A Study of an Alternative Visual Aid Used to Teach Orthographic Drawing in an Introductory Drafting Course

by

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ABSTRACT

Orthographic projection drawings are the primary communication media of engineers, architects and other designers. While learning how to create this type of drawing, students often struggle in correctly placing the individual views of the object within the orthographic layout so that the drawing can convey its full meaning. In this study a visual aid based on a bowl was added to a unit on orthographic drawing to find whether students found this alternative visual aid helpful.

It was found that many students in this investigation responded positively to the Bowl visual aid with some reporting it more helpful than the hinged glass box visual aid. It was also found that many of the students who found this alternative visual aid helpful predominantly shared two common spatial visualization deficiencies that were easy to identify with simple spatial visualization pre-tests.

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Chapter I: Introduction

Engineers and other designers must communicate with each other and with those who will create their designs. The engineering print is the means of communication that designers use to communicate with each other as well as with the welders, machinists, carpenters and many other professionals that help create new products. One of the challenges that designers face in the process of communicating with production workers is that their product is three-dimensional (3-D) in nature, while the drawing representing it is two-dimensional (2-D). For a successful communication of ideas between these two groups, it is essential that the designer creates drawings that conform to engineering standards (Coover, 1966; French & Vierck, 1978). Drawing to a set of standards enables others to correctly read the print so they are able to interpret the information conveyed by the drawing with maximum clarity and minimal confusion (Brown, 1972; Hornung, 1957; Madsen, Folkestad, Schertz, Shumaker, Stark & Turpin 2002).

Engineering prints are not merely labeled pictures of an object. They are documents that convey meaning not only through the marks that appear on the paper, but also through the relationship of the various views of the object relative to each of the other views. The standardized rules about view placement and other aspects of engineering drawings are so specific and widely used by peoples of various nationalities that Spencer, Dygdon & Novak (1995) referred to this means of communication through technical drawings as its own language – "the graphic language". In this language the sender of the message and the recipient must both have a common understanding of the rules of this graphics-based language.

In order to completely describe a 3-D object through 2-D drawings, the orthographic projection technique was developed to show all the needed information in an organized manner. This most commonly used type of engineering drawing consists of multiple 2-D views of the object in a specified arrangement. The necessary views of an object are placed in positions relative to each other to allow the reader to transfer information from one view to another. Figure1.1 is an example of a third angle orthographic projection drawing. Each dimension of the object is given only in one view so that the reader must look to the other views for other information about this object. The use of this orthographic projection view alignment allows the reader to transfer information from one view to another view. In this case the top view indicates that the object is 20 mm deep.

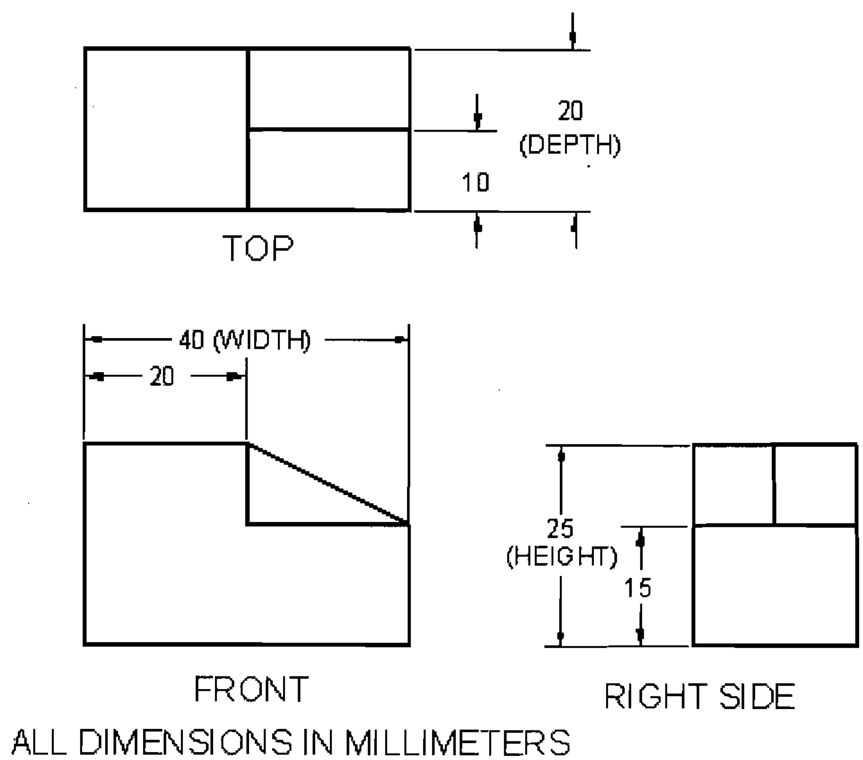

Figure1.1. An example of a third angle orthographic projection of a simple object.

In Figure 1.1, the height of the object is given in the right side view as 25 mm. This height dimension is the same for the front view. Likewise, the width of the object is given in the front view as 40 mm. The width of the top view is also 40mm due to the relative locations of the views within the layout. By placing views in the correct locations, an object is described completely so that the object can be created by a person who knows the standards of orthographic drawing.

This vital component of a standardized drafting language seems straightforward, yet the placement of the views of an object in an orthographic projection is a difficult task for some to master (Visualization, 2001). Mastering this aspect of orthographic projection is only possible when a student is capable of visualizing an object in his/her mind. The student must also be able to imagine what the 3-D object would look like as a 2-D drawing when rotated and viewed from various perspectives (Spencer, Dygdon & Novak, 1995). Once a student is able to visualize the object and isolate various views of the object, the student should be able to create orthographic drawings by placing each view of the object in its appropriate location and orientation relative to the other views of that object in the layout.

Success in view placement relies heavily on the spatial skills of the individual (Kang, Jean, Chung &Chung, 2004). Research has found that a student's level of proficiency in spatial tasks is a strong indicator of likely success in engineering and in creating engineering drawings (Kang, Jean, Chung & Chung, 2004; Boersma, Hamlin, & Sorby, 2004). After years of observations of the struggles that high school students have in introductory drafting courses, this researcher wondered, "Could I improve student performance in my high school introductory computer aided design (CAD) course by offering alternative instruction on orthographic view placement?"

While learning the conventions of orthographic projections, visual aids can be instrumental in helping students make the connection between visualizing the object and placing the appropriate view of that object in the correct location and orientation. Figure 1.2 is a picture of a widely used glass box visual aid (Box visual aid) that contains the object to be drawn. Students draw lines on the individual panes of glass that correspond to the actual lines of the object that are visible when viewing it through that pane of glass (Sundberg, 1972). When this Box visual aid is unfolded and laid flat, the lines of each view drawn on the sides of the box are in the correct position of a view in a third angle orthographic drawing.

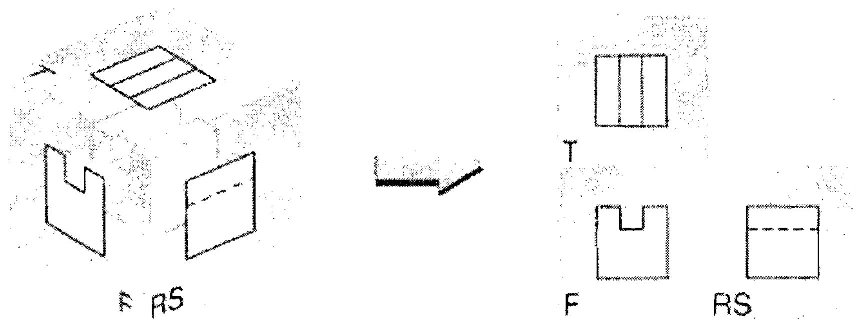

Figure 1.2. The glass box visual aid (left) unfolded to show correct view placement (right). (Bertoline, Wiebe, Miller and Nasman,1995, p. 391).

A depiction of some type of Box visual aid is included in most drafting textbooks to help describe view placement in third angle orthographic projection. During a review of over 20 textbooks (Berg, 1966; Bertoline, Wiebe, Miller & Nasman, 1995; Bethune & Kee, 1989; Brown, 1978; Carter & Thompson, 1943; Coover, 1966; Earle, 1985; French & Svensen, 1966; French & Vierck, 1978; Fox, 1907; Giachino & Beukema 1978; Goetsch, Nelson & Chalk, 1989; Grant, 1965; Madsen, Folkestad, Schertz, Shumaker, Stark, & Turpin, 2002; Spence, 1973; Sundberg, 1972; United States. Dept. of the Army and the Airforce, 1962;

Walker, 1982; Weaver, 1975; Weaver, 1982; Welch, 1959; Woolven, 1967) other than Spencer, Dygdon & Novak (1995) on drafting and blueprint reading, only one (Hornung, 1957) was found that did not contain a description and illustration of the Box visual aid. While the explanation of view placement using Box visual aid is sufficient for most students, classroom observations by the researcher have indicated that some students still do not understand orthographic projection view placement through the use of this concept alone.

Although most textbooks rely solely on the Box visual aid to demonstrate correct alignment of the views, one textbook (Spencer, Dygdon and Novak, 1995) included an alternative explanation of how to visualize the layout of an object in third angle orthographic drawing. This explanation consists of a series of illustrations in which a hand progressively rotates an object toward the reader's viewing plane. (See Figure 1.3.) Each illustration in the series is progressively more rotated than the previous illustration. The final illustration in each sequence is rotated 90 degrees from the object's original orientation to the correct location and orientation for an orthographic projection layout.

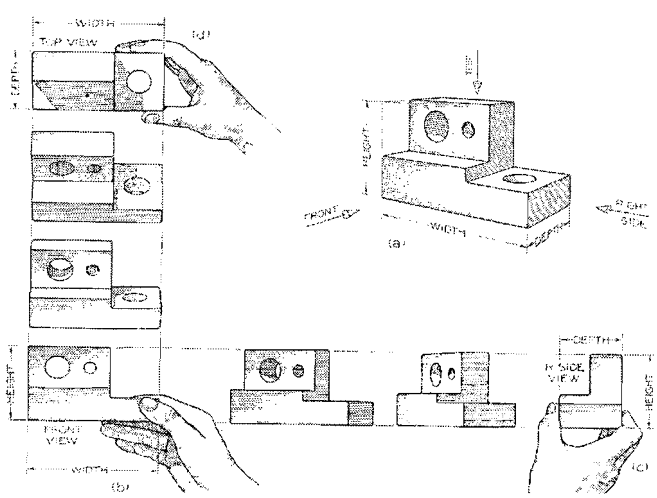

Figure 1.3. Orthographic view placement explained through rotations of an object (Spencer, Dygdon & Novak, 1995, p.124).

This drawing of progressive rotations yields the correct position and orientation of the views of the object as they would appear in an orthographic projection drawing. However, this researcher has observed that students attempting to use this rotation method often make the mistake of rotating the object the opposite direction and place the left side view on the right side of the front view. This same type of error often occurs with the top view. If the student mentally rotates the object in the opposite direction, the result is an arrangement of views known as first angle projection (see Figure 1.4). The first angle projection arrangement is used in many parts of the world, particularly in Europe. For the purposes of this study, the first angle projection view arrangement would be considered incorrect because the third angle projection is the standard used in the United States.

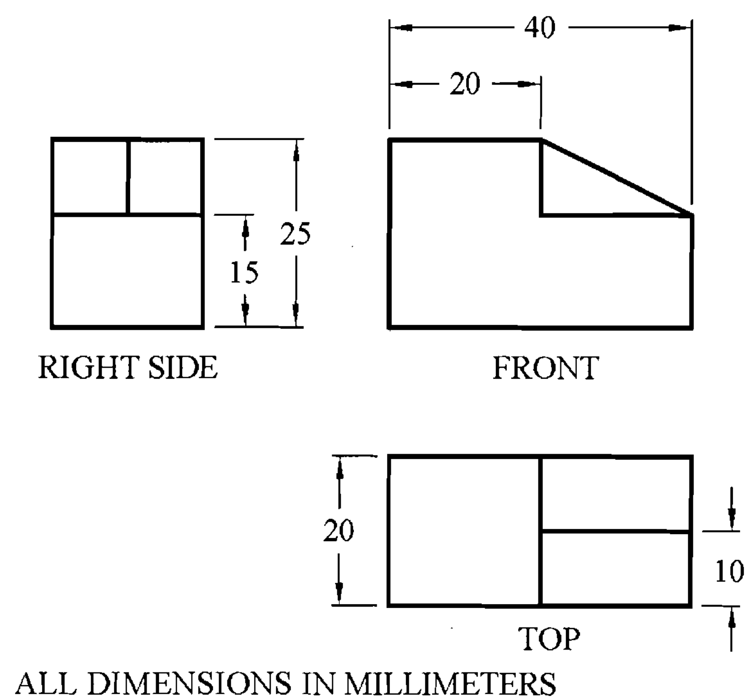

Figure 1.4. A first angle orthographic projection of the object used in Figure 1.1.

In an attempt to correct this common mistake, a framework for remembering the direction of the rotation would help those learning the rotational view placement technique. The rotation of the object shown in Figure 1.3 could be described as sliding the object up the sides of a large bowl. One could place the object in the bottom of the bowl with the front view of that object facing the viewer. One could then slide the object from the bottom of the bowl up to the top rim of the bowl while keeping the bottom of the object in contact with the bowl. By the time the object reaches the top surface of the bowl, it has been rotated 90 degrees. The view of the object is correct for a third angle orthographic projection layout. The idea for this Bowl visual aid was originally supplied to this researcher by K. Fozzler (personal communication, June, 1996), when explaining the relationship between a completed part and an orthographic print used to inspect that completed part.

In this investigation, the researcher has enhanced the rotation method shown in Figure 1.3 by creating the Bowl visual aid. Actual photos of this visual aid can be found in Appendix K. The Bowl visual aid provides a physical framework to help students remember which direction to mentally rotate the object in order to produce correct views for a third angle orthographic layout. In Figure 1.5, the rotation of the object using the Bowl visual aid is shown from the side of the visual aid in order to explain the way the object should slide along the sides of the bowl. Figure 1.6 is an illustration of the view placement provided by the Bowl visual aid when looking down perpendicular to the top surface of the bowl. The resulting view placement conforms to third angle projection standards as shown in Figure 1.1.

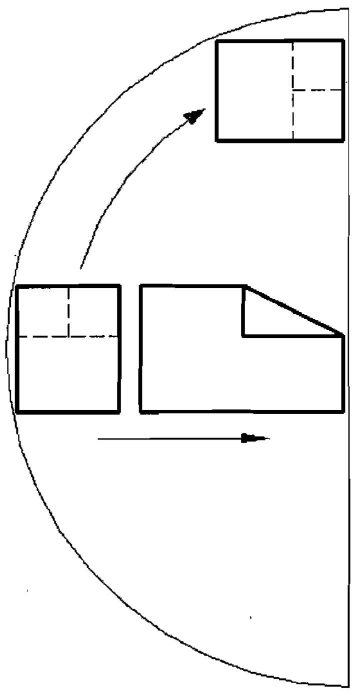
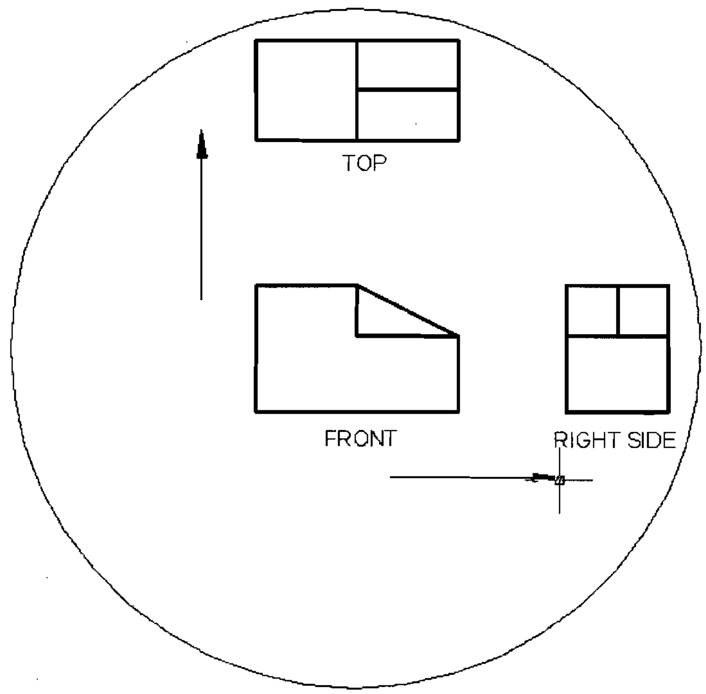

Figure 1.5. Side view of the Bowl visual aid showing the rotation of the object.

Figure 1.6. Correct view placement (provided by the Bowl visual aid).

Since some students struggle to understand third angle orthographic view placement when shown only the Box visual aid, this researcher questioned whether the use of the Bowl visual aid could help struggling students by emphasizing a different way view placement can be visualized. This researcher hoped to help more students succeed in creating orthographic drawings by offering them an alternative solution to the problem of visualizing orthographic layouts. This researcher also wondered whether the Bowl visual aid would be an even better way to explain the concept of orthographic view placement to students than the wisely used Box visual aid.

Statement of the Problem

Understanding how to arrange the 2-D views in an orthographic projection drawing of an object is the cornerstone for success in drafting (Hornung, 1957). In a typical secondary level drafting classroom, there are a number of students who struggle with this concept even after seeing a demonstration of the Box visual aid. Since most textbooks explain this view arrangement concept in the same way, little information can be found on alternative or additional ways to teach this essential concept in engineering drafting. Could the Bowl visual aid be more helpful to introductory level drafting students than the widely used Box visual aid?

Purpose of the Study

This study was an investigation of the effectiveness of the Bowl visual aid in increasing student understanding of key engineering drafting conventions. Both the Bowl visual aid and Box visual aid were used to teach the correct placement of the three primary views of objects in engineering drawings. Did the alternative visual aid provide drafting students with another way of visualizing view placement that was easier for some students to understand than the traditional Box visual aid? If the Bowl visual aid is preferred by at least some of the students participating in this study, can a profile of those students be determined to help identify students that may benefit from this visual aid in future classes?

Research Questions

The study is based on the following questions:

1. Are there students who find the Bowl visual aid more helpful than the Box visual aid when learning to create orthographic drawings?

2. Do students who indicate a preference for the Bowl visual aid, demonstrate significant improvement between orthographic sketching pre-tests and post-tests?
3. Which approach (Bowl, Box, both or neither) do students feel is best to use when teaching third angle orthographic projection view placement?
4. What common traits are shared by students who find the Bowl visual aid more helpful than the Box visual aid?

Justification for the Study

The following reasons are offered as justification of the study:

1. Since orthographic projection is a difficult concept for students to grasp, new teaching aids could prove helpful to better explain relationships between the views of an orthographic projection layout.
2. In order to continuously improve pedagogy in a time of rapid technological change, teaching methods must change from time to time as well. While tried and true methods are enough to help most students understand view placement in orthographic projection drawings, alternative teaching methods may be identified that are better able to capitalize on students' spatial abilities when learning to create orthographic drawings.
3. Since there is limited information on alternative teaching methods for explaining orthographic view placement, research should be done to investigate the effectiveness of an alternative visual aid and to identify the profile of students who may find this alternative visual aid more helpful than the Box visual aid when learning to create orthographic drawings. By finding common traits of these individuals, it may be possible to identify the best teaching strategies to help all students succeed in the introductory level drafting classroom.

Assumptions of the Study

In order to draw valid conclusions from this study, the following assumptions about the test groups and conditions must be made:

1. Since this experiment was conducted in an elective course after the students' deadline to drop classes had passed, it was assumed that all students in the class were motivated to learn, and thus all students were receptive to learning the visualization techniques demonstrated by the instructor.
2. Since Basic Graphics was an elective course offering, it was assumed that the students participating in this study would perform at their personal best for each of the spatial visualization assessments administered throughout this experiment.
3. It is possible that once the direct instruction on visualization techniques was complete, students may have received help from their peers from time to time as well as from their parents. Since in-class presentations were reinforced through multiple examples demonstrated consistently with the same visual aids, this study assumed that the students' knowledge of orthographic projection was primarily formed by the direct instruction of the classroom teacher. This assumption was also made because it was impossible to control the content of the advice that students received from sources other than the classroom instructor.
4. It was assumed that the time of day when the assessments were given did not affect student scores between the three sections of the Basic Graphics course.

5. Due to the nature of this investigation, the researcher must assume that the pre-test results are the best way to predict the success rates of the participants in regard to creating orthographic drawings. This assumption was made to determine whether the alternative visual aid was successful in helping students that were likely to struggle in creating orthographic drawings.

Definition of Terms

Conventions/standards. Rules followed by draftsmen that make it possible for others to easily and accurately interpret their drawings.

Drafting. The practice of creating technical drawings used as a means of communication between designers and producers of products (Spencer, Dygdon & Novak, 1995).

View. A two-dimensional drawing that represents what is actually seen when looking at an object from one stationary perspective perpendicular to one of the faces of the object (French & Vierck, 1978).

Orthographic projection. A means of graphically describing a three-dimensional object through the use of multiple two-dimensional drawings showing various views of the object arranged in a manner that suggests a relationship between the views (French & Vierck, 1978).

Layout. The standardized arrangement of the necessary orthographic views that completely describe an object.

Third angle orthographic projection. The convention of orthographic projection most commonly used in North America and therefore the focus of this thesis. The primary views in this convention are created when the viewing plane is between the object and the viewer.

(Bertoline, et. al, 1995). In this format, the top view of the object is found above the front view and the side view is found to the right of the front view (Ryan, 2002). (See Figure 1.1).

First angle orthographic projection. The layout of the primary views in this convention is created when the object is between the viewing plane and the viewer (Bertoline, et. al, 1995). This is the convention of orthographic projection most commonly used in Europe. The view of the top of this object is found below the front view and the right side view of the object is on the left side of the front view (Ryan, 2002). (See Figure 1.4).

Limitations of the Study

Due to the sample of this study, there were various limitations to the conclusions that could be drawn. The test group was made up of three sections of the Basic Graphics class at Franklin High School in Franklin, Wisconsin, consisting of 51 total student participants. Because the students in each section were randomly selected through the school's master scheduling software, it was impossible to use separate classes to form three test groups that shared relevant student attributes in uniform proportion. The limitations for this study based on factors that affect results were as follows:

1. The population of the study was secondary level students. It was not assumed that the results of this study would be similar to that of a similar study conducted with test groups of a different age group.
2. The test group contained students with an age range of 14-18 years. Since experience of the individual is a factor that affects their visualization ability level (Strong & Smith, 2001), younger students may exhibit different levels of cognitive growth than the older students of the same ability level when entering the course and the same exposure to identical instruction on visualization techniques.

3. The sample participating in this study was mostly comprised of males. Since there were only 10 females in the group of 51 participants in this study, it was not assumed that the results of this experiment could accurately predict the results of a study conducted with an equal representation of male and female students in each test group. Furthermore, the results of this study may not correlate at all to the results of a study that was limited to female participants only (Strong & Smith, 2001).
4. Although nearly all of students who were eligible to participate in this study did so, a total sample group of 51 students is not large enough to allow the researcher to draw highly accurate conclusions that can be generalized with reliability to larger populations.
5. The students participating in this study were all willing participants who enrolled in the Basic Graphics course; thus the participants were not randomly selected.
6. Due to the small number of participants available for this study and also due to the duty of the instructor to assist all students in learning, it was not possible to create a legitimate control group.
7. A final limitation of this study was the use of data supplied by the student in the form of survey questions. This major source of data was used in an attempt to develop the profile of students that may benefit from the Bowl visual aid.

Outline of this Paper

To perform this investigation a review of literature was conducted to determine which topics related to the creation of orthographic drawing should be explored. This review of literature on orthographic drawings led to an exploration of theories on intelligence and cognition. Through this review, several spatial abilities needed to create orthographic drawings were identified. Once the skills need to create orthographic drawings were identified, a review of spatial abilities test was conducted. Traits that can be used as predictors of the spatial ability level of students were also identified. The review of literature concludes with a discussion of the need to establish the likely profile of a student who may benefit from the addition of the Bowl visual aid when learning orthographic drawing. This researcher used spatial abilities pre-test results as well as student responses from the Student Profile Survey to create this Bowl visual aid preference profile.

The third chapter in this investigation includes a description of the one-group pre-test/post-test research model used in this investigation. A description of the various survey instruments and spatial aptitude tests used to collect data follows which includes details on the types of tests used and the rationale for creating new tests for this investigation. The subject selection procedures for this investigation are explained as well as the precautions taken to ensure the confidentiality of the participants in this study. Procedures regarding data collection and data analysis are explained and the limitations of the methodology are discussed.

The fourth chapter reports the results of the study by addressing each of the four research questions outlined in this introduction. The data gathered was statically analyzed to answer each of the four research questions. The fifth and final chapter in this study includes a summary of the study, and conclusions drawn from the study. This study concludes with a series of recommendations for replications of this study, recommendations for further study related to this topic, and lastly, recommendations for the high school drafting instructor.

Chapter 2: Literature Review

The goal of this study is to investigate the benefit of the Bowl visual aid in helping students to correctly place views in orthographic drawings. In this chapter, the topic of orthographic drawing will be clarified, as there is more than one type of orthographic projection. Next, cognition and intelligence will be discussed to determine the specific skills or abilities that enable a person to visualize and identify the potential views of an object used to create and interpret orthographic drawings. These findings lead into a review of theories on individual differences in the development of spatial intelligence and predictors of success in spatial visualization. Spatial visualization tests are also examined to gain an understanding of research instruments that measure student abilities related to the problem under investigation. This chapter concludes with a comparison of the two visual aids used and the need to construct a skills profile of the students who found the Bowl visual aid more helpful.

Orthographic Drawings

In technical drawing, there are two types of orthographic drawings that are commonly used: first and third angle orthographic projections. Third angle projection is most widely used in the United States and Canada, while first angle projection is commonly used in Europe (Ryan, 2002). Figure 1.1 is an example of third angle projection and Figure 1.4 is an example of first angle projection. The important difference between these two techniques in respect to this study is the placement of the various views of the object on the paper in relation to the most detailed primary view known as the front view. In third angle projection, the top view of the object (as seen looking down on the top of the object) is placed above the front view, while in the first angle projection the top view of the object would be placed below the front view. Similarly, in third angle projection, the right side view of the object (as seen looking at the right side of the object) is placed to the right of the front view, while in the first angle projection the right side view of the object would be placed to the left of the front view. These distinctions become important when explaining the idea of rotating a part because if students visualize this rotation without an organizational structure provided by some type of visual aid, students could place views in locations that fit the definition of a first angle projection instead of the desired third angle projection. For the purpose of this study, the terms orthographic projection and orthographic drawing will refer to third angle orthographic projections.

Intelligence and Cognition

There are many aspects of intelligence. H. Gardner (1999) theorizes that intelligence is not just one entity but rather a composite of several distinct areas in which humans are capable of developing a level of proficiency. Gardner's thoughts on the existence of multiple intelligences have become widely embraced in educational theory (Guignon, 1998). Of Gardner's seven original intelligences (more have been added since) the intelligence that most closely relates to the task under study is known as spatial/visualization intelligence. Spatial intelligence is defined by Gardner in *Intelligence Reframed* as the "potential to recognize and manipulate patterns" in wide or confined spaces (1999, p. 42). Gardner's definition of spatial intelligence includes much more than the abilities needed to succeed in creating orthographic drawings, therefore this investigation of cognition and intelligence must identify and focus on the specific skills and abilities students need in order to be successful at creating orthographic drawings.

Spatial Abilities

The elements that make up the broader category of spatial intelligence include many different types of spatial tasks. The skill of the student in some of these individual tasks are not necessarily important to success in creating orthographic drawings, while skill in other tasks are critical if a student is to succeed. Mathematics researcher S. Olkun (2003) refers to a number of these necessary spatial abilities as spatial relations. These spatial relation skills include the ability to perform mental rotations, the ability to mentally fold and unfold objects and the ability to make 3-D to 2-D transformations. These skills allow the individual to mentally rotate objects and make visual comparisons between similar objects, abilities that are needed in order to create accurate orthographic drawings (Olkun, 2003).

One important aspect of spatial visualization needed in drafting is the ability to correctly identify 2-D views of a 3-D object and the reverse. Spatial visualization also includes the ability of the individual to "unfold" a 3-D object into a flat sheet or vice versa (Olkun, 2003). The ability to make mental rotations, the ability to mentally fold patterns into solids, and the ability to translate a 3-D object into 2-D representations are the three key spatial abilities required to create a correct orthographic layout.

Studies on ways to increase spatial and visualization abilities have been conducted in an attempt to improve the graduation rates of women in college engineering programs (Boersma, Hamlin & Sorby, 2004; Alias, Black & Gray, 2002; Kang et al., 2004). Boersma, Hamlin and Sorby (2004) found that remedial instruction in spatial visualization can improve the success rate of students in college engineering programs. These spatial and visualization skills are so important to engineering and manufacturing that research has been funded by the National Science Foundation and private companies such as General Electric in order to find ways to improve these skills (Visualization, 2004). Student preferences toward either of the two visual aids used in this study may be based on the level of skill that the student has in each of the three key spatial abilities when they begin the orthographic drawing unit. This researcher has wondered: "Could spatial ability pre-test scores or simple survey information related to the predictors of success in spatial tasks indicate whether that student would prefer the Bowl visual aid when learning to create orthographic drawings?"

Predictors of Initial Ability

When investigating the predictors of success in spatial tasks, there are four personal traits that can account for some of the differences in spatial task achievement between individuals. These personal traits are the individual's gender, previous experience, age and mathematical ability. All of these traits have been found to independently contribute to the varying levels of spatial ability that the students may display in this study.

Gender. Evidence for spatial ability differences between the genders can be found in a number of cross-cultural studies that have found a general male advantage in performing most spatial tasks (Kimura, 1999). A possible explanation for the differences between the genders in spatial tasks could be based on the cultural expectations of boys and girls. This explanation contends that boys are expected to engage in different type of activities than girls and it is through the experiences of "boy" activities that boys begin to develop a greater level of spatial skill at an earlier age than their female peers. This theory, however, neither fully explains why spatial ability gaps exist between the genders nor why these gaps develop early in life. An example of a task in which young boys have an advantage over females is in their ability to quickly reconstruct 3-D lego models. The use of legos as the medium for a spatial abilities test may appear to give boys an advantage in testing spatial abilities since most lego sets are marketed toward boys. However, when similar tests were conducted using different objects, boys still displayed an advantage in these tasks (Halpern, 2000). Halpern concluded that the cultural gender related expectations of children can not completely explain the differences between the sexes in spatial abilities.

Perhaps the most convincing evidence for gender-related differences in spatial abilities comes from experiments involving hormone manipulations. Kimura (1999) reported on a study done in which people undergoing hormonal therapy in preparation for a sex change operation were given tests on spatial relationships before and after the hormone therapy. Women receiving hormone treatment to make them male scored better on the test administered after the treatment, while men undergoing treatment to become female did slightly worse on the same test after hormone treatment. These results suggest that there is something about the hormones that alters the way the mind works, with female-associated hormones resulting in lower spatial ability and male-associated hormones resulting in greater spatial ability.

Previous Experiences. While there is a difference in the abilities of males and females, training and experience can improve results and seem to benefit males and females equally. Baenninger and Newcombe (Kimura, 1999) found that there was no closing of the gender gap in spatial abilities as a result of equal, short-term spatial instruction. This was contrary to their hypothesis that equal training and experience would help increase female scores more dramatically because of the female group's lower level of initial ability. If this same result were to hold true in this study, then all students demonstrating growth in creating orthographic drawings should be able to make similar amounts of progress from pre-test to post-test after practice and instruction over a four-week period.

Kimura (1999) identified a number of experiences that seem to increase spatial abilities. These experiences include participation in some types of sports, video game playing and car repair. In childhood, playing with build blocks such as legos also contributes to increased success in spatial tasks. Kimura also speculated that those who enjoy these spatial ability enhancing activities are initially above average in spatial ability, and simply tend to enjoy taking part in activities that they find easy, engaging and challenging. Kimura further concluded that any early advantage in spatial abilities continues to increase as children with high spatial abilities tend to gravitate toward activities that help develop these skills throughout their childhood. Because males tend to be more capable of succeeding in spatial ability related tasks early in childhood, males and females tend to increase the initial skill level gap through their choice of leisure activities.

Age. Age is another individual trait often linked with the ability to perform well on spatial visualization assessments. This difference can be in part explained by the way a child progresses through the stages of cognitive development identified by Jean Piaget (Ginsburg & Opper, 1979). The stage that seems to play a large role in allowing a child to mentally visualize objects is the formal operational stage. The formal operational stage is the stage in which students begin to demonstrate the ability to think abstractly. Piaget claimed that most people develop the ability to think abstractly between the ages of 15 and 20 years with some developing this ability as early as 11 years of age (Ginsburg & Opper 1979). Piaget also observed that some teens as well as adults do not show signs of reaching the formal operational level in some cognitive areas while they may in others. This observation would tend to support Gardner's theory of multiple intelligences mentioned earlier.

Piaget attributed an apparent lack of ability in abstract thinking to the subject's lack of familiarity with the topic. He theorized that experience and domain specific knowledge play a large role in determining one's ability to think abstractly and perform mental operations such as making mental rotations or making the 3-D to 2-D transformations needed to be successful in creating orthographic drawings. If experience is a factor in developing spatial visualization, then it would seem that an older student would generally be more capable than a younger student. According to Piaget's theory, the important factor associated with age would be whether the student has entered the formal operational stage in the specific area of spatial relations. As the age of the child increases, the likelihood that they are in the formal operational stage increases, giving the advantage again to the older students in the class.

Mathematical Ability. In mathematics, males generally do better in problem solving and geometry (Kimura 1999). On the other hand, females seem to have an advantage in the area of mathematical computations. Technical drawing text books often contain sections on descriptive geometry. Entire books on the topic of descriptive geometry can also be found under the category of geometry in the mathematics section of libraries. The inclusion of descriptive geometry in mathematics and technical drawing textbooks indicates that there are skill sets that both disciplines share in common. Students who are successful in descriptive geometry in a mathematics course, can logically be expected to succeed in descriptive geometry exercises found in a technical drawing course. Mathematics researcher Olkun (2003) recognized a link between mathematical ability and success in technical drawing. Olkun claimed that math students benefit from receiving direct instruction on engineering drawing as a way to improve their spatial abilities.

The link between mathematical abilities and spatial abilities may be explained by Piaget's theories on cognitive development. While reaching the formal operational stage is important to the development of spatial abilities, it has also been found to be equally important in a student's ability to perform some mathematical functions (Sigel & Cocking, 1977). Success in both mathematics and spatial tasks requires a level of cognitive maturation and the ability to think abstractly that Piaget described in his discussion of the formal operations stage of cognitive development.

Testing Spatial Abilities

Spatial intelligence is one type of intelligence that can easily be measured in the form of a test. Therefore spatial intelligence is a large component of general intelligence tests (International, 2005). In an on-line search of IQ tests, it was found that items related to spatial intelligence can comprise 20% of the test makeup (Tickle, 2005). This is because, of the seven intelligences described by Gardner, two are not easily assessed in a web-based test format. Because spatial intelligence is such a large factor in determining the measure of overall intelligence, there are whole books dedicated to testing and improving spatial skills (Turner, 1972). For similar reasons, spatial visualization test items are often included on occupational aptitude tests.

Strength in spatial tasks has traditionally been used as a predictor of candidate potential in pre-employment screening assessments. The Department of Defense uses an aptitude test called the Armed Services Vocational Aptitude Battery (ASVAB) in order to assess a recruit's potential for success based on their skill level in specific domains. They also use the results of this test to place the recruit into an occupational category that fits his/her skill set. Because of the importance of spatial visualization skills in some careers found within the military, the Department of Defense added a section to the ASVAB in December of 2002 called "Assembling Objects" that is a computer-based test that is designed to assess the spatial abilities and mechanical aptitude of new recruits (Powers, 2005).

A common aptitude test that assesses mechanical abilities is the *Detroit Mechanical Aptitude Examination* (Baker, Voelker, & Crockett, 1939). This mechanical aptitude test includes several specific aspects of spatial visualization such as visually estimating length, rearranging puzzle pieces into a meaningful picture, and interpreting the direction and estimating the relative speed of a pulley driven by a belt connected to another pulley. Although this test measures spatial abilities to some extent, much of the focus of this exam is on mathematics and other areas of knowledge and skill related to success in mechanical fields. Another set of spatial intelligence tests are found in Turner's (1972) *Mechanical Aptitude and Spatial Relations Tests.* Some of the tests are similar to the *Detroit Mechanical Aptitude Examination*, but this book also has additional tests that focus on skills that seem to be more closely related to those needed to succeed in creating orthographic drawings.

For the purpose of this study, a more specific and narrowly focused set of tests were needed. Since there were many tests available to measure spatial abilities, yet not directly related to creating orthographic drawings, this researcher consulted a number of drafting workbooks and the aforementioned spatial abilities tests in order to create a set of test instruments that would measure student skills in the spatial tasks most necessary for success in creating orthographic drawings.

A Comparison of Visual Aids

Most textbook sources used in introductory drafting courses explain the placement of views in an orthographic drawing through the use of the Box visual aid. Based on three years of observations made while teaching the Basic Graphics course, this researcher has found that the Box visual aid alone was helpful to the majority of students but it did not help all students to understand the correct placement of views in an orthographic drawing layout. No textbooks (Berg, 1966; Bertoline, Wiebe, Miller & Nasman, 1995; Bethune & Kee, 1989; Brown, 1978; Carter & Thompson, 1943; Coover, 1966; Earle, 1985; French & Svensen, 1966; French & Vierck, 1978; Fox, 1907; Giachino & Beukema 1978; Goetsch, Nelson & Chalk, 1989; Grant, 1965; Hornung, 1957; Madsen, Folkestad, Schertz, Shumaker, Stark, & Turpin, 2002; Spence, 1973; Sundberg, 1972; United States. Dept. of the Army and the Airforce, 1962; Walker, 1982; Weaver, 1975; Weaver, 1982; Welch, 1959; Woolven, 1967) other than Spencer, Dygdon & Novak (1995) offered an alternative explanation to the Box visual aid, and no source was found with any illustration or description of a Bowl visual aid as a model for describing the correct view placement in orthographic drawings.

As a beginning machinist this researcher was given an explanation of a bowl-based model by K. Fozzler (personal communication, June, 1996) that helped him remember the correct placement of orthographic views within a layout. In his explanation, Fozzler made no claim that he was the originator of this explanation; rather, he was simply passing on a useful bit of advice to a co-worker. This explanation was easy to understand when an actual object was compared to an orthographic drawing. This researcher was able to gain a greater understanding of the orthographic drawing itself by simply manipulating the object to make it correspond with the orthographic drawing. After hearing this concept, orthographic drawing layouts immediately made much more sense. This researcher quickly abandoned the Box visual aid in favor of Fozzler's bowl-based organization aid referred to in this paper as the Bowl visual aid.

This organizational aid appears to have been shared within the manufacturing industry. An on-line source in a chat forum for Autocad users described the organizational framework of a bowl. Spirit's (2004) explanation was the same as the one offered by Fozzler. Spirit indicated that he had learned this explanation from someone else in a manufacturing environment. He also stated that this explanation was easier for him to understand than previous explanations. In both cases the bowl explanation was offered to help compare orthographic drawings to completed objects, not to explain how to draw the orthographic drawings correctly. This investigation was conducted to determine whether a visual aid in the shape of a bowl could be a helpful alternative to the traditional Box visual aid used in the drafting and design environment to help students learn to create orthographic drawings.

In comparing the two visual aids used in this experiment, one difference is apparent. The two visual aids seem to rely on either the student's ability to mentally unfold an object as in the hinged glass Box visual aid, or to mentally rotate an object as in the case of the Bowl visual aid. It is this researcher's opinion that the Box visual aid relies on the ability of the student to mentally unfold an imaginary box, an area of spatial abilities that has a female advantage (greater success in this concept). Because females demonstrate an advantage in folding and unfolding objects (Kimura, 1999) this researcher would logically expect to find a female preference for the Box visual aid when learning orthographic view placement. The Bowl visual aid however, relies on the students' ability to mentally rotate an object, an area of spatial abilities that has a strong male advantage. The male advantage in making mental rotations could lead to the logical expectation that males would find the Bowl visual aid more effective in explaining orthographic view placement.

The Need for a Bowl Preference Profile

The results of this investigation would be more beneficial to the classroom teacher if a profile could be created that identified the common characteristics of students who find the Bowl visual aid more helpful than the Box visual aid. One way to find shared characteristics of a sub-group within a larger group is through a type of data analysis known as discriminate analysis. Discriminant analysis is a tool within the Statistical Package for the Social Sciences (SPSS) program commonly used in research to perform a number of tasks such as: determining the best way to distinguish members of one group from members of another group, classify individuals into groups depending on bits of data that are related to determining group membership and lastly in testing the predicted profile against the original data, to test the accuracy of the profile generated by discriminant analysis (Garson, n.d.). While discriminant analysis can be used for many other applications, the uses above are those that pertain to this study.

The creation of profile for students who would likely prefer the Bowl visual aid could be a great way to help teachers identify students who may struggle in creating orthographic drawings after seeing only the Box visual aid demonstration. By identifying those students at the beginning of the orthographic drawing unit, drafting instructors would be able to meet the needs of these students more efficiently. This researcher teacher sought to establish a profile of a student who would find the alternative Bowl visual aid helpful based on student responses to a simple survey or based on pre-test scores.

Chapter 3:Research Methods

The methods and procedures used in this investigation to determine the effectiveness of the Bowl visual aid used to demonstrate orthographic drawing conventions are divided into the following headings: Description of Research Method, Selection of Subjects, Instrumentation, Procedures and Analysis of Data.

Description of Research Method

The research method used in this study is based on the one-group pre-test/post-test research model. In this study, the one group was made up of high school students enrolled in three separate course sections by Franklin High School's class scheduling program prior to the beginning of this study. Students in all sections received equal instruction on how to create correct orthographic layouts. This research model was selected to partially address the potential differences in the makeup of the three sections of the course due to external factors beyond the control of the researcher and also due in part to the small number of participants within each of the three course sections. These two factors would have made it difficult, if not impossible, to create a true control group to which results could be compared. Equal treatments were also used to reduce the possibility of skewed data collected through the use of unequal samples.

Selection of Subjects

This investigation was carried out in a CAD lab at Franklin High School, using students enrolled in all three sections of the Basic Graphics course. These course sections were generated by the school's computerized scheduling program based on student course requests. There were 15 student participants in two sections of the course and 21 participants in the third section. As a result of using predetermined sections, the individual course sections may have been made up of participants who shared traits relative to the predictors of spatial task success in disproportionate levels when compared to the prevalence of those traits in the other two sections of the same Basic Graphics course. For example, if only one section of an honors mathematics course was offered, it may have caused students taking this math course to enroll in greater numbers in one section of the Basic Graphics course, while another section of Basic Graphics offered during the time of this math course may have no students in higher level math courses due to scheduling influences.

The participants in this study were selected due to their choice to enroll in Basic Graphics, the first course in the drafting and design sequence at Franklin High School. Students participating in this study ranged in age from 14 to 17 years of age. Participants also had varying levels of over-all ability but similar to the range of abilities that one might expect to find in an upper-middle class suburban high school. Most students participating in this study were male, as only 10 of the 51 participants were female. The demographic make-up of the separate sections of the Basic Graphics course was not a primary concern in this investigation due to the design of this research. The traits of the individuals themselves were the most important characteristics of the participants as they were used to create the Bowl preference profile

Of the 51 participants, only a few students were not able to participate in all surveys and complete all of the test instruments. The two reasons for mortality in this investigation were, in one case, a lengthy absence and in three cases, the participants returned incomplete surveys. Of the assessments that were given, only one, the Missing Lines pre-test, experienced mortality during the course of this investigation. This is because one student simply did not take the pre-test. Three participants did not complete the Student Profile Survey in full. In particular, they did not respond to the hobby-related questions on the survey. These missing replies were treated as negative responses. Unless otherwise stated, all results are based on all 51 student participants.

Instrumentation

Because spatial intelligence encompasses such a broad range of skills, standard spatial abilities tests include items unrelated to the focus of this study. The three specific spatial abilities necessary to create correct orthographic projection drawings are the ability of participants to make 3-D to 2-D transformations, the ability to make mental rotations and the ability of students to mentally fold flat patterns into three-dimensional objects. In addition to these basic abilities, a basic understanding of orthographic drawing standards is also needed.

The individual spatial abilities test instruments used in this study were created by the researcher and were in part based on spatial abilities tests found in a compilation of spatial tests (Turner, 1972) and other worksheets found in various drafting workbooks (Jensen, Briggs, DiMonte & Sarrubbo,1981; Gerevas, 1972; Spencer, Dygdon & Novak, 1995) as well as worksheets created by previous instructors at Franklin High School. All of these test instruments were pilot-tested on five individuals who were not participants in this study to ensure the clarity of the directions given to the participants and the accuracy of the instrument. Once the first individual completed all sections of the instrument, revisions were made, if needed, and then the second individual completed the entire instrument and so on. Once the five revision steps were completed, the instruments were tested on two course sections who were not participants in this study. Over the course of the revisions and pilot-testing, the directions were easily understood, and no errors were found within the test beyond the second revision.

The full test instrument used for both the pre-test and post-test consisted of seven items. These tests were designed to measure student skill levels in activities that, in part, contribute to a student's ability to successfully create orthographic drawings. Table 3.1. is a listing of the first five pre-tests that were based on specific spatial abilities. Table 3.1 identifies the spatial ability that each test is designed to measure and also gives the percentage weight of each of the tests when calculating the total Spatial Abilities Battery score. The final two test items in the complete instrument were the Orthographic Sketching pre-test and the Missing Lines pre-test which were both used to assess orthographic projection comprehension proficiency.

Table 3.1. Pre-tests developed to assess the spatial ability levels of students.

Pre-test Name	Spatial Ability Assessed	% of Total Battery Score
Mental Rotations	Rotational Abilities	33%
Folding Abilities	Folding Abilities	33%
Surface Identification	3-D to 2-D transformations	11%
Single View Isolation	3-D to 2-D transformations	11%
Orthographic/ Isometric Matching	3-D to 2-D transformations	11%

The Mental Rotations test (Appendix D) used in this investigation was a fifteen item test that first presented an isometric object. Students were then asked to choose from a pool of four possible choices. Students were to identify which choice was the same as the original object, only rotated to a different position. In some examples on the Mental Rotations test, the object was rotated about one axis, in other examples the object was rotated about two axes. False choices were also loosely patterned after the false choices found in Turner (1972). The shapes of these objects were changed so that the assessment was new for this study. This test included a sample item to demonstrate how the test should be completed. The results of the Mental Rotations test were reported as the average percent of correct answers for each of the three preference groups in Table 4.4.

The Folding Abilities test (Appendix E) used in this investigation consisted of seventeen item test that first presented an unfolded shell of an object. Students were then asked to identify which of four isometric choices the unfolded shell would look like if it were folded into its three-dimensional form. This assessment was also based on the folding spatial abilities test found in Turner (1972). Changes were made to the shapes of the objects in Turner's test in the same manner as in the Mental Rotations test. This test, like the Mental Rotations test, also included a sample item to demonstrate how the test should be completed. The results of the Folding Abilities test were reported as the average percent of correct answers for each of the three preference groups in Table 4.4.

For the purpose of this experiment, the ability of participants to make 3-D to 2-D transformations was considered to be critical. Three separate tests were created to measure the ability to make 3-D to 2-D transformations. The three 3-D to 2-D transformations tests used in this investigation were based on exercises found in a number of drafting workbooks (Jensen, Briggs, DiMonte & Sarrubbo,1981; Gerevas, 1972; Spencer, Dygdon & Novak, 1995). These three 3-D to 2-D transformation tests were grouped together and, as a group, they were weighted equally to the Mental Rotations test and the Folding Abilities test when calculating the total Spatial Abilities Battery score.

The Surface Identification test (Appendix B and C) was the first test used to determine student proficiency in 3-D to 2-D transformations. This test asked the student to view an object in isometric form with each of its individual surfaces labeled. Students were asked to place the labels from the isometric drawings on the corresponding surfaces of the orthographic drawings that accompanied the labeled isometric drawing. The scoring of this instrument was completed by assigning each surface label a value of one point. The results of the Surface Identification test were reported as the average percent of surfaces labeled correctly for each of the three preference groups in Table 4.4.

The second 3-D to 2-D transformation test was the Single View Isolation test (Appendix F) which asked students to view isometric views of simple objects and to identify the correct choice of five possibilities for a single predetermined orthographic view of that object. The results of the Single View Isolation test, which consisted of 30 objects, were reported as the average percent of correct answers for each of the three preference groups in Table 4.4.

The third 3-D to 2-D transformation test, the Orthographic/ Isometric Matching test (Appendix G) asked students to match sixteen objects drawn in isometric form to their corresponding full orthographic layout from a pool of twenty-four choices. The pool of possible answers consisted of sixteen correct choices for this instrument along with eight additional incorrect choices. The results of the Orthographic/ Isometric

Matching test were reported as the average percent of correct answers for each of the three preference groups in Table 4.4.

In order to identify a deeper understanding of the principles of orthographic projections, two additional tests were designed. One such test, the Orthographic Sketching test (Appendix H), asked participants to correctly translate eight isometric drawings on an isometric grid to their orthographic equivalent on a standard two-axis grid. The scoring of this test item was the most subjective of all tests in this study. Each of the eight examples was assigned 12 points. These 12 points were divided into each of the three necessary views, giving each individual view a value of 4 points. If a view was drawn correctly and in its correct location, it was awarded all four points. If the view was flawed, points were subtracted for that individual view based on the fraction by quarter of the drawing that was correct. For example, if a student completed a view that was about half correct, they earned two points of four. If that view was out of place or rotated, an additional point was subtracted, reducing the score for that view to one point. The lowest score a student could receive on an individual view was zero. The results of the Orthographic Sketching test were reported as the average percent of the drawings created correctly for each of the three preference groups in Table 4.4.

The sketching format was chosen for the Orthographic Sketching test instead of a CAD based test to eliminate errors that students might make due to the introduction of another variable in the form of a software program. This assessment was the primary tool used to measure the improvement the students made in correctly placing individual views in an orthographic layout after instruction.

The second test of orthographic projection comprehension was the Missing Lines test (Appendix I) which asked the participants to use their knowledge of the relationships between the individual views of an orthographic layout to finish incomplete layouts by drawing the missing lines in the correct locations. Participants earned points on this item by correctly sketching in the missing lines. No points were deducted for incorrect lines. The results of the Missing Lines test (which consisted of 65 missing lines) were reported as the average percent of correct lines drawn for each of the three preference groups in Table 4.4.

These two orthographic projection comprehension assessments were administered as both pre-tests and post-tests to obtain a base level of ability in orthographic drawing as well as to measure the growth of the participants' abilities after the visual aids were explained. The Orthographic Sketching and Missing Line test items were created based on a composite of related test and worksheet items found in various drafting workbooks (Jensen, Briggs, DiMonte & Sarrubbo,1981; Gerevas, 1972; Spencer, Dygdon & Novak, 1995). In both tests, any occurrences of projection line use and mitre line use were recorded as present or not present for each student. This was done to determine the number of participants who were using techniques that indicate a deeper understanding of the relationships between the individual views of an orthographic layout.

In addition to the spatial abilities test instruments designed for this study, two survey tools were designed to gather information before and after the orthographic drawing unit. The Student Profile Survey (Appendix A) asked the participants to provide information on each of the four factors (age, gender, mathematical ability and experience) that indicate likely student success in creating orthographic drawings as identified in

Chapter Two. This information was used along with data gathered from the spatial abilities pre-tests to create the profile of students who may prefer the Bowl visual aid.

On the Student Profile Survey, students either indicated "yes" or "no" to a series of questions about hobbies or educational experiences that might indicate exposure to tasks involving the use of the three skills tested in the pre-tests of this investigation. The occurrences of reported experiences were then added together to determine separate total exposure ratings for the hobbies and for the educational experiences that could have given students an advantage in the spatial abilities pre-tests due to a participant's previous experience. Another experience that could be related to the development of spatial abilities in childhood is the frequency with which children play with building block toys. Participants reported how frequently they played with these types of toys through the use of a likert scale on which a rating of 1 indicated that the participant never played with building block type toys while a rating of 5 indicated that the participants played with these types of toys all the time.

The self-reported math GPA was determined by asking students to circle a letter grade or range of letter grades they usually receive in their math courses. The math GPA was calculated based on a standard 4.0 scale with those indicating "A/B" as their most common math grade scoring 3.5, indicating that they were between the "A" and the "B". This researcher assumed that the nature of the mathematical experiences could also be interpreted as an indication of a student's mathematical ability. The student participants also were asked to indicate the courses they had taken by placing a check next to the name of the courses they had taken or were currently taking. This information was collected in order to identify those participants that were in a general, remedial or advanced track of mathematics.

The final survey used in this investigation was the Student Feedback Survey (Appendix J) given to determine the participants' perceptions of the helpfulness of each visual aid in order to determine whether students had a preference for one of the two visual aids when learning about view placement in orthographic projections. The first two questions on this survey asked the students to rate the helpfulness of each of the two visual aids used in class to explain view placement in orthographic drawings. A likert scale from 1 to 10 was used, with 1 indicating "not helpful" and 10 indicating "very helpful." The third question on this Student Feedback Survey asked students which method of instruction (Box only, Bowl only, both or neither) the teacher should use next year when teaching the unit. The final item on this survey asked the participants to explain their reasons for the recommendation they made in the third question.

Data Collection Procedures

The Student Profile Survey (Appendix A) was administered in the very beginning of the school year. This survey was distributed in class and students were asked to take it home to complete. The next day, the surveys were collected in a "ballot box" type format so that the result of the survey would be known only to the student and the investigator. The main purpose of this information was to gather information about the individuals that were willing to participate in this study in order to create a profile of students who found the Bowl visual aid more helpful. In this experiment, only one of the eligible candidates chose not to participate.

At a later date in the course, at the beginning of the unit on orthographic drawings, the Surface Identification, Mental Rotations and Folding Abilities tests were given during the course of one 50 minute class period. The following day, the Orthographic/ Isometric Matching test was given after the participants had viewed a demonstration on the relationships between the views of an object within an orthographic layout. This was described by manipulating a solid object to show the appearance of the individual views of an object. Projection lines were also used between the views to show how each of the views are related to each of the other views. On this second day of pre-tests, participants also completed the Single View Isolation test and began the Orthographic Sketching item. On the third and final day of pre-tests the participants finished the Orthographic Sketching test and the Missing Lines test.

The instruction phase of the unit began on the fourth day of the unit. This class period consisted of direct instruction on surface identification using class demonstrations and worksheets to improve student proficiency in 3-D to 2-D transformations. On the fifth day of the unit, participants received instruction on orthographic projections using the glass Box visual aid to demonstrate the correct location and orientation of the views of an object in orthographic layouts. This instruction was delivered through a lecture conducted in small groups using a hinged Plexiglas box in order to fully explain and demonstrate the Box visual aid. On this same day, the students also received instruction in small groups on orthographic drawings using the Bowl visual aid to demonstrate the correct location and orientation of the views of an object in orthographic layouts This instruction also consisted of lecture using a large bowl with a transparent lid as its top surface (see Appendix K). The Bowl visual aid had an access hole in one side so that the object placed inside could be rotated along the sides of the bowl into the correct position on the transparent top surface by the instructor.

After receiving direct instruction on the use of the two visual aids, students worked on orthographic sketches as well as CAD drawings. This drawing phase began on the sixth day of the unit and continued for a total of twelve class periods of 50 minutes in length. Students worked on orthographic assignments and were encouraged to use projection lines between the views to make sure that the views were in alignment with the other views in the layout. These assignments included three class periods of orthographic sketching on grids and exercises in drawing the missing views within a layout. Students then drew various objects over the course of eight class periods in orthographic form using AutoCAD. The final activity of this practice phase was devoted to the topic of missing lines in orthographic drawings. This topic was included to demonstrate how projections between the views could be used to determine where missing lines should be drawn to complete unfinished drawings.

This unit concluded with a three day test phase in which the same pre-test instruments were administered as the post-test. The tests were given in the same order, with the same tests given on the same testing days as reported earlier in the pre-test. Upon completion of the Orthographic Sketching and Missing Lines post-tests, the assessments were checked for evidence that the student used projection lines. On the final day of testing, upon completion of the Missing Lines test, participants were also asked to respond to the Student Feedback Survey (Appendix J). This survey asked students to rate the helpfulness of the two visual aids in learning to draw orthographic layouts and recommend how this unit should be taught next year while supplying a reason for their suggestion. These surveys were also collected in the same "ballot box" format so that the results of the survey would be known only to the student and the investigator.

Data Analysis

In order to separate the participants into groups according to which visual aid they found to be more helpful, a score differential was created by comparing each student's responses to the first two questions of the Student Feedback Survey. The questions were as follows:

1. How helpful was the Bowl method in explaining view placement in orthographic drawings?

2. How helpful was the Box method in explaining view placement in orthographic drawings?

The participant's likert scale rating of the Box visual aid's helpfulness was subtracted from the Bowl visual aid's helpfulness rating to create the differential score. A differential of 0 indicated that the student found both visual aids to be equally helpful, thus they had no preference toward either visual aid. A positive differential indicated that the student found the Bowl visual aid more helpful than the Box visual aid and they were classified as showing a preference toward the Bowl visual aid. A negative differential indicated that the student found the Box visual aid more helpful than the Bowl visual aid and they were classified as showing a preference toward the Box visual aid.

Once the preference groups were established, it was possible to isolate the members of the group that preferred the Bowl visual aid. The data was then statistically analyzed to find whether the resulting gains from pre-test to post-test indicated that those who preferred the Bowl visual aid actually improved their scores in the Orthographic Sketching test (Appendix H). The responses to the final two questions on the Student Feedback Survey responses were also reviewed to find out what most students thought would be the best approach when teaching this class next year. The questions were:

3. Next year Mr. Kurszewski should: (check one please)

_____ Teach the **Box** method only

_____ Teach the **Bowl** method only

_____ Teach **both** methods again

_____ Teach **neither** method

4. Please tell me why you chose box, bowl, both or neither in question 3.

Finally, correlation tests and discriminant analysis of the data was conducted using SPSS's discriminant analysis function in an attempt to create a profile of a student that would likely prefer the alternative Bowl visual aid. The data used to create the profile was obtained through the Student Profile Survey (Appendix A) and from student scores on the various spatial abilities pre-tests (Appendices B thru I). Discriminant analysis and Pearson's correlations identified important characteristics of the Bowl preference group that could be used to predict membership of this group. By identifying these traits in advance of the orthographic drawing unit, an instructor would be able to adapt the instruction of the unit in a way that better addressed the needs of the students in the drafting classroom.

Limitations

There are four main limitations to the methodology and procedures used in this study. The first and perhaps the most serious limitation is that the demographic make-up and size of the course sections were created by the student scheduling program and not by the researcher, severely limiting control over many possible variables that relate to predictors of success in spatial tasks. Due to the way participants were selected, control groups and separate treatments of each group were not possible.

A second limitation of this study was the use of a number of unproven instruments in gathering the data needed to conduct this study. The true reliability of the spatial abilities test instruments is unknown.

The interaction between individual members of the three sections of the Basic Graphics course is a third limitation. One of the three course sections had a higher number of students in the class. Because of the large class size in the section, the students may not have received instant help from the instructor and, as a result, they may have been more prone to seek help from one of their classmates. In the second course section, the number of students in the class was smaller, yet the students in that section of the course had more questions and needed more individual help in order to operate independently. This group often took longer to get on track because of the higher proportion of "needy" students within the group. Thus, students would often seek help from their peers when encountering difficulties. The third course section had about the same number of students as the second course section. This group however, seemed to have a more capable group of students evident by their fewer questions, a higher rate of achievement on assignments in all drafting units, and greater access to the instructor when facing difficultly with class assignments.

The fourth limitation to the method of this study was a result of the gender imbalance that existed within the group. To be able to draw more valid conclusions from a study of this nature, a larger group of female participants would have been desired.

Summary

Students in this study were willing participants enrolled in three sections of Franklin High School's Basic Graphics course. The demographics of the students, especially the disproportionately high percentage of male students participating in this study was a limitation. Two other limitations in this study were the lack of a randomly selected group of participants as well as the unavoidable interaction between the students in each course section. A final limitation was the use of untested spatial abilities test instruments used to gather data.

Data was collected through two surveys and seven spatial abilities tests. Initially students were asked to respond to questions related to spatial ability level predictors. The spatial abilities pre-tests were then given to students before they received instruction on orthographic drawing to determine their initial spatial ability level for skills necessary for success in creating orthographic drawings. The instruction phase included demonstrations using the two visual aids in this study, which was then followed by practice time. Upon completion of the practice time, the pre-tests were administered as post-tests to determine the level of student growth in creating orthographic drawings. Students were then surveyed to find their opinions of the helpfulness of each visual aid and to solicit their recommendations for future instruction.

Chapter IV: Findings

In the course of this investigation data was obtained through the use of two surveys and seven visualization tests given as both pre-tests and post-tests. The first data collecting instrument used was the Student Profile Survey (Appendix A). This instrument was used to collect data related to the predictors of spatial task success discussed in Chapter Two. The seven pre-test scores were also used to create a profile of students who may prefer the Bowl visual aid when learning to create orthographic drawings. The final survey, the Student Feedback Survey (Appendix J), asked students to report how helpful they thought each of the two visual aids were in helping them understand orthographic drawing layouts.

Perceptions of the Bowl Visual Aid

Research Question 1 was: "Are there students who find the Bowl visual aid more helpful than the Box visual aid when learning to create orthographic drawings?" The first two questions on the Student Feedback Survey asked respondents to rate the helpfulness of each visual aid by selecting a number on a likert scale ranging from 1 to 10. On this scale a score of 1 indicated that the respondent found the visual aid "not helpful at all"; a score of 5 indicated that the respondent found the visual aid "somewhat helpful"; and a score of 10 indicated that the respondent found the visual aid "very helpful". Based on their responses to these two questions, students were categorized into three preference groups (Box, Bowl or Neither) according to which visual aid they gave a higher score. Table 4.1 shows the number of respondents in each group and the average helpfulness rating for each of the visual aids. All participants in this study provided data for these survey items.

Table 4.1 Visual aid preference group membership including helpfulness ratings given to both visual aids by each preference group.

Visual Aid Preference Group	Number of respondents	% of participants	Average Box rating	Average Bowl rating
Box Visual Aid	29	56.9%	8.3	6.1
Bowl Visual Aid	12	23.5%	6	7.8
Neither Visual Aid	10	19.6%	7.5	7.5
All Respondents	51	100%	7.6	6.8

When the respondents were grouped by visual aid based on the differential score outlined in Chapter Three, the data shows that most students (56.9%) found the Box visual aid to be more helpful. The Bowl visual aid was the preferred visual aid for 23.5% of respondents, while a similar number (19.6%) were found to give the same score to both visual aids. On average, respondents in each group thought both visual aids were at least somewhat helpful, as the average scores for both visual aids by group were all 5 out of 10 or greater. In five individual cases, the respondents indicated that they found at least one of the visual aids to be less than somewhat helpful. The only student reporting both visual aids were of little help was a student who had no preference for either visual aid.

This study has found that the answer to Research Question 1 is yes; there are students who find the Bowl visual aid more helpful than the Box visual aid when learning to create orthographic drawings. There were 12 students (nearly 24% of the sample) who rated the Bowl visual aid more helpful than the glass Box visual aid.

Growth Demonstrated by Those Preferring the Bowl Visual Aid

Since it was found that some students preferred the alternative Bowl visual aid, Research Question 2 was investigated. Question 2 was, "Do students who indicate a preference for the Bowl visual aid demonstrate significant improvement between pre-test and post-test?" This question was investigated to determine whether members of the group demonstrating a preference for the Bowl visual aid actually improved their ability to create accurate orthographic drawings. If students who preferred the Bowl visual aid did not show significant improvement in creating orthographic drawings, there may be no benefit to their exposure to the Bowl visual aid. For the Bowl visual aid to be considered worth using for future instruction, students who indicated that they found the Bowl visual aid more helpful than the Box visual aid must show some level of improvement. To answer this second research question, the pre-test and post-test results of the Orthographic Sketching test administered during this experiment were analyzed through the use of a paired T-test to determine whether significant improvement was made by the 12 members of the Bowl preference group. Table 4.2 shows the results of the paired T-test comparing pre-test and post-test results of the Orthographic Sketching test. The differences between the scores (improvement) was significant at the .01 level. Even though the results show that Bowl preference group students showed significant improvement in their ability to create orthographic sketches, it can not indicate that the Bowl visual aid was responsible for this gain. The data simply shows that students who found the Bowl visual aid more helpful than the Box visual aid improved significantly.

Table 4.2 Comparison of Orthographic Sketching pre-test and post-test results for students who preferred the Bowl visual aid (Paired T-test).

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Orthographic View Placement Pre-test	54.42	12	20.367	5.879
	Orthographic View Placement Post-test	81.75	12	12.686	3.662

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Orthographic View Placement Pre-test & Orthographic View Placement Post-test	12	.779	.003

Paired Samples Test

		Paired Differences					
					95% Confidence Interval of the Difference		
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t
Pair 1	Orthographic View Placement Pre-test - Orthographic View Placement Post-test	-27.333	13.166	3.801	-35.698	-18.968	-7.192

Paired Samples Test

		df	Sig. (2-tailed)
Pair 1	Orthographic View Placement Pre-test - Orthographic View Placement Post-test	11	.000

Student Recommendations for Future Instruction

Research Question 3, "Which approach (Bowl, Box, both or neither) do students feel is best to use when teaching third angle orthographic projection view placement", was investigated by examining the third and fourth questions on the Student Feedback Survey. The third question on the Student Feedback Survey asked students which approach they recommended when the orthographic drawing unit is taught next year: a) teaching only the Box visual aid, b) only the Bowl visual aid, c) both visual aids or d) neither visual aid. This survey allowed students to share their perceptions of the effectiveness of the visual aids used in this experiment.

The fourth survey question asked respondents to explain why they made their choice in question three. The recommendations and comments they made in questions three and four indicated that many respondents believed there was value in demonstrating both visual aids. Table 4.3 lists the numbers of responses given in favor of each of the four teaching approaches.

Table 4.3 Recommendations made for next year's orthographic drawing instruction including the helpfulness rating of each visual aid by recommendation group.

Recommendation For Future Instruction	Percent of Students who Recommended	Average Helpfulness Rating of Bowl Visual Aid	Average Helpfulness Rating of Box Visual Aid
Use the Box visual aid only	29%	5.4	8.2
Use the Bowl visual aid only	13%	7.3	5.7
Use both visual aids	59%	7.4	8.2
Use neither visual aid	6%	8.0	6.3

There were fifteen respondents who recommended that next year the Box visual aid should be the only visual aid demonstrated in the orthographic drawing unit. On a scale of 1 thru 10, these fifteen respondents gave the Bowl visual aid an average score of 5.4 and the Box visual aid an average of 8.2. Six of the 15 respondents within this group commented in survey question four that the viewing planes were easier to visualize and that the relationships between the views of the object were easier to comprehend through the use of the Box visual aid. Two of the 15 respondents indicated that they liked the Box visual aid because the object remained stationary when viewed. Three of the 15 respondents also commented that the Bowl visual aid was too confusing. One respondent thought the Box visual aid was the best, and therefore the Bowl visual aid was redundant. Of all four groups, those who recommended the Box visual aid only indicated the greatest gap between the helpfulness ratings of the Bowl and Box visual aids.

There were seven students who recommended that next year the Bowl visual aid should be the only visual aid demonstrated. On a scale of 1 thru 10, they gave the Bowl visual aid an average score of 7.3 and the Box visual aid an average score of 5.7. Four of the seven respondents commented that the Bowl visual aid was easier to understand. Most students who recommended the Bowl visual aid commented that the Box visual aid confused them. One respondent reported that the Bowl was the superior visual aid because all three views of the object can be drawn on one surface, making it similar in appearance to what the student would draw on paper.

The majority of respondents (26 of 51) recommended that next year both visual aids should be demonstrated. On a scale of 1 thru 10, they gave the Bowl visual aid an average score of 7.4 The highest rating given to the Bowl visual aid by any group) and the Box visual aid an average of 8.2. Within this group however, there were differences of opinion on which visual aid the members of this group thought was most helpful. To explore these differences, this group was further divided into subgroups that either favored the Bowl or Box visual aids based on which one received a higher scale rating.

Four of the 26 respondents who recommended that both visual aids should be demonstrated in the future found the Bowl visual aid more helpful than the Box visual aid. On a scale of 1 thru 10, these four gave the Bowl visual aid an average score of 8.0 and the Box visual aid an average of 6.3. There were also seven students who recommended that both visual aids should be demonstrated even though they personally favored neither visual aid. These seven respondents gave the Bowl visual aid an average score of 8.3 and the Box visual aid an average of 8.3. The last subgroup was made up of fifteen students that recommended both visual aids, but personally favored the Box visual aid. These fifteen gave the Bowl visual aid an average score of 6.9 and the Box visual aid an average of 8.6.

The comments made by those students who recommended the use of both visual aids varied widely. Most students who recommended both visual aids (20 of the 26) commented that both visual aids were helpful. Eight of the 26 respondents suggested that more alternative explanations could help other students since people learn differently. Three added that they personally alternated between the two visual aid models depending on the situation and object they were drawing.

There was one final group of three respondents who suggested that neither visual aid should be taught in the future. Two stated that they felt they did not need a visual aid while the other suggested that students should be allowed to figure out orthographic drawing layouts by themselves so that they would have a better understanding of the topic.

This study has found that the answer to Research Question 3 is that students feel the best approach for teaching third angle orthographic drawings is to use both visual aids. Of the students responding to the Student Feedback Survey, 51 percent suggested both visual aids should be used when this unit is taught the following year. On the Student Feedback Survey, 47 of 51 respondents gave the Bowl visual aid a score that indicated the Bowl visual aid was at least somewhat helpful. Student replies on the Student Feedback Survey indicated that a majority of students suggest using both visual aids when teaching orthographic drawing as the best teaching method. The minority responses suggest that eliminating any one visual aid could have a detrimental effect on a moderate percentage of students enrolled in the drafting class.

The Bowl Preference Group Profile

The fourth and final research question was "What common traits are shared by students who find the Bowl visual aid more helpful than the Box visual aid?" To answer this question, the results of the pre-tests were examined after first segregating the groups according to the preferences indicated on the final Student Feedback Survey. Based on the respondent's answer to the first two questions in the Student Feedback Survey, a differential score was established for each student as outlined in the procedures section of Chapter Three. Once these differential scores were created, it was found that there were 10 students who showed preference for neither visual aid, 12 students who showed preference for the Bowl visual aid and 29 students who preferred the Box visual aid.

Throughout this investigation it was noted that the 12 students who preferred the Bowl visual aid generally achieved lower scores on all of the spatial abilities pre-tests. Table 4.4 reports the pre-test results sorted by visual aid preference including the five spatial abilities pre-tests as well as the pre-test of student's ability to sketch orthographic layouts and another pre-test of student's ability to draw in missing lines without the benefit of the Box or Bowl visual aids. The scores are reported for each preference group as the mean score of each preference group for that pre-test.

Table 4.4 Average pre-test scores for each visual aid preference group.

Spatial Abilities Pre-test	Mean Scores Bowl Preference Group	Mean Scores Box Preference Group	Mean Scores Neither Preference Group
Surface Identification	96.0%	94.8%	94.3%
Mental Rotations	63.3%	80.0%	80.0%
Folding Abilities	69.4%	77.6%	72.9%
Orthographic/ Isometric Matching	86.3%	90.6%	91.3%
Single View Isolation	92.7%	92.3%	92.3%
Complete Spatial Abilities Battery	75.6%	83.5%	81.9%
Orthographic Sketching	56.7%	68.4%	66.5%
Missing Lines	33.1%	46.3%	46.5%

A comparison of the means for each test shows a distinct achievement deficiency for the Bowl preference group as compared to the other two groups in the Mental Rotations pre-test, the Orthographic Sketching pre-test and the Missing Lines pre-test. There is a moderate achievement deficiency between the Bowl preference group and the other two groups in the Spatial Abilities Battery (a combined score of all five spatial abilities pre-tests), and the Orthographic/Isometric Matching pre-tests. In all of these pre-tests, the Bowl preference group demonstrated lower achievement than the other two groups, while only slight differences in mean achievement was observed between the Neither preference group and the Box preference groups.

The Bowl preference group did not always perform lower than the other two groups. The Bowl preference group scored higher than the other two groups in the Surface Identification pre-test and the Single View Isolation pre-test. In these two pre-tests, the Box and Neither preference groups scored identically, or nearly the same as each other. The only pre-test in which there was any real separation between all three groups was the folding abilities pre-test in which the Box preference group averaged moderately higher than the Neither preference group, and much higher than the Bowl preference group. Another finding from this data was that the Bowl preference group was the only group that achieved a higher group mean score on the Folding Abilities pre-test than on the Mental Rotation pre-test. Both the Box preference group and the Neither preference group scored collectively higher on the Mental Rotation pre-test than the Folding Abilities pre-test.

It was found that when individual scores on the pre-tests were ranked best to worst, the members of the Bowl preference group generally tended to make up the lower end of achievement on most of the pre-tests. In the Mental Rotations pre-test and the Missing Lines pre-test this trend was the strongest, with 75% of the Bowl preference group scoring below the median score of all participants on these pre-tests. The Missing Lines pre-test was completed by 50 students, all other tests were completed by all 51 students participating in this study. The results seem to indicate a deficiency in some spatial abilities, especially in the areas of mentally rotating an object and in correctly visualizing a view of that object after it has been mentally rotated. Figure 4.1 shows the percent of students in the Bowl preference group who scored below the median on each of the visualization pre-tests.

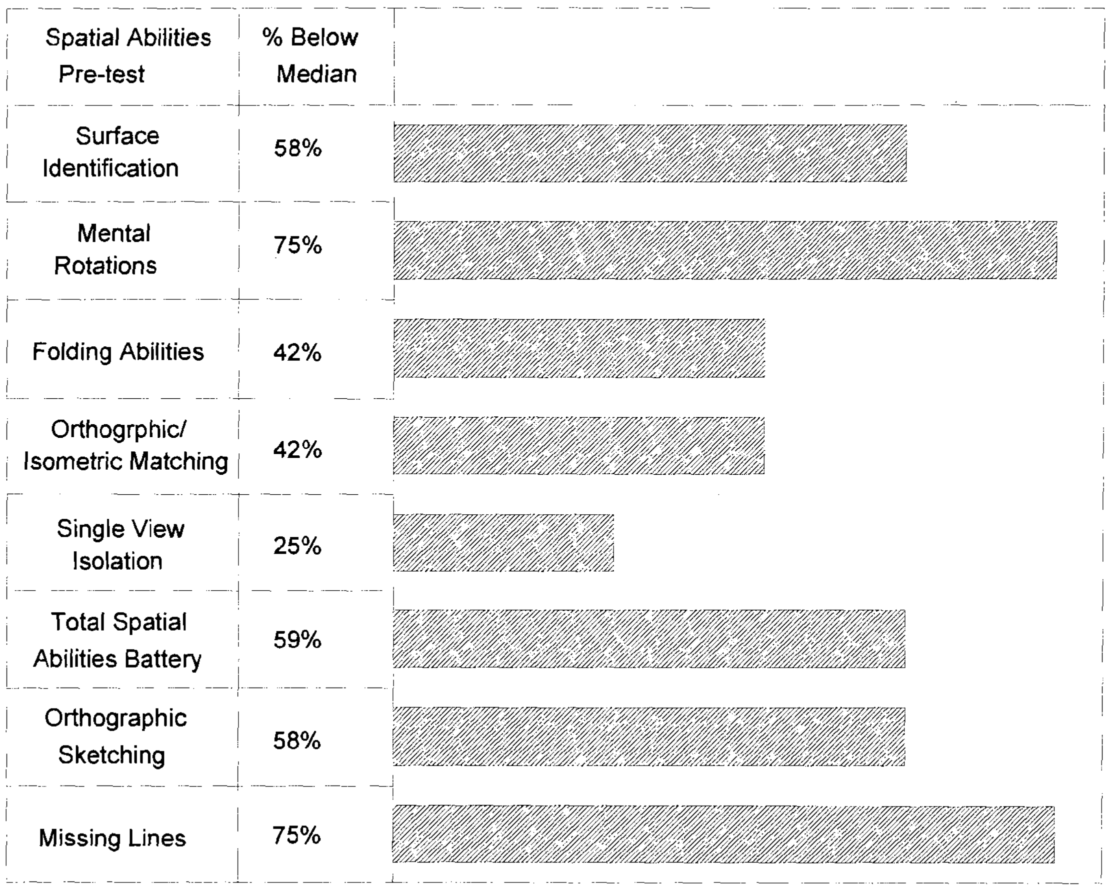

Figure 4.1. Percent of the Bowl preference group's pre-test scores below the median of all participants of each pre-test.

The data obtained from the pre-tests was reviewed in order to develop a profile of students who may prefer the Bowl visual aid. In addition to the results of the spatial abilities pre-tests, the Student Profile Survey collected information about the respondents that may predict a student's area of strength in spatial abilities that may be helpful in predicting a Bowl visual aid preference. This information shows a number of differences and similarities between the preference groups. On the Student Profile Survey students were asked for information in order to identify which of the different possible predictor traits of spatial ability they possessed. Some of the traits included in the Student Profile Survey could not be used to predict the type of visual aid the student preferred. Many of the predictors were eliminated due to the extremely small presence (one or two occurrences of 51 possible) of some traits due to the small sample size in this study.

One trait that was eliminated was gender. Since females were underrepresented as a whole, and disproportionately dispersed throughout the classification groups within this study, gender cannot be used in developing profiles of the Bowl preference group. Reported videogame usage, 3-D game preference, and sewing as a hobby had very uniform rates of occurrences (either nearly completely absent or unanimous) among all preference groups, and were likewise eliminated from the list of predictors used to create the Bowl preference group member profile. When the ages of the three groups were compared, the differences between the average age of the Bowl preference group is only 1 month less than that of the average age of the Box preference group. The Neither preference group's average age was nearly six months higher than the Bowl or Box preference group, but this information was not helpful in predicting members of the Bowl preference group.

Analysis of the mathematics-related data likewise revealed nothing significant. At first glance, it would appear that on average those that favor the Bowl visual aid had a slightly lower math GPA. Another way to compare math ability is to examine the rigor of the math courses that are taken by members of each group (see Table 4.5). By using this information, the researcher sought to rule out the possibility that an A student in the lowest level remedial course would be considered to have a higher level of mathematical ability than a B student in an advanced course. An examination of the data collected by the Student Profile Survey revealed that those respondents who favored the Bowl visual aid were slightly more likely to be enrolled in some type of remedial level math course and about half as likely to be enrolled in an advanced math course. While lower math ability would appear to be linked to a Bowl visual aid preference, the statistics show that no significant correlations were found (see Table 4.6).

Table 4.5. Occurrence rate of spatial abilities predictors by preference group.

Predictor of Strength in Spatial Abilities		Bowl preference group	Box preference group	Neither preference group
Math courses	Remedial Math Courses Enrollment	33%	24%	20%
	Higher Level, Yet Slower Pace Math Course Enrollment	0%	3%	20%
	Advanced Math Course Enrollment	17%	41%	30%
Other Related Courses	Enrollment in Other Related Courses	25%	41.3%	80%
	Students Enrolled in Multiple Related Courses	8.3%	13.8%	50%
Hobbies	Hobbies Requiring Spatial Abilities	75%	79.3%	90%
	Multiple Hobbies Requiring Spatial Abilities	58.3%	44.8%	70%

Not all pre-tests yielded results that could help create a Bowl preference group profile. Of the spatial abilities pre-tests, the Surface Identification and the Single View Isolation pre-test showed no dramatically different results between the groups when comparing group mean scores. Projection line use and mitre line use in solving missing line problems was also virtually nonexistent in all groups. To define the likely profile of a student who would prefer the Bowl visual aid over the Box visual aid, the factors that can influence spatial abilities were compared using Pearson's R to find correlations between these factors and visual aid preference (see Table 4.6).

Table 4.6 Pearson's correlations of predictors and pre-test scores with visual aid preferences (N=51).

Predictor or pre-test		Rating given to Bowl visual aid	Visual aid recommended	Differential score
Surface Identification	Pearson Correlation Sig. (2-tailed)	-.114 .425	.005 .972	-.069 .631
Mental Rotations	Pearson Correlation Sig. (2-tailed)	-.057 .689	-.393** .004	-.320* .022
Folding Abilities	Pearson Correlation Sig. (2-tailed)	-.065 .651	-.202 .154	-.229 .106
Orthographic/ Isometric Matching	Pearson Correlation Sig. (2-tailed)	.024 .868	-.135 .345	-.190 .181
Single View Isolation	Pearson Correlation Sig. (2-tailed)	.182 .201	.016 .912	-.058 .685
Orthographic Sketching	Pearson Correlation Sig. (2-tailed)	-.013 .925	-.238 .093	-.273 .052
Age in Months	Pearson Correlation Sig. (2-tailed)	-.145 .311	.012 .933	.031 .83
Remedial Math Courses	Pearson Correlation Sig. (2-tailed)	-.094 .513	.072 .615	-.050 .729
Self Reported Math GPA	Pearson Correlation Sig. (2-tailed)	-.029 .838	-.137 .336	-.025 .863
Gender	Pearson Correlation Sig. (2-tailed)	-.180 .206	.020 .890	.077 .591
Education Total Exposure	Pearson Correlation Sig. (2-tailed)	.066 .644	-.019 .895	.023 .874
Use of Spatial toys as children	Pearson Correlation Sig. (2-tailed)	-.004 .976	-.049 .733	-.097 .498
Hobby Total Exposure	Pearson Correlation Sig. (2-tailed)	.160 .263	.189 .184	.153 .284

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Bowl Preference Profile Using Three Groups. Further analysis of this data was conducted through the use of discriminant analysis in order to create a likely profile of the Bowl preference group student. Discriminant analysis was used to classify participants into preference groups based on similarities and differences within and between preference groups. The low Wilks' lambda score of .805 for the Rotation pre-test indicates that it is a substantial contributor to predicting group membership (see Table 4.7). An equally important Wilks' Lambda score was found for the Education Total Exposure variable, however, this variable is more closely associated with

Table 4.7 Test of identifying characteristics for significance in determining preference group membership. (three preference groups)

Predictor or pre-test	Wilks' Lambda	F	df1	df2	Sig.
Surface Identification pre-test	.989	.257	2	48	.774
Mental Rotations pre-test	.805**	5.819	2	48	.005
Folding Abilities pre-test	.959	1.033	2	48	.364
Orthographic/ Isometric Matching pre-test	.972	.688	2	48	.507
Single View Isolation pre-test	1.000	.006	2	48	.994
Orthographic Sketching pre-test	.937	1.601	2	48	.212
Age in Months	.963	.932	2	48	.401
Remedial Math Class	.989	.274	2	48	.762
Self-identified Math GPA	.981	.469	2	48	.628
Gender	.984	.396	2	48	.675
EDUCATION TOTAL EXPOSURE	.799**	6.029	2	48	.005
Preference for childhood building toys	.980	.493	2	48	.614
HOBBY TOTAL EXPOSURE	.948	1.325	2	48	.275

**. Wilks' Lambda is significant at the .005 level.

predicting members of the Neither preference group. Both the Mental Rotation pre-test and the Education Total Exposure variable were found to be significant determiners of visual aid preference at the .005 level. None of the other spatial abilities pre-tests or other predictors of student success were found to be significant in creating visual aid preference profiles for the three preference groups.

Based on the results of discriminant analysis, profiles for the three preference groups were generated. The profiles of each group were then tested by using data from the original subjects to test the profile's ability to classify the original respondents into their preference group. Table 4.8 is a report of the classification results that shows, of the three groups, discriminant analysis was most reliable in predicting membership of the Bowl preference group, with a success rate of 83.3%, while only incorrectly predicting Bowl preference membership in 2 of 39 occasions.

Table 4.8 Discriminant analysis classification results for Box , Bowl and Neither preference groups (76.5% of original grouped cases correctly classified).

			Predicted Group Membership			
		Visual Aid Found Most helpful	Box visual aid most helpful	Visual aids same	Bowl visual aid most helpful	Total
Original Sample	Count	Box visual aid most helpful	22	6	1	29
		neither visual aid more helpful	2	7	1	10
		Bowl visual aid most helpful	1	1	10	12
	%	Box visual aid most helpful	75.9%	20.7%	3.4%	100%
		Visual aids same	20.0%	70.0%	10.0%	100%
		Bowl visual aid most helpful	8.3%	8.3%	83.3%	100%

Bowl Preference Profile Using Two Groups. Further analysis found that the traits of the Bowl preference group were more distinct when compared to all other participants. Table 4.9 shows that the scores earned on the Mental Rotations pre-test and the Missing Lines pre-test were very significant determiners of visual aid preference. Results of the Mental Rotations pre-test were found to be significant at the .001 level, while the results of the Missing Lines pre-test were found to be significant at the .05 level.

Table 4.9 Tests of identifying characteristics for significance in determining preference group membership. (Bowl preference group vs. all other groups)

Predictor or pre-test	Wilks' lambda	F	df1	df2	Sig.
Surface Identification	.997	.130	1	48	.720
Mental Rotations	.809**	11.353	1	48	.001
Folding Abilities	.972	1.400	1	48	.243
Orthographic/ Isometric Matching	.974	1.287	1	48	.262
Single View Isolation	.999	.030	1	48	.863
Orthographic Sketching	.942	2.969	1	48	.091
Total Spatial pre-test Battery	.934	3.404	1	48	.071
Missing Lines	.896*	5.552	1	48	.023
Age in Months	.992	.401	1	48	.529
Remedial Math Courses	.985	.735	1	48	.396
Self Reported Math GPA	.984	.778	1	48	.382
Gender	.995	.238	1	48	.628
Education Total Exposure	.946	2.762	1	48	.103
Use of Spatial toys as children	.990	.507	1	48	.480
Hobby Total Exposure	.989	.530	1	48	.470

*. Wilks' Lambda is significant at the 0.05 level.

**. Wilks' Lambda is significant at the 0.001 level.

Based on the results of this second discriminant analysis that only used two groups, one composed of the twelve who preferred the Bowl visual aid and another group composed of those who did not prefer the Bowl visual aid, a second profile for the Bowl preference group was generated. When the new profile was checked against the original data, the results were a bit more reliable than when three groups were used. Table 4.10 is the report of the classification results which shows that, based on the two-group profile, discriminant analysis was able to correctly predict group membership based on the data 96% of the time, a near 20% increase in accuracy as compared to the results of discriminant analysis using three preference groups. Only one out of each of the two groups was predicted incorrectly based on the data collected.

Table 4.10 Discriminant analysis classification results for Bowl preference group vs. all other groups. (96.0% of original grouped cases correctly classified).

		Visual Aid Found Most helpful	Predicted Group Membership: Other than Bowl Visual Aid	Predicted Group Membership: Bowl Visual Aid	Total
Original	Count	Other than Bowl Visual Aid	37	1	38
		Bowl Visual Aid	1	11	12
	%	Bowl Aid NOT Most Helpful	97.4%	2.6%	100%
		Bowl Aid Most Helpful	8.3%	91.7%	100%

One purpose of this investigation was to attempt to identify individual traits of students that may prefer the Bowl visual aid over the Box visual aid. In reviewing the data, a number of distinct differences were found that could be considered Bowl preference group identifiers. Differences were found in the spatial abilities pre-test results and in the data collected related to certain individual traits shown to be predictors of spatial ability. While only two traits were statistically found to be significant predictors of Bowl preference group members, a number of other differences were observed that may be of use to the classroom instructor. The unique characteristics of the Bowl preference group are stated in the summary.

Summary

The Orthographic Sketching pre-tests showed that members of the Bowl preference group had the most difficulty creating orthographic drawings without the help of visual aids. Upon deeper analysis of the Orthographic Sketching pre-test item, the members of the Bowl preference group performed the best in drawing the object to the correct size, but were among the worst as far as using random incorrect view placement on the pre-tests. Unlike their peers, students who preferred the Bowl visual aid averaged a higher percentage of correct answers on the Folding Abilities pre-test than on the Mental Rotations pre-test. The most noticeable and significant differences between the those students who preferred the Bowl visual aid those who did not were found in the Mental Rotations pre-test and the Missing Lines pre-test. Both Pearson's R correlations and Wilks' Lambda test of equalities indicate that these two pre-test scores were the most significant traits than can be used to predict the Bowl preference group based on the participant sample in this study.

Chapter V: Discussion

This chapter is a summation of the findings, conclusions and recommendations of this investigation of the effectiveness of an alternative Bowl visual aid used to teach orthographic drawing in an introductory level drafting class. Conclusions drawn from the data collected are discussed and recommendations for future study are suggested based on the findings of this investigation.

Summary

One of the most difficult topics for beginning drafting students to understand is the relationship between the views in orthographic drawings. While the Box visual aid can help many students understand this essential concept of technical drafting, a few students in each class still struggle to create orthographic drawings that contain accurate views of the object in the correct location and orientation. This investigation sought to determine whether a blueprint reading tip learned by the researcher as a machinist could prove helpful to students in a high school level drafting class learning to create orthographic drawings. The description of this investigation is divided as follows: The Problem, Research Method and Procedures, and Major Findings.

The Problem. Learning the basic standards of drafting is important for those who wish to pursue careers in engineering and other design fields. One such standard is the arrangement of the 2-D views in an orthographic layout. In a typical secondary-level drafting classroom, there are a number of students who struggle with this concept even after direct instruction using the most common visual aid, the hinged glass Box visual aid. Could an alternative visual aid help some of the struggling students understand this essential concept in engineering drafting? Could a visual aid based on a bowl (the idea for which has been used for years in manufacturing settings) be more helpful to some introductory level drafting students than the widely used Box visual aid?

Research Method and Procedures. The method for this investigation consisted of a survey given to students that asked students to provide information about factors that can influence an individual's spatial ability level. This survey was given to help determine if any particular trait of the individual could prove to be a likely indicator of a preference for the alternative Bowl visual aid. The information provided by the students was used to determine whether there was a link between these individual traits and a preference for the Bowl visual aid. This data was also examined in order to create the profile of students most likely to prefer the Bowl visual aid.

After the survey was completed, the students were given pre-tests on various spatial skills that were deemed valuable in creating orthographic projection drawings. The skills assessed included mental rotations and folding, surface identification, isolating single views of an object, matching orthographic layouts to isometric drawings, sketching orthographic layouts and an assessment of the student's ability to identify missing lines in partially complete orthographic layouts. These skills were assessed through pre-tests given to determine whether the students' level of spatial skills before direct instruction could indicate which visual aid they preferred. The Orthographic Sketching pre-test was also used as a post-test after direct instruction on the use of both visual aids to determine whether real growth in orthographic drawing ability occurred as a result of the direct instruction and practice.

The final component of this experiment was the survey given to the students after they completed the orthographic drawing unit. On this survey students responded to questions that asked them to rate the helpfulness of the two visual aids. Students were also asked to give their opinion of which visual aid, neither, or both, they thought would be the best way to demonstrate orthographic drawing in the future. Students were then asked to briefly explain why they made this recommendation.

Major Findings. In the course of this investigation, it was found that there was a sizeable minority of the sample who found the Bowl visual aid more helpful than the Box visual aid. When the students enrolled in Franklin High School's Basic Graphics course were asked to rate the two visual aids, nearly 24% of the students rated the Bowl visual aid as more helpful in explaining orthographic drawings. On the same survey, 26 of the 51 participants recommended that both visual aids should be used when teaching this unit in the future. Students also reported that they thought the Bowl visual aid was a helpful addition to the orthographic drawing unit even if they personally did not prefer it.

Students who favored the Bowl visual aid demonstrated growth in orthographic drawing skills and in their understanding of orthographic projection standards from pre-test to post-test. This growth in abilities was observed after instruction demonstrating both the Bowl and Box visual aids. This unit also included exercises that were designed to increase student comprehension of orthographic drawing. Due to the design of this research, it could not be determined how much of the growth could be attributed to the use of, or preference for, the alternative Bowl visual aid.

One of the most interesting findings of this study came from the attempt to generate a profile of the student most likely to benefit from the Bowl visual aid. It was found that lower student scores on the Mental Rotations pre-test were strongly correlated with a preference for the Bowl visual aid. This correlation was found to be significant at the 0.001 level. The Missing

Lines pre-test was also found to be a significant predictor of a student's visual aid preference. This Missing Lines pre-test score was significant at the .05 level.

Conclusions

In drawing conclusions from this investigation, this researcher began by focusing on the first and third research questions which were: "Are there students who find the Bowl visual aid more helpful than the Box visual aid when learning to create orthographic drawings?" and "Which of four approaches (Bowl, Box, both or neither) do students feel is the best approach for teaching third angle orthographic projection view placement?" Based on the responses obtained from students through the Student Feedback Survey, it was found that in a high school drafting course there are students who find the Bowl visual aid more helpful than the Box visual aid when learning to create orthographic drawings.

Further student comments on this same Student Feedback Survey revealed that students thought the best way to teach the orthographic drawing unit is to use both visual aids. There were various reasons given by the students for recommending both visual aids, but by far the most common was some variation of, "all students learn differently." It would seem as though students feel it is best to offer multiple explanations even if they personally don't need them. Students' comments indicated that they recognized the Bowl visual aid as a better approach for some of their peers. All evidence indicates that it would be beneficial to add the Bowl visual aid to instruction during the orthographic drawing unit of an introductory level drafting course.

Another research question was related to the level of improvement shown between the pre-test and post-test. It was found that all students improved in their orthographic drawing ability from pre-test to post-test. On average the Bowl preference group students showed the greatest improvement as a whole, nearly completely closing the achievement gap on the

Orthographic Sketching post-test as compared to the results of the other preference groups. This researcher concludes that the level of improvement in orthographic sketching is substantial within the Bowl preference group, yet it can not be determined to what degree that the improvement is attributed to the Bowl visual aid itself. It can be concluded that this group of students felt that seeing the Bowl visual aid made it easier for them to succeed in creating orthographic multi-view drawings.

By far the most significant traits associated with students who prefer the Bowl visual aid were their low rotational ability that they displayed on the Mental Rotations pre-test and the Missing Lines pre-test. This conclusion was drawn based on the strong Pearson's correlation as well as the low Wilke's Lambda score discovered through discriminant analysis. Both of these statistical reports point to low rotational abilities and visualization skills as the common link between members of the Bowl visual aid preference group.

Recommendations

In the course of this investigation, it was found that some students at Franklin High School benefited from the addition of the Bowl visual aid when learning to create orthographic projection drawings. While the majority of students participating in this study did not find the alternative Bowl visual aid more helpful than the Box visual aid, a number of the students participating in this study thought that the Bowl visual aid was helpful when they learned to create orthographic drawings. Based on this and other findings of this study, the researcher makes the following recommendations.

Recommendations for Repetitions of This Study. Because the sample size of this investigation was limited to willing participants enrolled in the Basic Graphics course during the 2005-2006 school year, any future investigation of this nature should seek a larger sample group and also one that better represents a general population to verify that the results of this investigation are generalizable. Specifically, the demographics of the participants of any similar study should be more proportional to the population at large. In this investigation, the female gender was underrepresented.

Future study of this Bowl visual aid should also be conducted using a research design in which the visual aids are tested independently. One group should see Bowl visual aid only, one group should receive instruction using the Box visual aid only, one group receiving instruction using neither visual aid and a fourth group that received no visual aid instruction at all. This type of study should be conducted outside of an educational setting, as an instructor may become uneasy when withholding a possible source of help from a group of students participating in the study.

Recommendations for Further Study. The results of this investigation inspired this researcher to ask new questions. The strong correlation found between low rotational abilities pre-test scores and a preference for the Bowl visual aid used in this investigation caused this researcher to wonder whether there was a direct connection between low rotational spatial ability and the preference for the Bowl visual aid. This seems counter-intuitive to the logical expectation that those students who preferred the Bowl visual aid would have stronger rotational abilities than those who did not prefer this alternative visual aid. An answer to this enigma might be found in a deeper investigation of the relationship between rotational abilities and folding abilities. Perhaps one might find that folding an object is simply multiple rotations about multiple connected axes. If folding and rotational abilities are highly related, perhaps folding is a more difficult version of a simple rotation rather than a completely different spatial skill. Further research on this topic could lead to a greater understanding of spatial abilities and how they are related to each other.

While this investigation did reveal some value to the Bowl visual aid for beginning draftsmen, a better application of this visual aid may be in comparing a completed object to an orthographic representation of that object. It was in this situation that the concept of the Bowl visual aid was first revealed to this researcher. Perhaps the best use of the Bowl visual aid would be in a blue print reading course offered to those entering manufacturing trades. When used to compare an orthographic drawing to a physical object matching the specifications of that drawing, the Bowl visual aid seems to be effective in building an understanding of the relationships between the individual views of the orthographic layout. This visual aid may be well suited to helping students understand the relationship between orthographic drawings and a physical object, therefore further study involving the Bowl visual aid in print reading is recommended.

Recommendations for the Drafting Instructor. Based on the results of this investigation, this researcher believes that the Bowl visual aid should be included in orthographic drawing instruction. Furthermore, the participants in this study most frequently recommended that the orthographic drawing unit should be taught using both the Bowl and Box visual aids.

The Bowl visual aid appears to be especially helpful for those students who struggle with orthographic projections after first seeing a demonstration of the Box visual aid. Students who prefer the Bowl visual aid also demonstrate lower than average rotational abilities on pre-tests as well as lower than average ability to complete missing lines pre-test items. This researcher recommends that those who teach drafting at the high school level should use a rotational ability pre-test and a missing line visualization pre-test to gauge the initial ability of the students in the class. By identifying those students who have difficulty making mental rotations and visualizing objects, an instructor may be able to identify those students in need of extra help when learning to create orthographic drawings.

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Appendix A: Student Profile Survey

Name_________________

1. What is your age? _____years _____months

2. Please place a check on the blank before the math courses you have taken or are taking.

   _____ Geometry   _____ Advanced Algebra   _____ Physics
   _____ AP Calculus   _____ Math Connections   _____ Algebra

3. What types of grades do you usually get in your math classes: (Circle one)

   A   A/B   B   B/C   C   C/D   D

4. Are you: MALE or FEMALE (circle one please)

5. Please place a check on the blank before the technology courses you have already taken or are taking this semester.

   _____ Metals   _____ Woods   _____ Survey of Tech
   _____ Autos   _____ Construction   _____ TV Tech

6. How often did you play with Legos, Lincoln logs, tinker toys, K'Necs, or other building block toys when you were younger? (circle one number please)

Never		Sometimes		All the time
1	2	3	4	5

7. Do you enjoy building models as a hobby?   Yes_____   No_____

8. Do you enjoy working on vehicles as a hobby?   Yes_____   No_____

9. Do you enjoy sewing as a hobby?   Yes_____   No_____

10. Do you enjoy construction related projects as a hobby? (roofing, remodeling)
    Yes_____   No_____

11. Do you enjoy origami as a hobby? (folding paper into shapes, usually animals)
    Yes_____   No_____

12. Do you play video games?   Yes_____   No_____

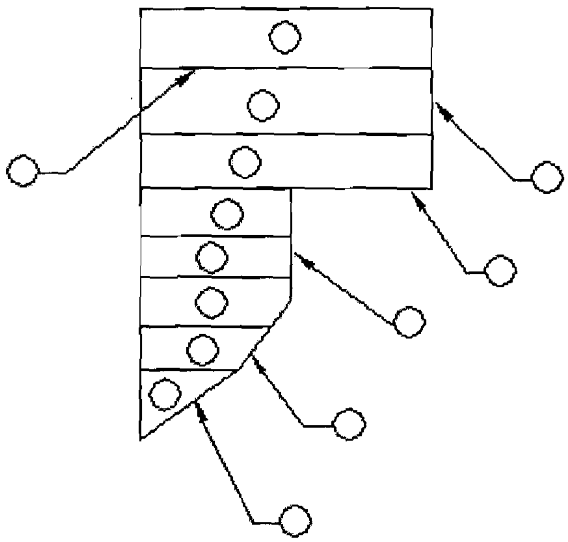
13. If yes, are your favorite video games mostly: (CIRCLE ONE PLEASE)

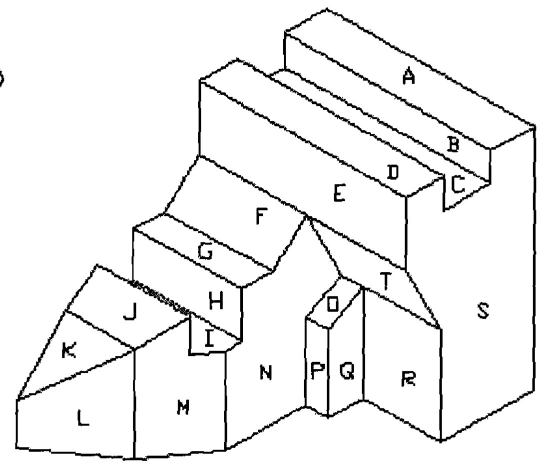
    2-D games (pacman and solitaire)   **or**   3-D Games (Bond or Mario Cart)

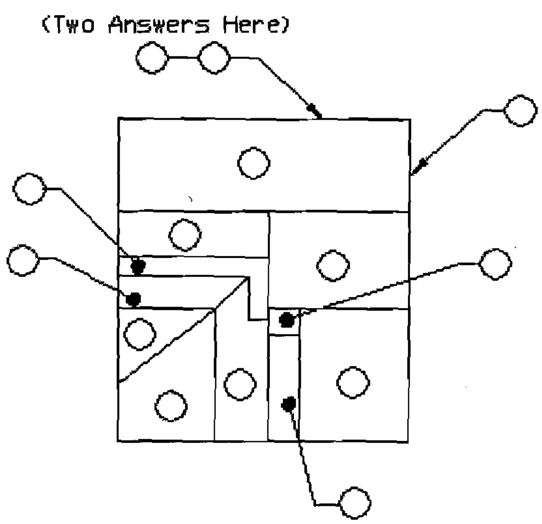
Appendix B: Surface Identification Test Side One

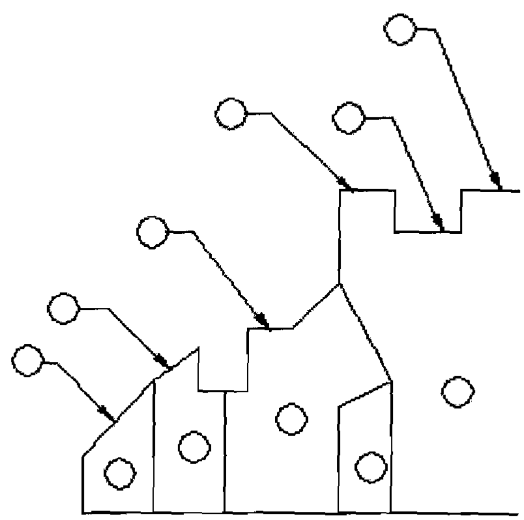
SURFACE IDENTIFICATION NAME ____________________

BELOW AND ON THE BACK OF THIS SHEET, YOU WILL FIND EXAMPLES OF ISOMETRIC DRAWINGS THAT HAVE SURFACES LABELED WITH LETTERS OF THE ALPHABET. YOU WILL ALSO FIND THE OBJECT'S ORTHOGRAPHIC VIEWS WITH CIRCLES ON SOME OF THESE SURFACES OR WITH LINES POINTING TO THE SURFACES. IN THE CIRCLES PLEASE RECORD THE LETTER OF THE ALPHABET THAT BEST MATCHES THE LABELED CORRESPONDING SURFACE OF THE OBECT'S ISOMETRIC VIEWS.





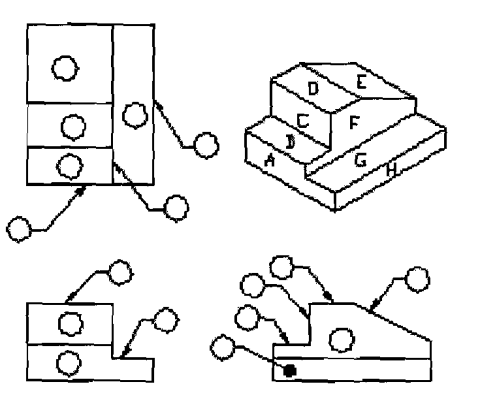


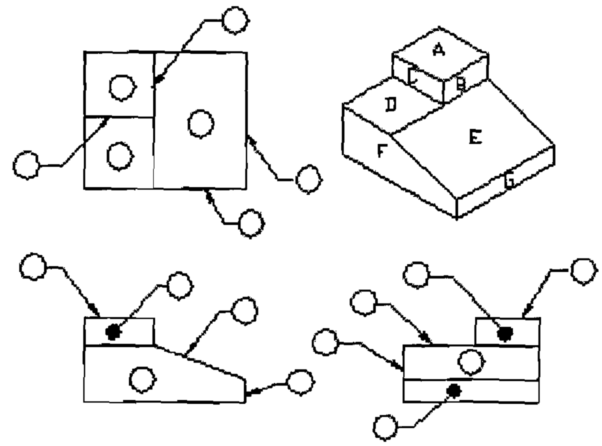


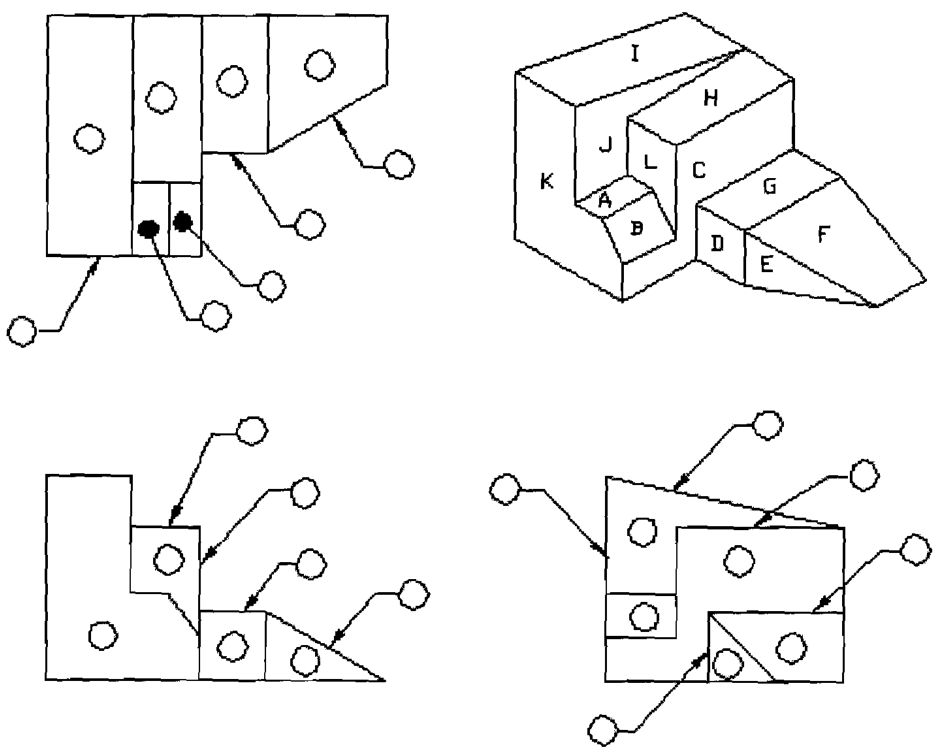
Appendix C: Surface Identification Test Side Two

SURFACE IDENTIFICATION NAME ____________________

BELOW AND ON THE BACK OF THIS SHEET, YOU WILL FIND EXAMPLES OF ISOMETRIC DRAWINGS THAT HAVE SURFACES LABELED WITH LETTERS OF THE ALPHABET. YOU WILL ALSO FIND THE OBJECT'S ORTHOGRAPHIC VIEWS WITH CIRCLES ON SOME OF THESE SURFACES OR WITH LINES POINTING TO THE SURFACES. IN THE CIRCLES PLEASE RECORD THE LETTER OF THE ALPHABET THAT BEST MATCHES THE LABELED CORRESPONDING SURFACE OF THE OBECT'S ISOMETRIC VIEWS.



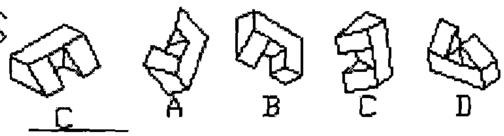




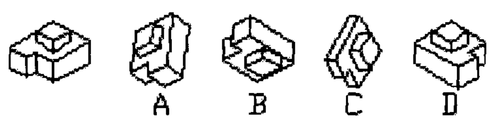
Appendix D: Mental Rotations Test

NAME ____________________

In the problems below, you will find a drawing of an object in its original position on the left and four possible choices (A, B, C or D) to the right. To complete this quiz, you must indicate the letter of the object that is the same as the object on the left, only rotated out of its original position. Indicate your choice by writing the letter of correct drawing on the blank provided under the drawing of the object in its original position.

S


C

1


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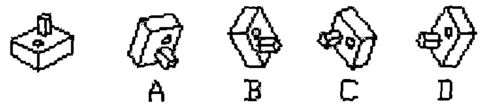

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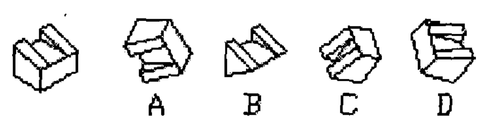

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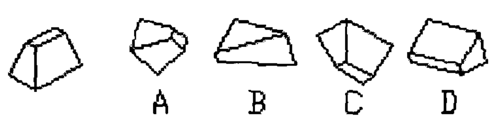

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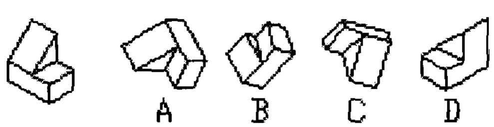

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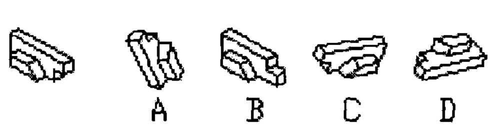

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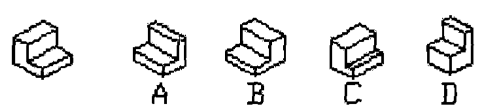

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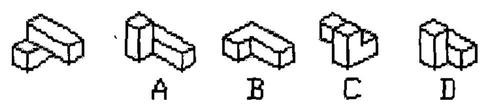

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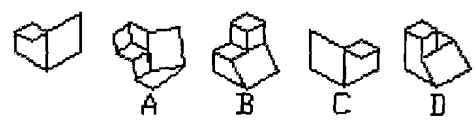

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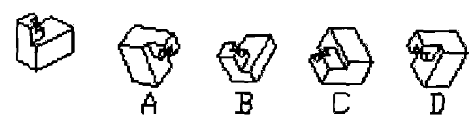

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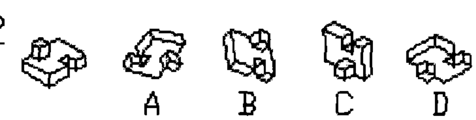

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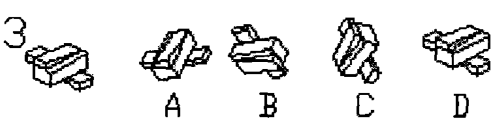

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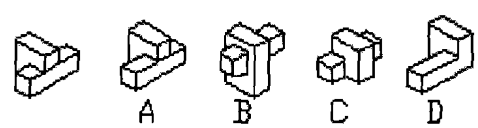

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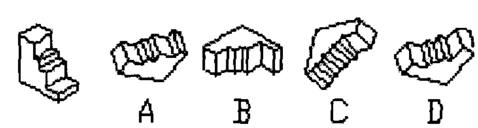
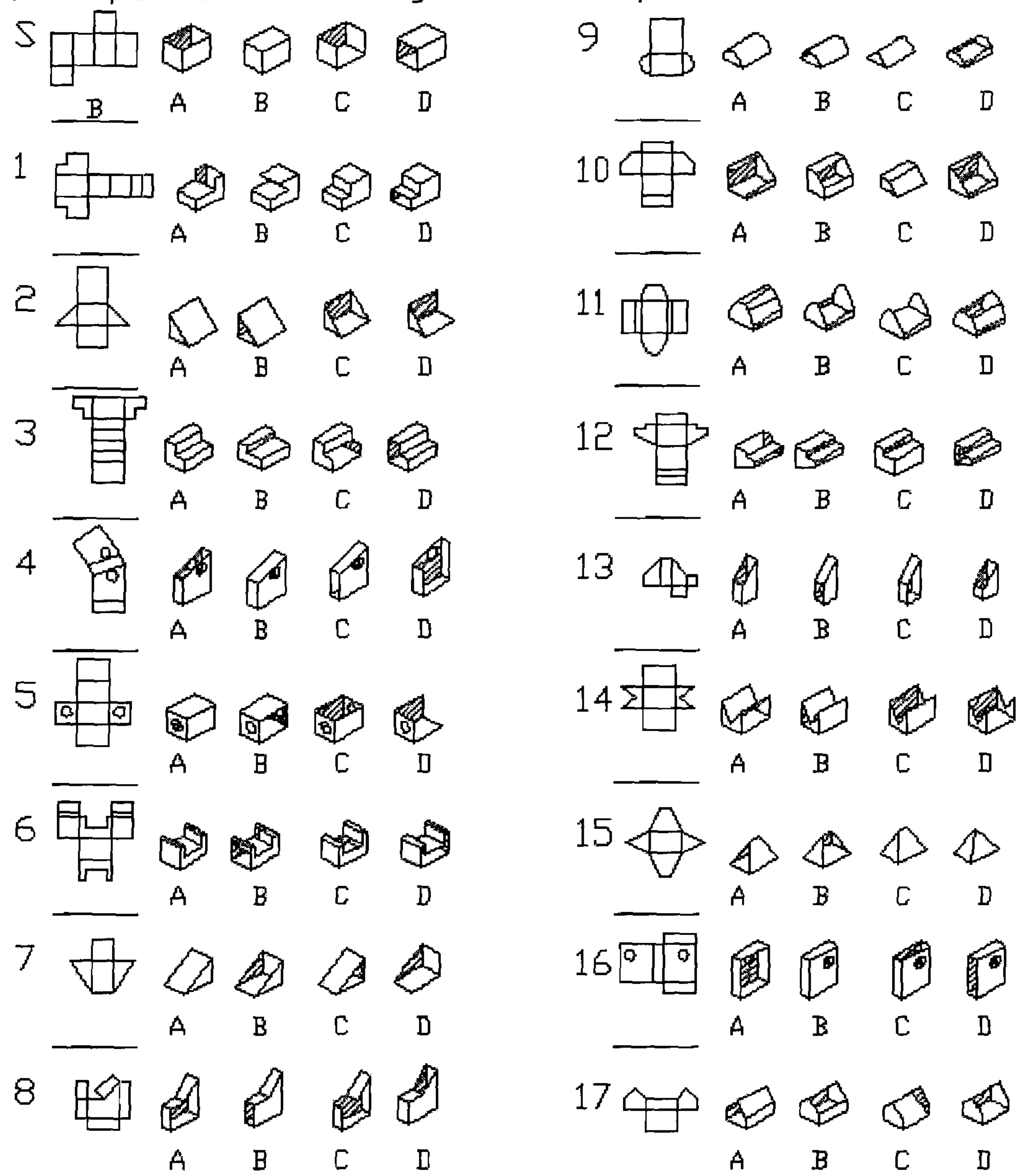


Appendix E: Folding Abilities Test

Name________________________

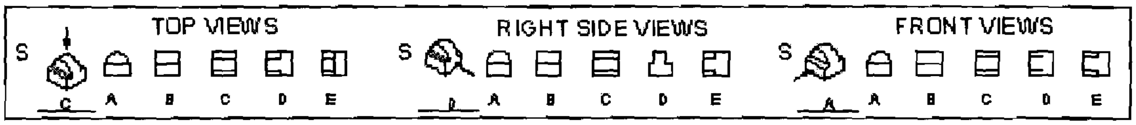
In the problems below indicate which of the four objects on the right (choices A, B, C or D) would be created if the flat pattern drawing on the left were folded along its lines to create a three dimensional shape. To complete this quiz, write the letter of the correct choice on the blank provided under the drawing of the unfolded object.

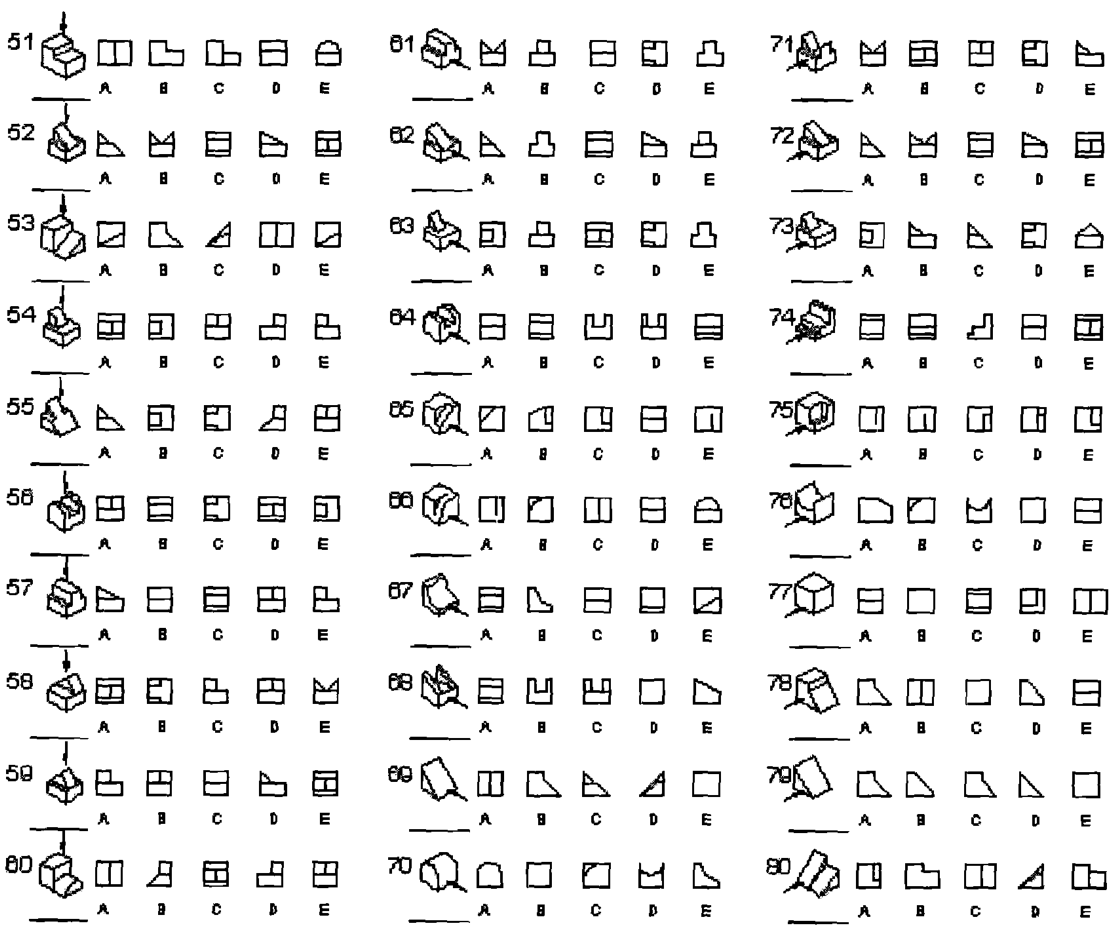


Appendix F: Single View Isolation Test

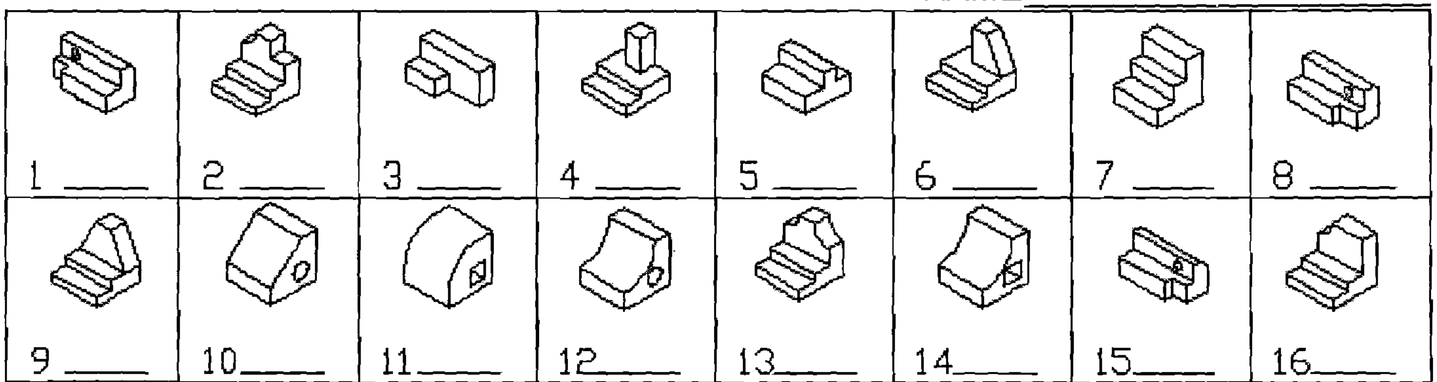
NAME ____________________

In the problems below, you will find a drawing of an object in its isometric (3-D) form. An arrow points to a side of that object to indicate which view you must find in the series of orthographic (2-D) views given as possible answers (choices A - E). Record the label of the correct choice on the blank provided under the isometric view. A sample for each of the three primary views is provided in the box below.

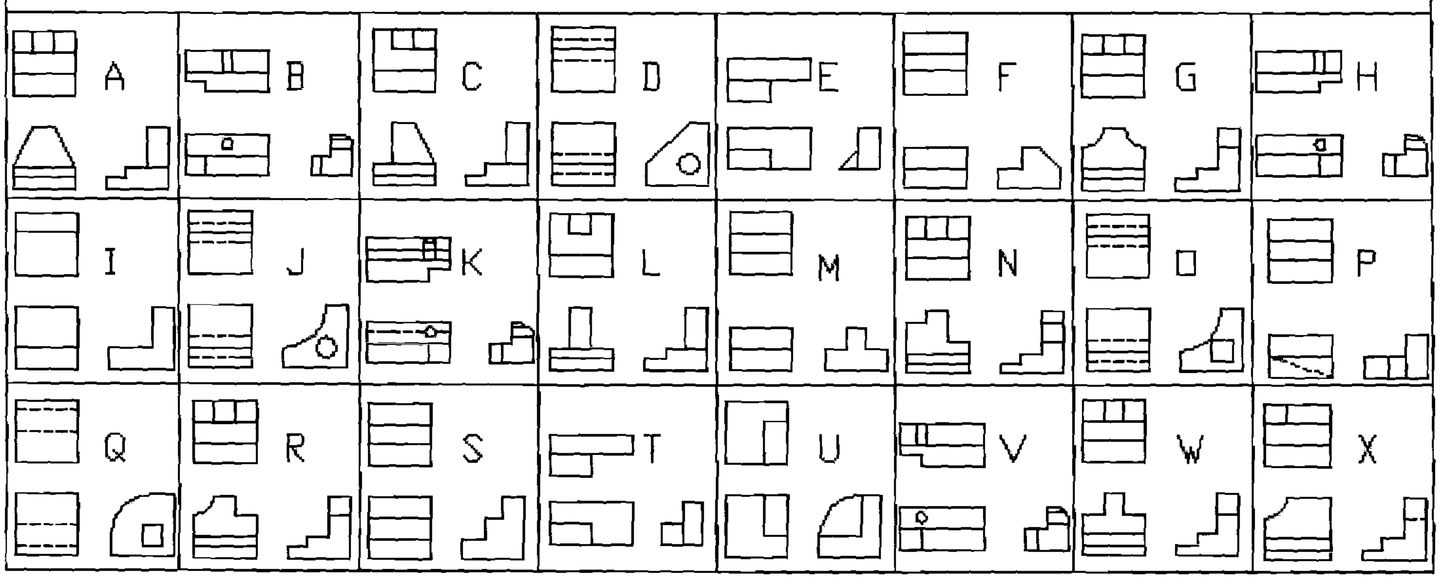




NAME ____________



Match the isometric drawings ABOVE to its three view orthographic depiction BELOW. Indicate your choice by writing in the letter of your choice on the blanks above.

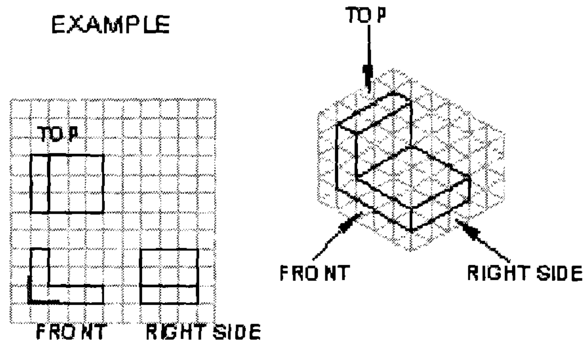


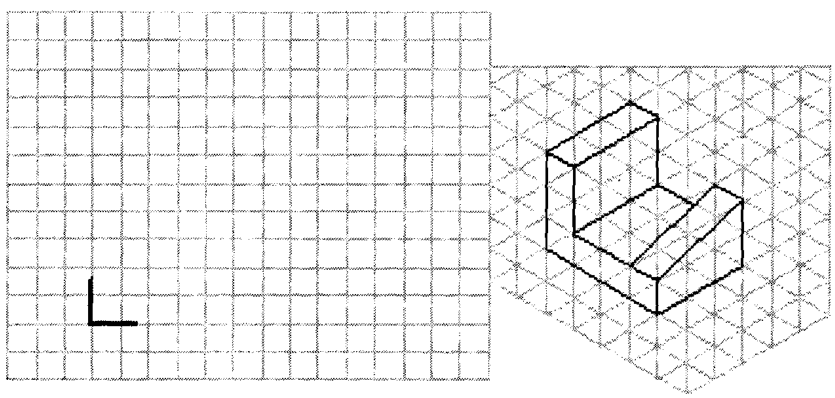
Appendix H: Orthographic Sketching Test

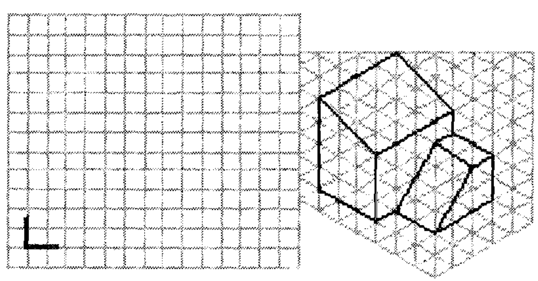
The example on the right shows how an object can be drawn in isometric form (3-d in appearance) and how it would also look in three separate views (orthographic projection). The three primary views used in orthographic projection are the top, front and right side views. In the problems below and on the back of this sheet, use the information from the grid in the isometric views to draw the three orthographic views of the parts. Begin drawing the lower left corner of the front view on the mark provided. Include two grid spaces between views to separate them.

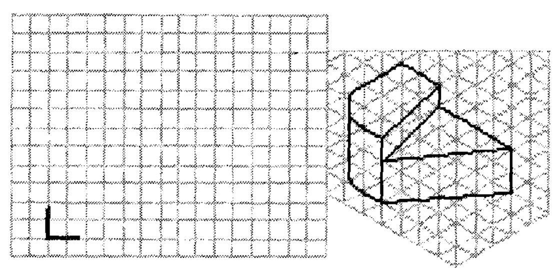
NAME ________________

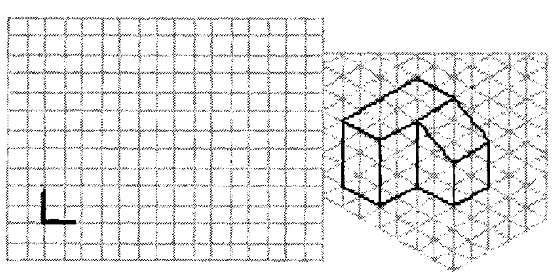
EXAMPLE

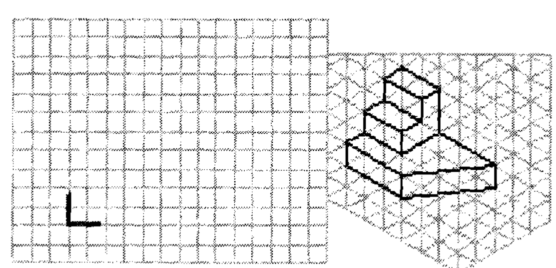




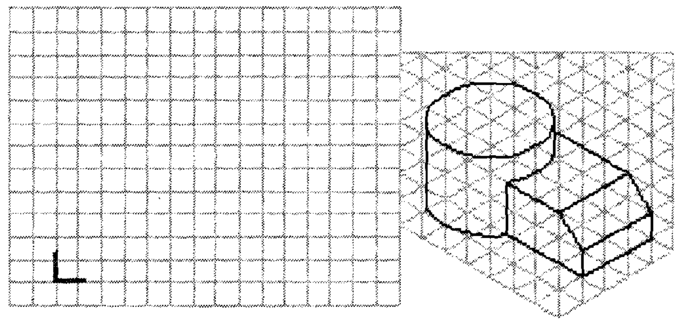


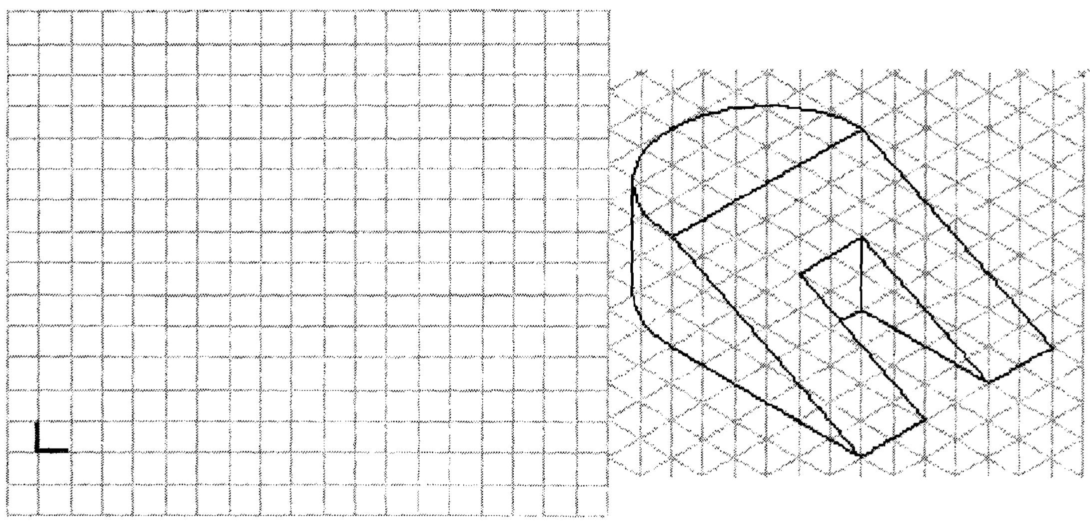


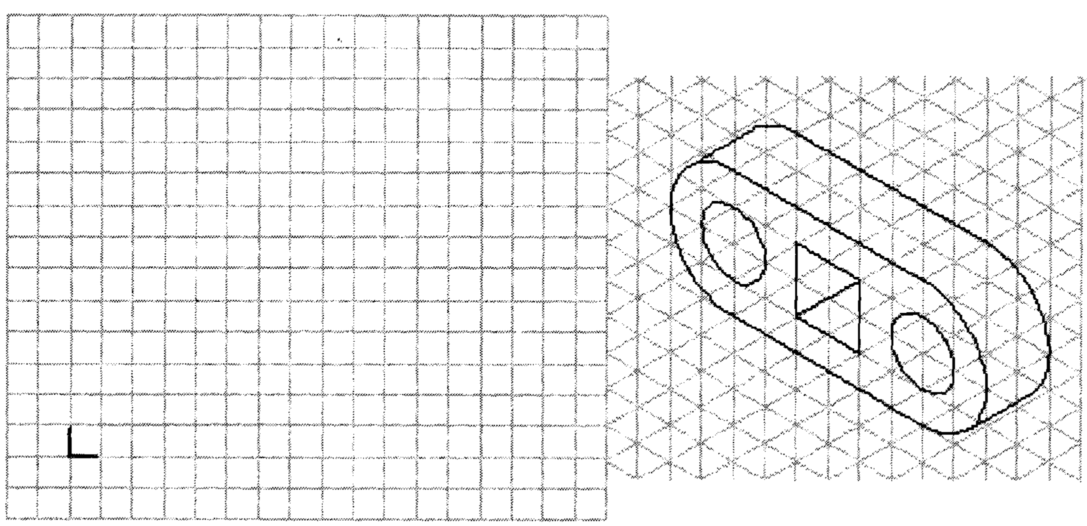




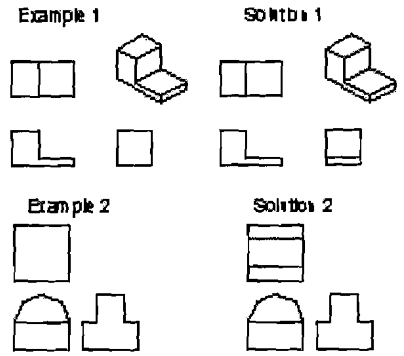
Appendix H: Orthographic Sketching Test (cont.)





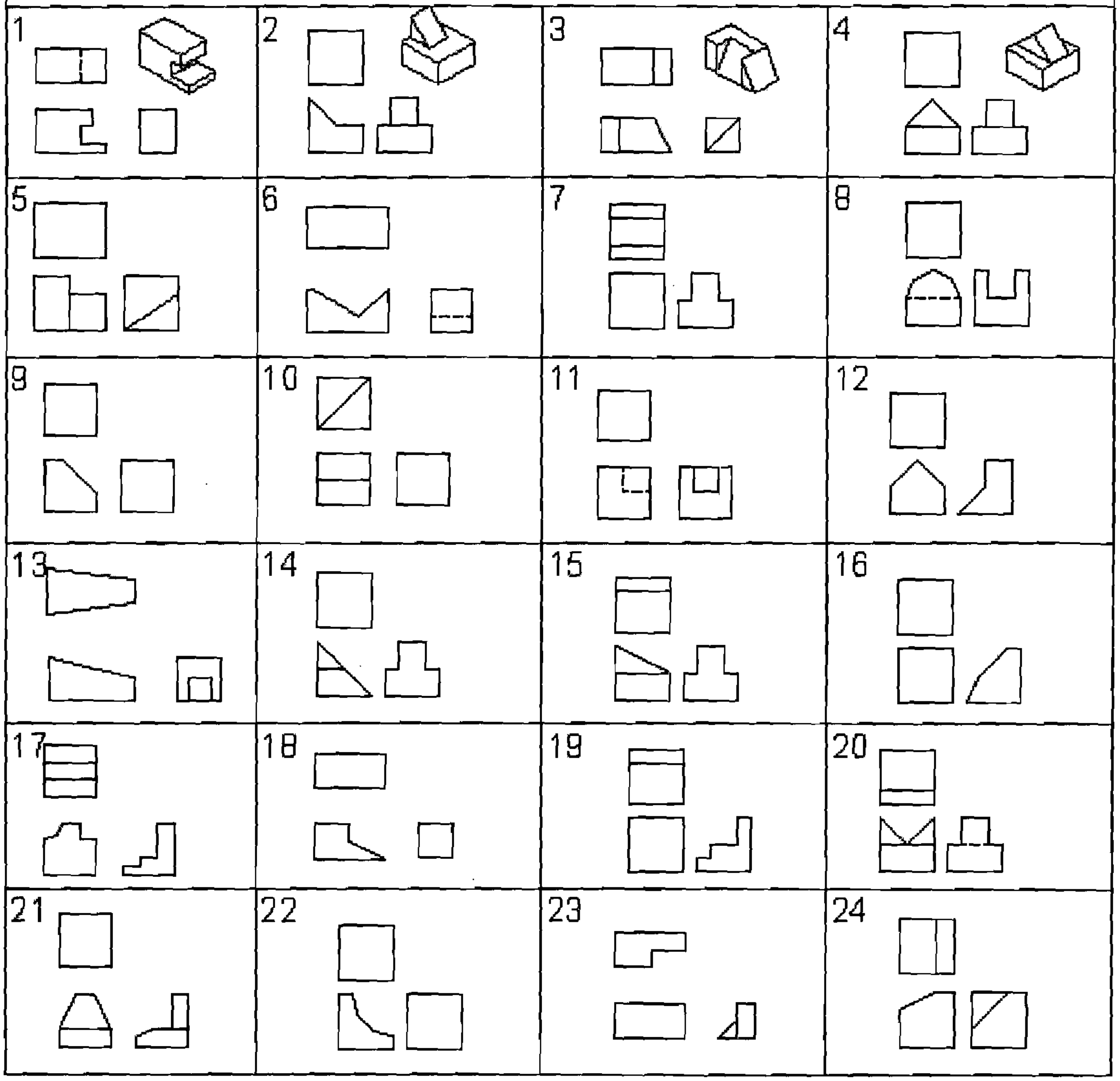


Appendix I: Missing Lines Test



NAME________________________

In each of the problems below, you will find an incomplete set of orthographic views of an object. The set is incomplete because there are one or more lines missing between the three primary views given. To complete this quiz, draw in the missing lines. Two examples along with thier solutions are given on the left. The missing line is shown in the solution as a light grey line.



Appendix J: Student Feedback Survey

Basic Graphics Student Survey   Name____________________

1. How helpful was the **bowl** method in explaining view placement in orthographic drawings?)

not at all				Somewhat				very helpful	
1	2	3	4	5	6	7	8	9	10

2. How helpful was the **box** method in explaining view placement in orthographic drawings?)

not at all				Somewhat				very helpful	
1	2	3	4	5	6	7	8	9	10

3. Next year Mr. Kurszewski should: (check one please)

_____ Teach the **box** method only

_____ Teach the **bowl** method only

_____ Teach **both** methods again

_____ Teach **neither** method

4. Please tell me why you chose box, bowl, both or neither in question 3.

____

____

____

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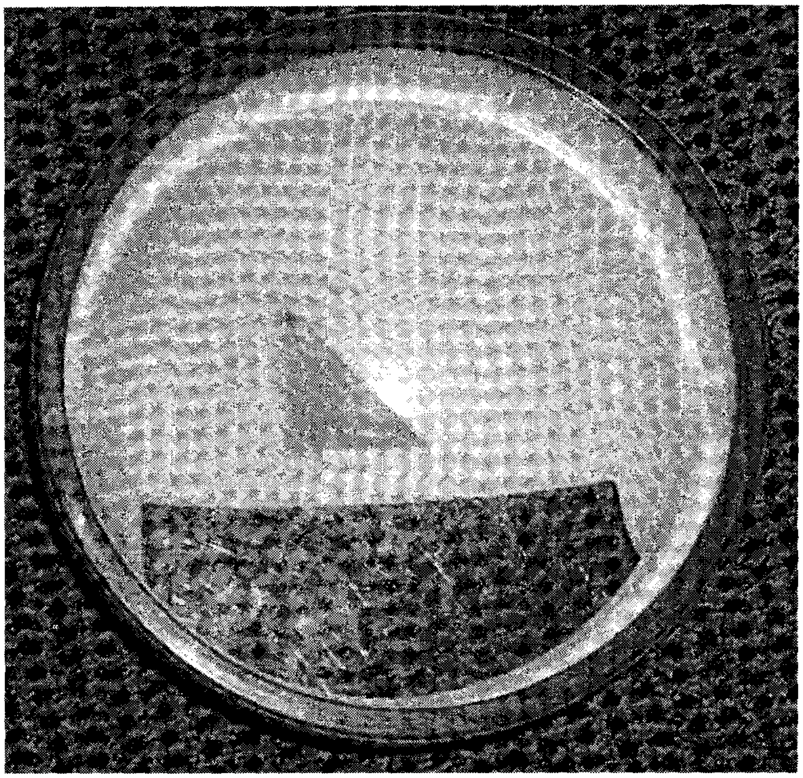
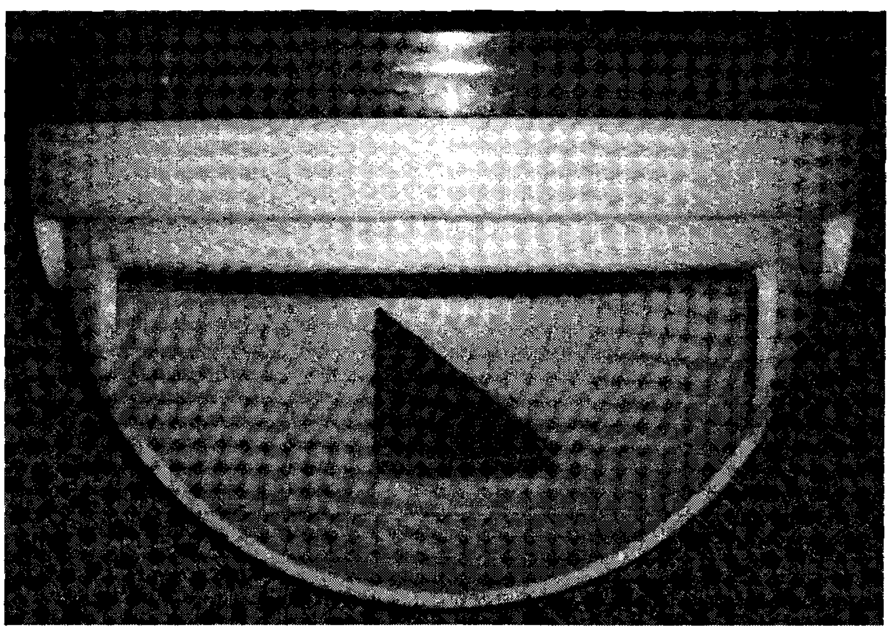
Appendix K: The Bowl Visual Aid

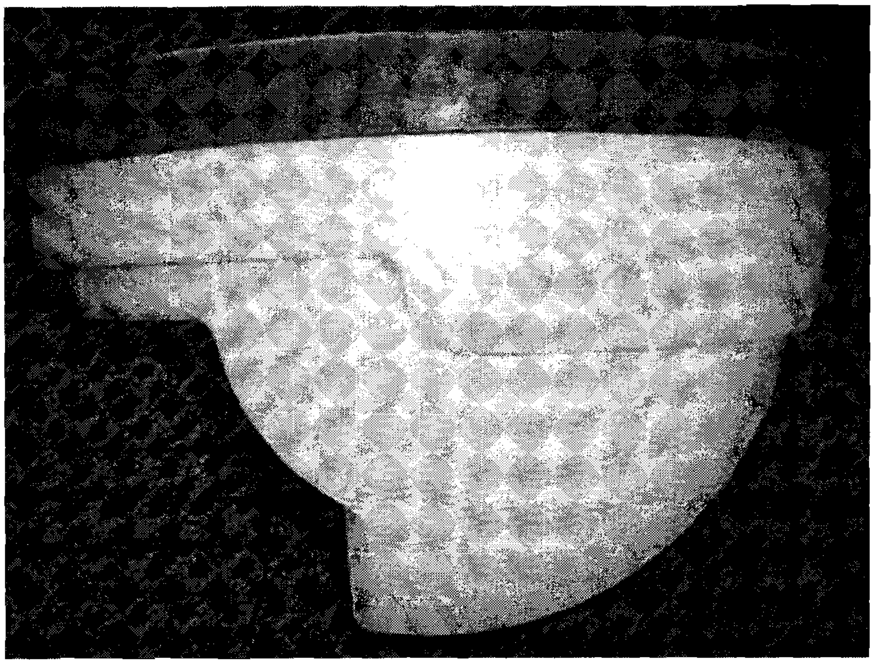


Above: Top view of Bowl visual aid with object inside of it in the front view position.

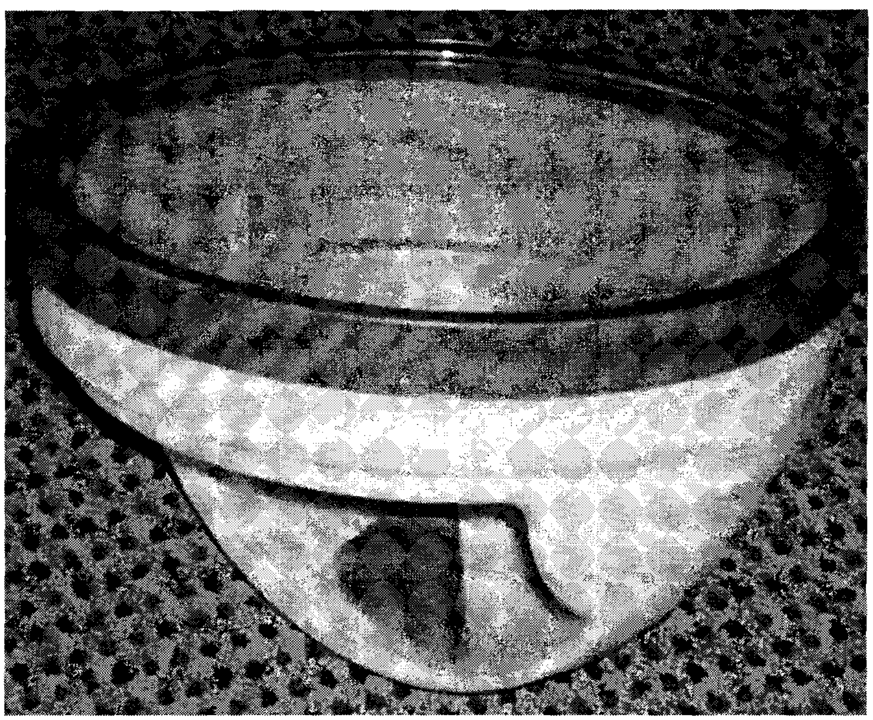


Above: Front view of Bowl visual aid with object inside of it rotating along the side of the bowl to the top view position.

Appendix K: The Bowl Visual Aid (continued)



Above: Side view of Bowl visual aid. The access hole for sliding the object is visible in the lower left of the photo.



Above: Isometric view of the Bowl visual aid.