D. What three views are represented on the drawing?
   Answer—Front; top, right side view

E. What three planes are represented on your drawing paper?
   Answer—Frontal; horizontal; profile
SUPPLEMENT TO LESSON PLAN NUMBER TWO

Three Space Dimensions and Reference Planes

I. Presentation by lecture and demonstration

A. Objectives

1. The student will be able to locate and use reference planes.

2. The student will demonstrate a knowledge of the three space dimensions—height, width, and depth.

3. The student will be able to locate in space a given height, width, and depth as related to a given point.

B. Lecture and demonstration using the projection box

1. Explanation of the three space dimensions using the projection box.

2. Explanation of the relationship of the planes to their views and space dimensions.

3. Explanation of how to measure from a reference plane by using dividers.

4. Explanation that any point can be located in space by giving its height, width, and depth when it is related to some other known point.

II. Review

A. Quickly summarize

1. The three space dimensions

2. Relations of the planes
3. How to measure from reference planes

4. How to locate points in space

III. Questions

A. What two dimensions can be determined from the front view?

   Answer—Height and width

B. What two dimensions can be determined from the top view and the horizontal plane?

   Answer—Width and depth

C. What two dimensions can be determined from the right side view and the profile plane?

   Answer—Height and depth

D. What instrument do you use to transfer measurements from a reference plane?

   Answer—Dividers
SUPPLEMENT TO LESSON PLAN NUMBER THREE

Classification of Lines and Surfaces

I. Presentation by lecture and demonstration

A. Objectives

1. The student will be able to classify surfaces according to their space relations.

2. The student will be able to classify lines.

3. The student will be able to determine the true size, shape, and length of any plane, surface, or line by using the line of sight which must be perpendicular.

B. Demonstration with the projection box

1. Use objects to teach students how to recognize surfaces.

2. Demonstrate by revolving the projection box the edge of a surface and how the surface and principal plane are parallel.

3. Explain that horizontal, frontal, and profile lines appear on their respective planes; explain the name of the line.

4. Explain that an edge appears in true length when it is parallel to the plane of projection.

5. Demonstrate that the lines, frontal, profile, and horizontal, can appear on their respective planes an infinite number of times.

II. Review

A. Quickly summarize

1. Surfaces of the object
2. Edge of surfaces

3. True size and shape—lines

III. Questions

A. What is the name of a surface parallel to the front view?

   Answer—Frontal

B. What is the name of a line which appears parallel to the horizontal plane?

   Answer—Horizontal line

C. How must one look at a surface to see that surface in its true size and shape?

   Answer—Perpendicular

D. How must you look at a line to see its true length?

   Answer—Perpendicular

E. What is the name of a line which appears parallel to the frontal plane?

   Answer—Frontal line
SUPPLEMENT TO LESSON PLAN NUMBER FOUR

Hidden Surfaces and Lines

I. Presentation by lecture and demonstration

A. Objectives

1. The student will be able to identify a hidden line.
2. The student will be able to identify a hidden surface.
3. The student will be able to understand intersecting surfaces which are hidden.

B. Demonstration using the projection box

1. Use object in the projection box to explain hidden lines.
2. Use object in the projection box to explain hidden surfaces.
3. Explain how hidden lines describe the object.

II. Review

A. Hidden lines and how they will help to explain objects

B. Hidden surfaces

III. Questions

A. What are hidden lines used for?

Answer—To help explain the object
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