THE EFFECTS OF TWO-DIMENSIONAL AND THREE-DIMENSIONAL STIMULI ON SPATIAL REPRESENTATION IN DRAWINGS

by

Tammy M. McGraw

Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Education

in

Curriculum and Instruction

Glen A. Holmes, Chairman
David E. Burton
John K. Burton
Norman R. Dodl
David M. Moore

March 26, 1997
Blacksburg, Virginia

Keywords: Spatial Perception, Children, Instructional Media

THE EFFECTS OF TWO-DIMENSIONAL AND THREE-DIMENSIONAL STIMULI ON SPATIAL REPRESENTATION IN DRAWINGS

by

Tammy M. McGraw

Committee Chairman: Glen Holmes
Curriculum and Instruction

(ABSTRACT)

Visual learning experiences are becoming increasingly prevalent in education as symbols, imagery and simulations replace traditional text-based materials. Although the utilization of images for instructional purposes is not a new occurrence, most images used in instruction have been two-dimensional representations, giving learners little experience working with three-dimensional images. Little research has been done to explain the effects of two-dimensional and three-dimensional stimuli on the learning process.

This study examined the effects of two-dimensional and three-dimensional stimuli on spatial representation in drawings. Through the use of stereopsis, a scene was projected as both a two-dimensional image and as a three-dimensional image. Students wore polarizing glasses to enable them to perceive the superimposed images as a three-dimensional scene; whereas a single slide was projected when the image was to be perceived as a two-dimensional scene. Four test groups were established from eighth grade students who elected to take art. Participants in Group A were ask to draw the scene from the two-dimensional stimulus and, a week later, from the three-dimensional stimulus. Group B was asked to draw the scene from the three-dimensional stimulus and, a week later, from the two-dimensional stimulus. Group C drew only from the two-dimensional stimulus while Group D drew only from the three-dimensional stimulus.

In all groups, participants were asked to draw the scene as realistically as possible using a graphite pencil. The completed drawings were evaluated for evidence of spatial cues and the students' perception and response to spatial information.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to my advisor Dr. Glen Holmes, as well as my committee members, Dr. John Burton, Dr. Norm Dodl and Dr. Mike Moore, for their guidance and genuine commitment to this effort. I am indebted to each of them for their important contributions to my work. I also want to thank Dr. Lee Wolfle for his assistance and encouragement. I owe a special thanks to Dr. David Burton, my friend and mentor who urged me to take an interesting idea and turn it into a dissertation.

I will be forever grateful for the assistance I have received from my colleagues Wendy Richardson, Gail Wertz, Margaret Whorley, Chip Addison, Karen Kunc, and Cynthia Taylor. I appreciate their willingness to share their exceptional talents and expertise. I also want to thank my superintendent, Mr. Leonard Gereau, for allowing me to take time from my work to pursue this dream.

Any goal that demands total commitment cannot be achieved without the assistance of good friends. I am grateful to Betty Blair for her constant support and encouragement and for her willingness to critique my work. I owe a special thanks to my dear friend Nancy Rinehart, whose confidence in me pulled me through the most difficult days.

Finally, I want to thank my family for their love and encouragement. My extraordinary parents gave me much more than the financial means to do this. Beyond their love and affection, they gave me two things I truly value--a belief that I can accomplish anything and a tremendous love for learning.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I
INTRODUCTION

Rationale for the Study

Visualization is a widely accepted method of presenting concepts and data to learners. Because students are able to comprehend and assimilate information through the process of visualization, many of our learning environments utilize illustrations and audio visual materials to assist learners (Auld & Pantelidis, 1994). In addition to the *effectiveness* of visualization on the learning process, we must also consider the *efficiency* of presenting concepts and data in a visual format. Larry Smarr (1991), Director of the National Center for Supercomputing Applications, states:

> The eye-brain system is incredibly advanced. Looking at the world, we absorb the equivalent of a billion bits of information per second, as much as the text in 1,000 copies of a magazine. But our mental “text computer” is limited by the fact we can read only about 100 bites--or characters per second (pp. 138-150).

The effectiveness and efficiency of visual learning experiences offer great promise to the field of education. Two of the most significant changes in education will be the shift in learning from printed information to simulations and the change in curriculum from being text based to imagery based (Helsel, 1992). These changes will most likely be exemplified in virtual reality applications. “There is a general concensus among educators that learning by experience, real or virtual, remains the most effective way to acquire knowledge” (Homan, 1994, pp. 224-227). Hedberg and Alexander (1994) assert that virtual reality offers great possibility in allowing learners to become active participants in a “community of practice.” They suggest that as learners progress to full participation in such a community, understanding will increase and the transfer of concepts to new contexts should be easier.

Learning in virtual environments presents other advantages. Possible uses of virtual reality include, but are not limited to, participation in historical events, learning languages via travel to foreign destinations, creating alternate worlds, exploring planets and other inaccessible places, and creating and manipulating abstract conceptual representations. Andolsek (1995) offers examples of educational applications of virtual reality. She discusses the role of virtual reality in the areas of special education, architecture, multiculturalism, history, literature, science, mathematics, medical education, corporate training, manufacturing, military training and training in the airline industry. The advantages of such technology in education and training seem clear. It stands to reason that visual literacy will become increasingly important as learning relies less on text-based materials and more on symbols, imagery and simulations.

Given the promising future of imagery and simulations in education, it appears necessary to understand the effects of two-dimensional and three-dimensional stimuli on learners. Are all learners better able to deal with information in a three-dimensional experience? Will more learning occur? Do learners deal with three-dimensional information differently than two-dimensional information? How can we train learners to be visual learners? These questions and others must be considered as virtual reality and three-dimensional imaging become viable media in education.

Statement of the Problem

Although there are numerous studies which examine visual space perception, considerably fewer have examined the comparison between what is perceived and what is drawn by the artist. This study focuses on the spatial qualities of drawings which were created from a two-dimensional stimulus and the spatial qualities of those created from a three-dimensional stimulus. Photographs and photographic slides are not perfect imitations of the scene they represent; therefore, we must consider whether or not the imperfection affects those who draw from two-dimensional images. Furthermore, we need to establish whether or not drawing from a three-dimensional scene results in a more realistic depiction of space. Theories regarding visual spatial perception and specifically, children's perception and representation of space, are examined to provide a basis for this study.

Visual Spatial Perception

The first segment of this literature review addresses the psychological and physiological aspects of visual spatial perception. In short, it is a brief discussion of how humans perceive depth. This discussion leads to the examination of literature which focuses specifically on children's perception and representation of space.

Historically, researchers have been concerned with how we gain information about distance and how we use the information we gather. The study of visual space perception centers around the concept of visual cues (Ittelson, 1960). Spatial cues are symbols which rely on previous interaction with other cues and the past experiences of the viewer (Hochberg, 1978). After reviewing the work of Ittelson (1960); Graham (1965); Okoshi (1976); Frisby (1979); and Rock (1984), the following list of psychological spatial cues has been provided with operational definitions as they relate to this study. It should be noted that the term *spatial icon* is a term coined by the investigator and does not appear in the references cited.

1. occlusion--the partial covering of one object by another.

2. linear perspective--parallel lines that recede from the subject appear to converge.

3. atmospheric perspective--the tendency of objects to appear tinged with blue because of impurities in the atmosphere. It also refers to the loss of visible detail in distant objects.

4. texture gradient--nearer elements in a texture are represented larger than distant elements of the same apparent size.

5. modeling--reproducing in a drawing, the effect of light and shadow on a three-dimensional form to create a realistic, three-dimensional appearance of the form.

6. shadows--shading that results from the depth within the object itself and from that which falls on surrounding surfaces.

7. familiar size--if we are familiar with an object's typical size, our memory of its visual angle at varying distances could allow us to estimate its distance.

8. size constancy--objects of equal size at varying distances project images whose visual angles are inversely proportional to their distance.

9. foreshortening--the difference in the projection of equal distances in the third dimension.

10. shape constancy--the tendency to compute the shape of an object based on our perception of the distinct distances of parts of the object.

11. vertical positioning--representing space in such a way that distant objects appear higher on the picture plane.

12. spatial icon--a symbol or convention used to indicate the relative distance of the viewer from the object, for example, "m" birds or "lollipop" people.

The aforementioned cues, with the notable exception, are identified as psychological cues by Okoshi (1976). He states that the four physiological cues are the most important cues in the perception of depth. They are binocular disparity, convergence, accommodation , and monocular movement parallax.

Monocular vision refers to vision with a single eye, while binocular vision requires the coordination of the two eyes (Graham, 1965). Pirenne (1970) examined Hemholtz's work and found that, theoretically, it is virtually impossible to distinguish between a picture of a room and the room itself when the room is viewed with one eye. In effect, all but the pictorial cues have been eliminated (Rock, 1984). If we use both eyes, the flatness of the picture would be noticed.

There seems to be a general consensus that binocular vision is the basis for our perception of the world as three-dimensional (Pirenne, 1970; Frisby, 1979; and Rock, 1984) and the perception of depth is the result of the combination of two slightly dissimilar images (Luckiesh, 1965).

The difference between the two images is known as binocular disparity (Frisby, 1979). Two distinct images must be projected to each eye separately in order to present a sense of depth (Pirenne, 1970). When we view objects with both eyes, the image projected on each retina differs because of the difference in the position of the eyes. The achievement of depth from the binocularly disparate images is referred to as stereopsis (Rock, 1984).

Another factor in binocular vision is convergence. It is the angle formed by the eyes fixating at a given point in space. That is, the eyes look toward each other as they fixate on objects that are within a distance of twenty feet. Convergence serves as a cue for distance (Graham, 1965; Rock, 1984). In viewing at distances which exceed twenty feet, Sekuler and Blake, as cited in O'Donnell and Smith, 1994, noted that the observer's eyes are positioned straight ahead and convergence is not a factor .

Okoshi (1976) includes accommodation among the physiological cues for perceiving the depth of an image. Accommodation is defined as "the muscular tension of the ciliary body for adjusting the focal length of the crystalline lens" (Okoshi, 1976, p. 49). It is considered a monocular depth cue because the shape of the lens can change even when we view an object with a single eye. It works only as a depth cue when it is combined with other binocular cues and it is limited to viewing at a distance of less than twenty feet.

The fourth physiological cue is monocular movement parallax. This requires the movement of the viewing position of the observer and viewing the object from various directions. Movement parallax can occur by the observer fixating on an object which is in motion or by the observer fixating on stationary objects while moving his or her head from side to side (O'Donnell & Smith, 1994).

When we consider drawing from an existing picture (regardless of how realistic the photograph, painting, etc.), we must realize that it is not like the retinal image. A retinal image is a continuous impulse in the optic nerve and is not something to be looked at by an observer. On the other hand, a picture is a selection from a total scene which enables the observer to perceive some aspect of the visible world in the same way the artist perceived it (Gibson, 1960). The eye can be fooled into perceiving a painting or photograph as real, but only in certain conditions. For example, the observer must view the picture from the same position from which the artist viewed it or the camera photographed it (Rock, 1984).

The question remains as to why we perceive most representational pictures as good likenesses of reality. Rock (1984) offers the explanation that the retinal image from the picture is similar to the retinal image of the actual scene represented. More specifically, the *relations* within the picture and the image of the scene are very similar, more so than the absolute properties.

At this point, the psychological and physiological aspects of visual space have been established. This review now focuses on spatial perception and representation as it relates to children.

Children's Perception and Representation of Space

The overwhelming interest in children's drawings is not a new phenomenon. Psychologists and educators have long been aware that children's drawings can help us understand their cognitive and emotional development. C. Seefeldt as cited in Guthrie & Su, 1992, acknowledged drawing as an important educational activity that aids children in the processes of learning and remembering. Among the most widely used measures of intellectual functioning is the Goodenough Draw-A-Person test. It requires that the child draw a person; and it is inferred that the person drawn is a reflection of the child's self-image (Leeds, Dirlam, & Brannigan, 1983).

Early studies of children's drawings date back to the late 1800's. Perhaps the most important contribution of the early researchers was that children progress through stages, and that children's drawings are developmental in nature (Harris, 1963). There have been numerous studies conducted that have provided insight into the nature and value of children's drawings; however, this review will be limited to studies that focus on the development of spatial perception and spatial representation.

Leeds et al. (1983) proposed that "after developing a stage or organization of spatial representation it would be possible to assess a child's development level by analyzing his drawings" (p. 141). Piaget and Inhelder, as well as Lowenfeld, propose theories of spatial development which provide a framework for this literature review; however, the following questions identify other issues that are important in understanding children's perception and representation of spatial information (See Appendix A).

1. What exactly does the child's conception of space entail?

2. Does the ability to perceive a spatial relationship ensure that the child can reproduce the relationship?

3. Is drawing from a three-dimensional model more difficult than drawing from a two-dimensional model?

4. Does media affect the child's ability to perceive space and represent space?

5. What effect does a child's knowledge of a scene have on his ability to draw the scene?

6. What effect does teaching and familiarity of the task have on a child's ability to depict the appearance of an object?

Piaget and Inhelder's view of spatial representation differs somewhat from that of Lowenfeld's; therefore, the literature will be examined separately. Other researchers have had interesting findings which are significant and are mentioned as well.

In an explanation of spatial perception, Piaget and Inhelder (1967) suggest that there are two developmental phases: spatial perception and spatial representation. They point out that spatial perception is something that gradually evolves and is not available to the child at mental development. The "construction" of spatial perception occurs during three periods of the sensori-motor development. In an evaluation of Piaget's and Inhelder's theory, Leeds et al. (1983) noted that an infant in the sensori-motor stage of development forms his perceptions through constant contact and interaction of objects. The first period involves topological aspects, the second period focuses Euclidean and projective aspects, and in the third period the child explores both Euclidean and projective aspects together.

Topological space refers to the concept that objects possess certain spatial characteristics. These were denoted by Piaget and Inhelder as proximity, separation, order, enclosure and continuity. In other words, the child is able to perceive that objects are close to each other, that separations exist between objects, that objects can appear inside an area or between two other objects, that objects can appear in succession, and that objects can appear clustered together without being physically connected.

Euclidean spatial concepts deal with the relationship or similarities between objects. In this period the child becomes aware of the relationships of angles, straight lines and geometric shapes. The child also begins to gain understanding of perspective.

Finally, in the third period of sensori-motor development the child explores Euclidean and projective concepts cooperatively. The child becomes increasingly aware of perspective and the varying relationships between objects within an environment.

In each period the child's perceptual space is ordered differently. It isn't until the child passes through the last period of sensori-motor development that he/she makes his/her first attempt at drawing. Drawing, at this stage of intellectual development, can be described as scribbling. That is, the drawing process is a kinesthetic activity in which the child moves his/her entire arm to create a mark that often extends beyond the drawing surface. This indicates that the child's conception of space has progressed beyond spatial perception and becomes representational in nature (Leeds et al., 1983).

Leeds et al. (1983) concluded that Piaget and Inhelder's theory of spatial representation follows the same model as their model for spatial perception. More specifically, three periods of development, which were originally proposed by Luquet and later adopted by Piaget and Inhelder, exist in the child's spatial representational development. These periods are synthetic incapacity, intellectual realism, and visual realism, and correspond with the topological, Euclidean, and projective concepts realized in spatial perception. It is important to note, however, that in their theory of spatial perception, development occurs within the sensori-motor stage of development or during the first two years of life. The synthetic incapacity stage occurs at ages three and four, the intellectual realism stage at ages five through eight, and the visual realism stage at ages nine through fourteen.

During the synthetic incapacity stage, children make their first effort to represent objects. They do so by exploring the topological concepts of proximity, separation, order, enclosure, and continuity. The child's drawings lack proportion, perspective, and depth. The objects represented are "composed of imperfect circles, squares, and lines" (Leeds et al., 1983, p. 142). Typically, a child's drawing of a face might have the features drawn inside an imperfect circle, or the child might have trouble with the inside and outside relation and place the features outside the circle. Often a child will not separate the objects he is drawing. Objects might share some of the same lines, and it may become difficult to draw a distinction between the two objects. It is not uncommon to find that objects that would normally be attached are juxtaposed but do not touch. Such would be the case with a drawing of a person riding a horse where the person is not actually touching the horse. Finally, in drawings of more complex shapes such as a person, the child often draws parts (arms, legs, etc.), floating in the space around the figure (Leeds et al., 1983).

As the child moves into the period of intellectual realism, he or she masters the topological concepts described above and begins to move toward the Euclidean and projective concepts of geometric shapes, perspective, transparency, and projection. Typically, the child's drawings in this stage of development show everything that is present; but the child has yet to master distance relationships, perspective, or proportion.

The child employs geometric shapes, angles, and straight lines to represent all types of basic objects. Although children use geometric shapes and lines, they are incapable of representing a unified perspective. In fact, several views might be present in a single picture. Another feature that is characteristic of this stage of development is transparency. A child might draw a house and include "an x-ray view" of the interior of the house.

In the last stage of spatial representation development known as visual realism, the child has become skillful in using topological, Euclidean, and projective features in his/her drawings. He/she approaches drawing in a *naturalistic* way; making objects appear the way they would look in a photograph. There is evidence that the child can represent correct proportions, distance relationships and perspective.

The child is aware of the differences in size of familiar objects and now possesses the ability to depict such differences. His/her ability to represent perspective is refined to the extent that it is possible to see a single point of view in his/her drawings. Finally, the child is aware of depth relationships between objects and realizes that objects which are farther away can be placed higher in the drawing, drawn with less detail, and drawn to diminish in size as they recede into the distance to achieve a representation of depth (Leeds et al. 1983).

Although Piaget and Inhelder are considered to be among the greatest contributors to the body of knowledge concerned with the child's conception and representation of space, they do not rise above criticism. Kose (1983) cited the work of Siegal and Schadler, 1977; and Siegal 1981. They found that the techniques employed by Piaget and Inhelder to gain information about the child's conception of space underestimated the child's knowledge. They argued that children's practical knowledge of spatial arrangements is a better indication of their conceptual competency than the construction of maps and spatial models used by Piaget and Inhelder.

Leeds et al. (1983) also noted that Piaget and Inhelder failed to explicably state criteria that would determine what features could be derived from children's drawings. Much must be inferred from their discussion. Even with the noted criticism, it is important not to overlook the significance of their work.

Another significant work to consider is Viktor Lowenfeld's theory of spatial representation. Although Piaget's stages refer to intellectual development, Lowenfeld found that similar stages are present in art. Lowenfeld agrees with Piaget's claim that children think differently from adults. Drawings can provide evidence of a child's gradual change from an egocentric point of view to a greater awareness of his/her place in a larger environment.

The very young child's conception of space develops long before his/her motor abilities. Through immediate contact with his environment the child moves from manipulating objects to developing concepts. His/her understanding and organization of space follows a particular sequence. Lowenfeld's first recognized stage of development is the scribbling stage which occurs between two and four years of age. The scribbling stage occurs too early to see much evidence of spatial representation.

The preschematic stage occurs between the ages of four and seven. Sometime during this stage the child makes his/her first attempt at representing objects. His/her representation of space is qualitatively different from that of an adult. Lowenfeld points out that the representation of space also differs widely among adults depending on the individual and the culture in which they live. For example, space is generally represented through the use of perspective in our culture; however, there are contemporary artists who disregard mechanical perspective. In oriental cultures, space is typically represented by placing distant objects higher on the page. The point being made by Lowenfeld is that there is no one right way to depict space; and a child's representation of space is as accurate and valuable as any other.

The objects in a child's first representational drawings appear to be randomly placed around the page. Closer inspection will reveal that the objects are not randomly drawn; but rather placed in relation to the child. "No spatial relationship has yet been established outside the child's concept of himself. Space, therefore, is conceived of as revolving around the child, with no relationships established between objects" (Lowenfeld & Brittain, 1982, p. 211). Furthermore, preschematic children have little regard for correct size relationships; and their choice of color is based entirely on what appeals to them emotionally without consideration of the object's local color. Geometric lines and simple shapes are used to represent objects and often different combinations of those lines and shapes will represent the same object. Objects that relate to a specific activity are frequently represented in the child's drawings (Leeds et al. 1983). As the child develops, he/she moves beyond this period of egocentrism and begins to understand objects in relation to adjacent landmarks.

The child reaches the schematic stage at about seven years of age and continues in that stage until the approximate age of nine. Schema, or a constantly repeated representation for objects, develops in this stage. The child has a specific way of representing a house, tree, dog, etc., and uses these symbols each time a need arises to represent an object. The child has become increasingly aware of ordered spatial relationships; he/she is able to relate objects to one another. Perhaps the most noticeable characteristic present during this stage of development is the base line. All objects are placed on the base line, apparently indicating that a child has a new awareness of himself in relation to his environment. Lowenfeld cites a study conducted by Wall (1959) in which 5000 drawings were examined. The study revealed that by the age of eight, ninety-six percent of the children included a base line in their drawings. The occurrence of the base line appears to be universal and part of the child's natural development. When questioned about the base line, children usually respond that it is the ground.

Two base lines will sometimes appear in a child's drawing; however, it is usually later in a child's development. The child who employs two base lines is moving toward the use of perspective. It is interesting that the objects in the picture still relate to the base lines even though the child has elected to use two of them.

Similar to the base line, and appearing during the schematic stage, is the sky line. It is drawn at the top of the page. Children identify the space between the base and sky lines as air. Lowenfeld makes an interesting point when he states that adults think the sky should meet the ground; however, the adult representation is as much an illusion as the child's sky line. Again, the child's representation of space is as valid as our own.

Although the base line is the most frequently used attempt at representing space by the schematic child, deviations from this practice do occur. For example, the subjective spatial representation of folding over occurs. The child who uses the process of folding over has determined that both sides of a scene are important, and although part of the picture appears upside down to us, it is again perfectly valid when we realize that the child sees himself/herself as being at the *center* of things.

Another variation of the base line is the practice of depicting objects in a circle. A drawing of seated figures around a table is a good example of this type of spatial representation. What is particularly important about this is that the child includes more than one viewpoint in his/her drawing.

Plan and elevation combinations are another method of spatial representation. The child finds it necessary to show the most important elements of a scene regardless of their actual relation to each other.

Finally, a child may create an x-ray picture. This usually occurs when the child feels that the interior of an object is more or equally as important as the exterior of the object.

The child at this stage of development is still unable to represent the three-dimensional quality of objects. The schema, therefore, tends to be two-dimensional in nature. The objects in the child's drawings are composed of geometric shapes. More detail is added to those objects in the form of additional parts drawn inside the objects. For example, apples may be included on a tree, and doors and windows are added to houses. Objects that are identical tend to be drawn the same color.

A final characteristic of the schematic child's drawings is that there is often a deviation from a schema indicating an emotional experience involved. A child might exaggerate or omit something in his drawing which might indicate its significance to the child. A deaf child, for example, might draw himself or herself without ears, or with especially large or small ears.

Between the ages of nine and twelve, the child moves into the gang age or a period of dawning realism. He/she gradually becomes better able to deal with abstract concepts. Schemas are tossed aside as the child reacts to and attempts to represent the unique characteristics of objects. The base line is no longer used as the child sees objects in relation to each other and arranges them on the paper accordingly. He/she approaches the representation of space in a more naturalistic way. He/she discovers the space existing between the base and sky lines and fills the space in his/her drawings. The base plane becomes a substitution for the base line. Although some children will still rely on the base line from time to time, they usually consider the space below the line to be ground.

The sky line disappears as the child begins to connect the sky and what is probably, at first, a base line. Although this line will later become the horizon, the child is not aware of the horizon as such. The child's visual perception of distance is not fully developed. The child does, however, draw things from a single viewpoint and is more likely to be able to identify how another person seated at a different position might see the same scene.

Overlapping is another characteristic of the child's drawing at this age. Lowenfeld found this to be particularly significant because "it implies a recognition of the interrelationships between objects" (Lowenfeld & Brittain, 1982, p. 290). Overlapping greatly contributes to the naturalistic look of the child's drawing.

The fifth stage of spatial development identified by Lowenfeld is the age of reasoning. The child has become aware of the apparent reduction in size of distant objects and attempts to create the illusion of distance in his drawings. Although many children at this age understand the three-dimensional qualities of space, Lowenfeld insists that they should be allowed to discover the means to represent distance on their own. They are not necessarily ready to learn the mechanical rules for drawing in perspective, and it would be detrimental to the child to interfere with his search for ways to represent depth.

The last stage proposed by Lowenfeld is known as the Period of Decision, or the adolescent stage. This stage runs from approximately fourteen to seventeen years of age. The child has developed the visual perception of depth and is capable of learning perspective. Space can now be manipulated for expressive purposes; but the majority of students attempt naturalistic representations.

Lowenfeld and Piaget are not the only researchers who proposed that children progress through stages of development, and that the child's developmental level of spatial representation is evident in his drawings. Researchers such as Kellogg (1969), Lark-Horowitz, Lewis, and Luca (1967) and Eng (1931/1964) have described the stages of development in drawing, as well. They vary slightly from one another; but they are all essentially the same (Hagen, 1985). Researchers continue to examine the developmental aspects of children's drawings. Dalton and Burton (1995) concluded that children's conception of the base line is more complex than previously reported and that the shape of the drawing paper may influence a child's efforts to represent objects in space. "Recognizing the shape of the drawing paper and the character of its edge may play a role in some children's baseline concept and should remind us how easily inadvertent elements can influence research findings and interpretations" (Dalton & Burton, 1995, p. 112).

After having examined what is meant by the child's conception of space, and reviewing the necessary background for understanding children's spatial representation, the question must be considered, "Does the ability to perceive a representation ensure that the child can reproduce the relationship?" Kose (1983) reported the findings of a study conducted by Liben (1982) in which preschool children's practical knowledge of a familiar environment was compared to their ability to construct a model of the same environment. Liben found that the children demonstrated greater spatial knowledge when acting in the actual environment than when constructing a model of the same environment. She pointed out that children's manipulation of space varies with different tasks, and we should refrain from drawing conclusions about children's spatial capabilities based on their performance on any one task. With regard to Liben's findings, it seems likely that a child may be capable of perceiving a spatial relationship without being able to represent the relationship in a drawing or in the construction of a model.

Kose (1983) conducted a study which focused on children's understanding of spatial relationships and the way in which they demonstrate their understanding in drawings and photographs. Sixty children, ages five, eight and eleven, were asked to discriminate and reproduce the depth relationships of enclosure, occlusion and perspective. Half of the children were randomly assigned to a group in which they were asked to discriminate and reproduce line drawings of these spatial relationships. The other children were asked to discriminate and reproduce black and white photographs of the same three relationships. Data from a matching task revealed that children in all three groups were able to discriminate and identify the spatial relationships of enclosure, occlusion and perspective. An analysis of the children's reproductions of the same spatial relationships revealed some important distinctions. Kose (1983) found that:

> The number of accurate reproductions increased with age, and there were significantly more accurate reproductions in the Drawing condition than in the Photographic condition. The analysis of these data also indicate that the particular type of spatial relationship had an effect on the children's ability to make accurate reproductions, and that this effect varied in the Drawing and Photographic conditions (pp. 5-6).

Kose offers an explanation for why the children varied in their ability to identify spatial relationships and reproduce that same relationship. First, he points out that Gibson (1979) suggested that photographs contain considerably more information than line drawings. Line drawings contain enough information to make perception and understanding of spatial representations possible. Photographs, on the other hand, are more realistic; but the additional information becomes confusing and interferes with the perception of spatial relationships.

His second explanation lies in the differences in taking a photograph and producing a drawing. Although drawing requires motor skills, it requires less utilization of spatial information than does taking a photograph. Drawing does not require manipulation and interaction with the objects to be represented and an established fixed viewpoint is not necessary. Taking a photograph, on the other hand, requires a knowledge of more spatial information, manipulation of the objects being photographed, and the establishment of a fixed viewpoint.

Kose concluded that it is very difficult to understand the child's conception of space and what it means to have such a conception. He further concluded that the ability to perceive a spatial relationship does not necessarily mean that the same relationship can be reproduced.

Olson and Bialystok (1983) also support the notion that children cannot always reproduce the spatial relationships they are capable of perceiving and identifying. They argue that a child may have a concept of a lollipop and be capable of identifying it in terms of the structural description which makes up its representation, without having access to the propositions (circles and stems) that are parts of the structural representation.

Wilcox and Teghtsoonian (Mandes, 1985) suggested that the effective use of pictorial spatial cues increases with age. They found their results to be supportive of the Gibsonian position that perceptual ability, and in this case, the ability to perceive depth, is a product of maturation.

Two drawing researchers, Guthrie and Su (1992) describe three factors that affect a child's spatial representation: cognition, perception, and graphic production. In their view, cognition refers to the child's knowledge of the objects; perception refers to the child's observance and interpretation of visual information and involves decisions such as whether to represent structure information or view-specific information, and graphic production is the child's ability to produce a drawing of the features realized through cognition and perception. They argue that the drawing process is very complicated and that children's drawings do not necessarily reflect their conception--that they understand more than they reflect in their drawings.

Ingram and Butterworth (1989) concluded that young children are able to represent spatial information from an arrangement of objects. They insist that the drawing processes, in addition to the finished products, must be studied if we are to understand the process of representing three-dimensional spatial information on a two-dimensional surface.

In a final study on the discussion as to whether or not a child's ability to perceive a spatial relationship ensures that he/she will be able to reproduce the relationship, Cox (1978) examined a previous study by Freeman, Eiser, and Sayers (1977) which suggested that young children do not attempt to represent depth relationships between objects in their drawings. In the study, children were asked to draw one apple behind another, and to draw one apple in front of another. The drawings had no indication of a depth relationship between the apples. Cox modified the experiment and found that the children did attempt to show a depth relationship between the apples when both apples were visible and attention was drawn to the depth relationship between them. Cox (1978) makes an interesting point when he states:

> Young children may be more competent than they appear simply because verbal instructions given in experimental tasks are often in themselves not sufficient to enable the child to grasp the nature of the task. In other words, the procedure may become a test of verbal comprehension rather than of the ability ostensibly being tested (p. 554).

Consider the question of whether drawing from a three-dimensional model is more difficult than drawing from a two-dimensional model. It is obvious that this question cannot be answered with a simple yes or no, although people have a very strong sense of which is more difficult for them personally. May Jane Chen (1984, 1985) has written some important material concerning young children's representation of solid objects.

Chen (1985) considered the effect of the model on a child's drawing of a three-dimensional scene. She compared children's drawings made from a real-life object with their own drawings copied from a line drawing and a photograph of the same object. The children tested were in two groups: kindergarten and first grade. The results indicated that older children (7-9) were more advanced in their drawings. This was determined by evaluating the drawings on a six-point scale. Children incorporated more features of the two-dimensional models at each level. Copied drawings were found to be more advanced than the drawings of the real object when drawings from the same scene were assessed. In addition, the drawings copied from the line drawings proved to be more advanced than the drawings copied from the photographs except in the case of the cube and cone. This indicates that the child experiences difficulty when translating the three-dimensional stimulus onto a two-dimensional surface. A photograph must be perceived, translated into regions, and the region boundaries must be translated into lines. That there was no evidence that the copying of the cube and cone produced better drawings than those done from life indicates that copying is not necessarily easier than copying from life. Furthermore, the results of Chen's study suggests "that the relative difficulty of copying and drawing from life depends upon both the form of the model and the nature of the copying task" (Chen, 1984, p. 384).

Chen states that the primary concern when drawing a three-dimensional image onto a two-dimensional plane is that of conveying depth information. The first consideration is that of deciding how much information about the subject should be included in the drawing. Secondly, the three-dimensional information must be translated onto a two-dimensional plane. The drawer must find ways to employ depth cues and surface perspective transformations to create an illusion of depth. Chen and Cook (1984) proposed that the ability to draw projectively is dependent on the possession of a repertoire of drawing devices and the capability to attend to and represent the appearance of an object in a drawing. The drawing devices consist of determined ways of projectively representing objects, and ways of showing surface perspective transformations and depth cues. Chen and Cook described two such drawing strategies which could be employed by a child who attempts to copy a perspective drawing: structure-directed and content-directed. In using a structure-directed strategy, a child copying a two-dimensional model would perceive the model as an abstract pattern and draw a corresponding image on his/her paper. In using a content-directed drawing strategy, the child would perceive the three-dimensional image and represent the model in terms of what he/she knows about the object. Chen and Cook suggest that the mature drawer would use both drawing strategies, and while it seems likely that the structure-oriented strategy would result in a more accurate copy, it is not necessarily true. The fact that a copy is drawn well is no indication that a structure-directed strategy was used. "Children with advanced drawing devices which are as complex as that depicted in the two-dimensional model should be able to draw from a life model as well as to copy the object's picture correctly" (Chen, 1985, p. 160).

Chen, Therkelson, and Griffiths (Dowell, 1990) conducted an experiment in which children were asked to draw from a three-dimensional cube, a photograph of a three-dimensional cube, and a line drawing of a three-dimensional cube. They found that drawings created from the photograph and line drawing resulted in a better depiction of perspective.

It is apparent that the form of a model has a great deal to do with a child's ability to draw it; but another consideration is the effect of media on the child's perception and representation of space. Kose's explanation of drawing and photographic media and its relation to the child's representation of space was discussed earlier in the review. Other researchers have examined the issue of drawing from a life model versus copying a graphic representation. Dowell (1990) recognized the overwhelming opinion that drawing from photographs or other printed imagery is undesirable because it is believed that it interferes with the creative process. She attributed this belief, in part, to the influence of Viktor Lowenfeld. Robertson (Dowell, 1990) concluded that students who drew from two-dimensional imagery improved their representational drawing ability. Wilson, Hurwitz, and Wilson (Dowell, 1990) referred to the graphic model "as the most important contribution to the development of drawing ability." Gibson has also given support to the notion that photographs are important sources of visual information. He suggests that foreshortening and spatial information are easily perceived in a photographic scene (Dowell, 1990).

Another study which dealt with photographs was conducted by Ireson and McGurk (1985). They evaluated young Malawians' ability to make accurate judgments of the relative size and spatial location in photographs when no horizon was present in the photograph. Cues which indicated size and depth were present in the photographs, and the objects that were photographed for the study were made available to the subjects. Ireson and McGurk concluded that children and adults from various cultural backgrounds can make accurate size and spatial location judgments without horizon information, and the ability to make accurate judgments increases with age. This indicates that the Malawians were interpreting pictorial depth. Based on these findings, Ireson, and McGurk refuted Hudson's (1962) conclusion that African children are unresponsive to depth information in pictures.

In another study of depth picture perception, Mshelia and Lapidus (1990) concluded that training can improve non-western children's ability to perceive pictorial depth cues. Furthermore, their results indicated a strong relationship between the cognitive style of field independence and depth picture perception among their subjects.

Nancy Smith (1983) wrote an interesting article about children, ages seven to nine, who chose to draw from observation as opposed to drawing from memory. The observation drawings "differed from memory drawings in that they included greater detail, overlapping, unconventional orientations, and complexly contoured shapes" (Smith, 1983, p. 25). Smith noted that the children failed to represent volume in these observation drawings, and none of the children appeared to notice the absence of volume in their drawings. She proposed that the lack of volume was the result of the children's concrete conception of the medium. It was flat and they represented their subject by drawing lines which correspond to the model. In order to show volume, the children's conception would have to be modified to the point that the lines upon the paper would correspond to the volume of the objects. In other words, their conception of the medium would have to become somewhat abstract. Since children at this age have yet to reach the point where they can think abstractly, they did not represent volume or feel the need to do so. Smith's study, along with the others mentioned thus far, supports the notion that media does affect the child's ability to perceive and represent space. Smith found that children chose to draw from observation and that their drawings were superior to memory drawings. This leads to the question, "What effect does a child's knowledge of a scene have on his/her ability to draw the scene?" Smith would certainly agree that providing the child with an interesting model, and consequently, more information about the subject, will result in richly detailed drawings with sensitive contours and attempts at spatial representation (overlapping).

On the other hand, Harris (1963, p. 193) in a discussion of Goodenough's theory of cognition and drawing, stated, "For little children, drawing is a language--a form of cognitive expression--and its purpose is not primarily esthetic." Nor is it, he affirmed, simply a matter of reproducing the visual image; rather the "child draws what he knows, not what he sees," to use Luguet's (1913) phrase. Likewise, Crook (1985) insists that our ability to draw a scene is affected by the things we know about it; but he points out that it is difficult to determine what knowing a scene entails. He reports two types of drawing features which lend support to the ideas that knowing affects drawing ability. The first is stereotyped objects which children often include in their drawings. The second involves intellectual realism. In an attempt to depict spatial relationships, a child may include a full representation of an object that is actually partially hidden from view. These features can interfere with a child's representations.

Crook cites two studies which make the idea of intellectual realism more clear. The first study was conducted by Freeman and Janikoun (1972). They found that children, when shown a cup with the handle hidden, might very well include the handle in their drawing. Freeman (1980) went on to explain this occurrence with the concept of canonical forms. Simply stated, there are ideal projections for certain objects.

As an example of the second type of intellectual realism, Crook presented Clark's (1897) experiment in which children were shown a hat pin pushed through an apple. The children's drawings revealed that they had apparently tried to reproduce the scene by drawing a line across a circle, a transparent view of the apple, it seems.

Crook states that the structure of a child's knowledge of a scene has a tendency to interfere with his ability to represent the spatial relationships in the scene. More specifically, the child employs a mental representation with a list-like structure when drawing. The objects in a child's drawing are often separate, thus adding support to this idea. This period of object isolation occurs during a period that was identified by Luquet as "synthetic incapacity." It is a period that passes quickly and the segregation of objects becomes an important tool to aid in understanding spatial relationships such as above, behind, or in front of another object (Crook, 1985).

Another aspect of children's knowledge that has a tendency to interfere with their ability to represent spatial relationships is the conflict that might occur when drawing rules are not compatible with the scene to be represented. In other words, the scene to be drawn requires that a child use a drawing rule that would ordinarily be used to indicate something different. Crook cites an example used in a study by Light and Macintosh (1980). A toy house was placed behind a glass in such a way that the house could be seen completely through the glass. Apparently, drawing a house inside a glass is a solution for the representation of the concept *inside.* The conflict that results has a detrimental effect on the child's ability to represent spatial relationships.

Teske, Waltz, and Shenk (1992) found that children might begin to incorporate inclusion in their drawings as a means of dealing with the conflict that exists between their desire to present the canonical view of objects and their awareness of the spatial relations within the object array. The task of depicting multiple objects is also a factor in the appearance of occlusion in children's drawings.

Finally, consider the question that is of particular interest to art educators. "What effect does teaching and familiarity of the task have on a child's ability to depict the appearance of an object?"

Earlier reference was made to a study conducted by Ireson and McGurk (1985) in which young black African children were found to derive spatial information from photographs containing no horizon information. They make a point of mentioning that, although these children were in school, they had less exposure to books, pictorial materials or television than children in Western cultures. Furthermore, less emphasis was placed on art in the school. This appears to indicate that the ability to perceive depth is not dependent upon one's exposure to visual materials or experience in manipulating materials. It now becomes a question of "How much can teaching and exposure to visual materials improve one's perception and representation of spatial relationships?"

John Willats (1977) supports the opinion that children progress through a series of stages differentiated by their ability to use various drawing systems; and the complexity of these drawing systems increases with age. He suggests that teaching will have very little effect on all but the last two stages in this developmental process.

Claire Golomb (1992) has also addressed the issue of spatial representation. According to Golomb, there appears to be a relationship between spatial differentiation and the theme of the drawing. For example, in drawings of a family, figures tend to be aligned across the center of the paper within one-third of the center area. On the other hand, outdoor scenes containing people are usually drawn at the bottom of the paper. Horizontal and vertical axes become representative of two directions of space, with the vertical axis serving as both up and down as well as far and near.

The playing-catch theme tended to result in horizontal side-by-side and triangular arrangements. She reported that drawings of interior scenes were most difficult, in part because of the limitations of a single baseline.

Golomb contends that children are confronted with the problem of solving spatial problems that occur within a figure, among figures, and between multiple figures and the total space. Additionally, the child must deal with the limitations of the graphic medium and make choices regarding the view and appearance of the object they are attempting to represent. That is, they must make the translation from a three-dimensional object to a two-dimensional representation.

In her interpretation of Willats' data, Golomb suggests that children may employ oblique projection and perspective projection systems at the same age, suggesting that they are capable of using either system at a given time. She also notes that Willats did not find a relationship between a given drawing system and the degree to which overlap was used in the drawing. She suggests that this is an indication that overlap and the drawing systems in question pose unique representational problems. Furthermore, Golomb notes that Willats' research supports the opinion that early drawing inventions are, for the most part, self taught and that children lay aside drawing systems when they do not meet their need to represent a more complex model. And though children attempt to represent more complex models, they are reluctant to abandon the portrayal of the true shape of an object. For example, they have difficulty replacing the rectangular shape of a table with a parallelogram. Golomb (1992) states that:

> However impressive the spatial-representational systems are that some children and adolescents invent, we ought to keep in mind that only few individuals reach the stage of oblique perspective representations on their own, that is without instruction, and this finding is quite remarkable given the rich pictorial environment of our contemporary culture (p. 106-107).

Golomb has also reviewed the work of Piaget and found areas of concern. She rejects the theory that knowledge and then viewpoint determines a child's use of a drawing system. She also points out that research exists that does not support Piaget's claim that a close relationship exists between concrete operational reasoning and drawing. She states, "The drawings in orthographic projection, which are typical for ages seven to twelve years, cannot be derived from 'knowledge' or from 'viewpoint;' they can neither be explained in terms of intellectual nor of visual realism" (p. 110). While recognizing the importance of Piaget's work, Golomb asserts that his conception of intellectual and visual realism does not offer a satisfactory explanation of drawing development.

According to Golomb, figures pose unique problems for children. For example, young children attempt to avoid overlapping forms; however, it is a less likely occurrence when the overlapping is internal to a figure. Foreshortening is also an important technique in depicting depth within a figure. Golomb suggests that it is rarely achieved prior to adolescence, and in those instances it is usually the result of instruction.

After examining literature that seemingly answers the question regarding the effect of teaching on spatial representation, a point of view has emerged that is radically different from everything discussed thus far. Margaret Hagen (1985, p. 76) simply states that "Drawing, in terms of systems of spatial representation, does not develop across culture or with increasing age." She supports the statement by saying that most people cannot draw as the artists in their cultures can; but drawing skills can be developed and children can be taught to draw. Motor control will improve with practice, according to Hagen; but it is cultural canons that must be mastered if a child is going to learn to draw.

Though opinions regarding a child's representation of spatial relationships widely differ, understanding these opinions and how they differ is important. It is through the study of children's drawings that we will discover the best ways to teach them.

This segment of the literature review is concluded with Hagen's thoughts because it emphasizes the differing opinions surrounding children's perception and representation of spatial relationships. Furthermore, it supports the view that additional research is needed in this area.

Instructional Media

A need for further research is also evident in the literature pertaining to instructional media. Allen (1991), noting the compound process by which two-dimensional spatial cues represent three-dimensional objects, suggests that it is critical for three-dimensional images to include spatial information (spatial cues), particularly when the 3-D image is used for instructional purposes. He points out that interpreting visual information from photographs, motion pictures and computer monitors is a learned skill and "visual literacy requires mastery of complex rules for inferring three-dimensional relationships from two-dimensional cues such as shading, apparent size, perspective, and occlusion of objects" (p. 47). Stating that visuospatial capabilities can be taught, Allen suggests that viewers must learn to navigate in three-dimensional space and must learn to construct mental models of their environment. Allen (1991) further states:

> We are searchers for patterns, meanings, and anomalies, guided in highly selective eye movements by internalized standards of significance. To be a trained observer is to know in advance what to look for. We abstract details that seem important at the time of visual inspection and forget the rest almost completely (p. 48). Visualization, according to Allen, is important to the reconstruction of experiences and to our ability to imagine and solve problems. He also suggests that it is the ability to manipulate images that may be of most value in instructional applications using three-dimensional graphics.

The utilization of images for instructional purposes is not a new occurrence; however, most images have been two-dimensional (photographs, drawings, etc.) in their representation of objects (Milheim, 1995). Milheim cited the work of Feldmann, Heller, and Bacon (1972) in suggesting that the increased usage of computers, particularly as a calculation and display device, has increased the instructional potential of three-dimensional graphics. Allen (1991, p. 47) also credits the evolution of processing and display capabilities of computers with the emergence of computers as a visualization tool in education. West (1991) suggests that computers will allow measurement of "a vastly increased range of visual-spatial and other socially valued skills which have not previously lent themselves to conventional paper-and-pencil methods of assessment" (p. 41).

Milheim, (1995, p. 95) describes Berthelot and Stolovitch's (1980) study as "one of the few research studies that critically evaluates the effectiveness of three-dimensional images as compared to pictures presented in two-dimensions." The study involved the use of images and an audio accompaniment to teach college students a particular Lacrosse shot. Milheim (1995) also stated that:

> Although there were no significant differences in learning based on whether visual images were presented in two dimensions or three dimensions, there was a non-statistical increase in scores for the 3-D group as the complexity of the psychomotor task increased (p.95).

Another important point made by Milheim (1995) is that most learners have had very little experience working with three-dimensional images, a situation that could be problematic in instances where learners manipulate images in three-dimensions. He warns that learners must receive practice with learner-controlled images to experience the benefits of three-dimensional instructional media.

Along with the evidence which supports a need for additional research, there exists a reminder to avoid past mistakes. Whalley (1995) warns of the frequent habit of those in education who have viewed each new technology as having the potential to revolutionize education and improve student achievement, only to find that the desired changes did not occur. He contends, however, that the use of computers for imaging will likely contribute significantly to teaching and learning.

Ullmer (1994) suggests that most traditional media research does not communicate clearly how students' intake of stimuli affects the learning process. That is, little has been discovered that explains the relationship of media to an increase in learning or greater proficiency in learning.

Recognizing that literature supports the likely use of imagery and simulations in education, and heeding the warnings of researchers to avoid past mistakes, the need exists for additional research. This study has the potential to provide a new level of understanding of two-dimensional and three-dimensional instructional media.

Summary

Visual spatial perception is centered around the concept of visual cues, specifically psychological and physiological cues. Binocular vision, which results from our perception of two slightly dissimilar images, is the means by which we see the world in three dimensions. We generally perceive pictures as "real scenes" because of the similarity to the actual scene.

Investigators often examine children's drawings to understand their perception and representation of space. A widely held belief is that children's drawings are developmental in nature. Piaget and Lowenfeld proposed highly regarded theories of spatial development which have found support by many researchers. Although the stages of development may vary slightly, there is general agreement that stages of development exist in children's drawings. However, some literature suggests that spatial representation does not develop with increasing age.

Evidence suggests that children may be able to perceive a spatial relationship without possessing the ability to represent the relationship, and that children understand more than they represent in their drawings. Verbal instructions might be insufficient in enabling children to represent spatial information in a drawing task. Furthermore, the importance of the drawing process cannot be overlooked.

The model used in representing a three-dimensional scene has also been found to affect children's spatial representation. Two-dimensional models have been shown to result in more advanced drawings with regard to spatial representation; however, children who possess advanced drawing strategies can draw from a three-dimensional model with equal effectiveness.

Opinions vary as to the appropriateness of using photographs and printed images as models. While some feel it inhibits creativity, others believe that photographs and printed images make spatial information, such as foreshortening, easier to perceive. Another controversial issue regarding the perception of spatial information in photographs is whether non-western children respond to spatial information in pictures.

Drawing from observation, as opposed to drawing from memory, has been found to result in a more realistic depiction of space. Some assert that children simply draw what they know rather than what they see. Often children's knowledge of drawing rules interferes with their ability to represent spatial information if it is in conflict with the scene to be represented. Media has also been thought to have an effect on children's ability to represent spatial information.

There appears to be a relationship between spatial differentiation and the theme of a drawing. Overlap poses unique representational problems; however, it seems to be less of a concern for children when the overlapping is internal to a figure. Foreshortening, a difficult technique, is rarely achieved prior to adolescence.

Drawing inventions are essentially self taught. Children abandon drawing systems when they are confronted with complex models that require another drawing system.

Interpreting visual information is a learned skill and thought to be important to our ability to solve problems. Traditionally, most instructional media has been two dimensional and learners have had little experience with three-dimensional images. Most traditional media research does not address the effects of stimuli on the learning process. It also typically does not address how media increases learning or promotes proficiency in learning. Given these conditions, it appears that a need exists for additional research in this area.

Hypotheses

Through the use of stereopsis, a scene will be projected as a two-dimensional image and as a three-dimensional image. Polarizing glasses will allow control over whether or not the scene will be perceived as a two-dimensional or three-dimensional image (independent variables). This study will provide insight into how depth cues are perceived and represented in drawings. The drawings completed from these varying stimuli (dependent variables) will show the effects on the representations produced from a two-dimensional stimuli or from a three-dimensional stimuli. The following hypotheses will be tested with a decision to reject the hypotheses specified at a significance level of .05.

Research Hypothesis 1

There will be a significantly greater number of identifiable spatial cues found in drawings when the stimulus is a three-dimensional stereoscopic photographic slide of a scene than when the stimulus is a two-dimensional slide of the same scene.

Research Hypothesis 2

There will be a significant increase in the number of identifiable spatial cues found in drawings when the stimulus in the first treatment is a two-dimensional photographic slide of a scene and the stimulus in the second treatment is a three-dimensional stereoscopic slide of the same scene.

Research Hypothesis 3

There is a significant decrease in the number of identifiable spatial cues found in drawings when the stimulus in the first treatment is a three-dimensional stereoscopic slide of a scene and the stimulus in the second treatment is a two-dimensional photographic slide of the same scene.

CHAPTER II
METHODOLOGY

Participants

The sample was collected from a middle school in southwest Virginia. The school, which is the only middle school in the school system, has an enrollment of 1558 and serves students in grades six through eight. The middle school is comprised of two halls housing two art laboratories among its facilities.

Four test groups were established. Each group was an intact class comprised of eighth-grade art students. It should be noted that the literature, particularly that of Piaget and Lowenfeld, clearly suggests that learners who have yet to reach this period are not developmentally ready to complete the task as required by this experiment. That is, prior to this time, a child typically will draw what he/she knows rather than what he/she sees. It was with this knowledge that the investigator selected eighth-grade art students for this experiment.

These groups contained all the students at the eighth-grade level who elected to take art. The four groups, labeled Group A, Group B, Group C, and Group D, were all enrolled in the elective course, *Introduction to Art*. The labels, A, B, C, and D were assigned to the groups. The groups were representative of students from various ethnic and socio-economic backgrounds (see Appendix B for exact group composition). Also, various levels of formal art training exist in each group. Two art specialists teach the four sections of *Introduction to Art*, each teaching two sections in his/her respective laboratory concurrently with the other specialist.

Procedure

A preliminary test (Pola-Mirror) was used to determine the status of binocularity in each student (see Appendix C for Pola-Mirror Test description). Participants whose performance on the Pola-Mirror Test indicated poor binocularity were not included in the sample.

Three individuals with certification as visual arts specialists were selected to analyze the drawings for spatial cues. The evaluators had a combined total of 50 years experience as classroom art specialists. Two of the three evaluators held a Master of Art Education degree while the third evaluator held a Bachelor of Fine Arts. Additionally, the evaluators brought experience in psychology, art therapy, and graphic communication to the evaluation process.

To ensure consistency among evaluators in performing this task, the investigator trained the evaluators using assessment consensus strategies. The evaluators examined twelve drawings and identified the spatial cues present in each. Four of the training drawings were created by students who were subjected to the same stimuli used in the experiment. The remaining eight drawings were done by students who worked from two additional projected images which contained the same twelve spatial cues. The responses were compared to determine the consistency among evaluators. Each response was discussed and a consistent set of standards was established with which to score the drawings. Additional drawings from the pilot study were used for clarification purposes and discussion. A consistency rate of .80 was obtained before proceeding with the evaluation of the drawings. The evaluators examined the drawings independently and judged the drawings in random order without access to any identifying information. The drawings were labeled with a five-digit number for the purposes of identification and were presented in a standard 4” black mat to achieve a window effect.

To prepare for this experiment, stereo slides were obtained by attaching identical 35mm Minolta cameras to a tripod and using a twin cable release to simultaneously take photographic slides of a scene. The camera lenses were separated by a distance of approximately six centimeters to emulate the interpupillary distance, thus giving the effect of binocular vision.

The scene was selected because of the number of identifiable spatial cues present in the scene. A panoramic view was avoided because three-fourths of the spatial steps in a stereo field are located between two and eight meters. To heighten interest in the image, a scene was selected which contained an interesting foreground with objects located two to three meters from the cameras. Moving objects were avoided, as they have a tendency to distort stereo images.

The slide film was commercially developed; however, the slides were hand-mounted for accuracy in an attempt to avoid the eye fatigue or nausea associated with poorly mounted stereo slides. The film was flattened by applying weights to the uncut strips to avoid distortion in the projected image. A simple mounting device was devised using a grid system superimposed on a portable light box. The vertical lines on the grid enabled corresponding points to be checked, and the horizontal lines on the grid assisted in placing the corresponding points at the same level. Glass mounts with aluminum masks (specially designed to avoid Newton’s rings) were used to prevent bulging of the film when heated by the projector lamps.

Projection was accomplished by using a Brackett Stereo Projector consisting of a dissolve unit with four lenses and attached polarizing filters. The participants were fitted with polarizing glasses and seated in front of a 50” x 50” silver lenticular screen. The screen was positioned so that its center was approximately two meters above the floor and was tilted and positioned at a right angle to the viewing direction to avoid distortions, including ghosting. Generally, silver screens appear brighter in the center and, consequently, students seated at the edges of the screen saw an image that was less luminous than that viewed by children situated more closely to the center of the screen. It was theoretically impossible to have perfect stereo projection for every student. The only position in which the student could see the image exactly as it was seen in reality was the ortho-stereo seat, a position that differs depending on the image angle used during the shooting of the slide.

Stereopsis was achieved when the slightly different images were projected and superimposed on the silver lenticular screen. The polarizing filters on the projector were aligned in a V-position while the polarizing materials in the glasses worn by the students were aligned in a reverse V-position. Consequently, each eye saw a slightly different image as the polarization lines crossed to form a 90-degree angle, thus causing the light (and image) to be extinguished in the corresponding eyes. The students perceived the image as a three-dimensional stimulus.

A single image from the procedure described above was used as a two-dimensional stimulus. Although it is possible that the polarizing glasses might have had an effect on the students’ ability to participate in this activity, they were not worn when the image was presented as a two-dimensional stimulus. Viewing the single image while wearing the polarizing glasses would result in the inability to view the scene with both eyes. The design of the Brackett Stereo Projector prohibited the investigator from removing the polarizing filters from the projector which would have made it possible to view the single image while wearing the polarizing glasses. To reduce the possibility that the glasses had an effect on the students’ ability to participate in the activity, the glasses were worn prior to the activity.

A pilot study was conducted to verify procedures and methodology. Seventh grade students in the middle school participated in the pilot study.

Three additional concerns were addressed prior to conducting the experiment: (1) the use of polarizing glasses was an atypical experience for the students--therefore, they were given the opportunity to draw while wearing the glasses one day prior to the experiment; (2) given that the effects of two-dimensional and three-dimensional stimuli on the drawings was examined, a period of one week existed between the first and second treatment; and (3) the influence of training was to be taken into consideration; therefore, the Solomon Square experimental design was used (See Appendix E). The Solomon Square design includes two experimental and two control groups which facilitates comparisons between the experimental groups and the control groups. This design allowed the investigator to examine the effects of the treatment variable and to determine the interaction between testing and treatment. Furthermore, the design provided information as to whether the first treatment sensitized the participants to the second treatment.

Group A

Each student present in Group A was asked to participate in this activity. All participants were given a sheet of 80 lb. white drawing paper measuring 11 1/4” x 13 1/2” (proportional to the projected image), a graphite pencil, and polarizing glasses. An adhesive label with a five-digit identification number was given to each participant to affix to the back of the drawing paper to aid the investigator in identifying the student without compromising confidentiality.

A color photographic slide of a scene (two-dimensional stimulus) was projected on the screen and the students were given the following instructions: “Draw the image on the screen as realistically as possible. You will have two 45-minute class periods to complete this activity.”

The subjects in Group A completed a second drawing one week after the completion of the first drawing. This procedure was designed to offset the possibility that the students had become sensitized after the first treatment. It also reduced the possibility that the subjects would become bored with the task. Again, they were provided with a sheet of 80 lb. white drawing paper measuring 11 1/4” x 13 1/2,” a graphite pencil, and polarizing glasses. A stereo image (three-dimensional stimulus) was projected and the subjects were given the following instructions: “Draw the image on the screen as realistically as possible. You will have two 45-minute class periods to complete this activity.”

Group B

Group B followed the same procedure as Group A except the subjects in Group B drew the three-dimensional image in treatment one and the two-dimensional image in treatment two.

Group C

Group C followed the procedure for completing the drawing of the two-dimensional image as described above. They did not draw the three-dimensional image.

Group D

Group D followed the procedure for completing the drawing of the three-dimensional image as described above. They did not draw the two-dimensional image.

The evaluators examined each drawing and assigned one point for each spatial cue present in the drawing. It should be noted that an attempt at representing the spatial cue constituted being present in the drawing and was not eliminated if the attempt was unsuccessful. All twelve spatial cues considered in this experiment were present in the projected images; therefore, each drawing had a possible score of 12 from each evaluator, or a combined score of 36 (see Appendix F for rating device). The range for this instrument was 0 to 12. Subjects who were not present for both treatments were removed from the sample.

Method of Analysis

This experiment was designed to test hypotheses regarding the number of spatial cues present in drawings; therefore, a mean number of spatial cues was obtained for each treatment. With regards to Groups A (2-D→3-D) and B (3-D→ 2-D), a *t* test for paired data was performed on the difference between their two means. A *t* test for independent groups was used on Groups C (2-D only) and D (3-D only) as they were subjected to only one treatment. Additionally, a *t* test for independent groups was used to compare Groups A (2-D→ 3-D) and C (2-D only) and Groups B (3-D→ 2-D) and D (3-D only).

Experimental Design

Solomon Four-Group Design

Group	Treatment 1	Observation	Treatment 2	Observation
A	2-D	O	3-D	O
B	3-D	O	2-D	O
C	2-D	O	____________	____________
D	3-D	O	____________	____________

CHAPTER III
RESULTS AND DISCUSSION

Analyses of Data

The main research question underlying this investigation focused on the effects of two-dimensional and three-dimensional stimuli on spatial representation in drawings. Examining these effects and evaluating the drawings in terms of the 12 spatial cues was particularly important in this investigation as an attempt was made to quantify a task that is typically thought to be very subjective. Evidence that the initial training of evaluators was successful in ensuring reliability can be found in the results of the interrater agreement assessment. The interrater agreement was assessed using Kazdin's (1982) Point-by-Point Agreement Ratio (See Appendix D). Twenty-five percent of the drawings and rating responses were randomly selected and assessed using the Point-by-Point Agreement Ratio. A consistency rate of .82 was obtained and indicated scoring reliability for this measure.

The first part of the analysis was done on Groups A and B, with Group A having been first subjected to the two-dimensional stimulus and then, a week later, subjected to the three-dimensional stimulus. Group B was subjected to the three-dimensional stimulus in the first treatment and, a week later, subjected to the two-dimensional stimulus. The descriptive statistics for Group A (2-D→3-D) are reported in Table 1.

Table 1
Descriptive Statistics for Group A

Stimulus	N	Mean	Min	Max	Median	TrMean	StDev
2-D	10	27.60	16.00	34.00	28.50	28.25	5.25
3-D	10	25.60	17.00	31.00	27.50	26.00	5.60

Table 1 contains the data for the descriptive analysis of Group A (2-D→3-D). The class identified as Group A (2-D→ 3-D) had an enrollment of 24; however, only 10 students participated in the study. A combined score of 36, or a score of 12 from each of the three evaluators, was possible for each treatment. The mean number of spatial cues present in each drawing completed during the two-dimensional treatment was determined to be 27.60. The three-dimensional treatment resulted in a mean of 25.60. The mean values ranged from 16.00 to 34.00 for the two-dimensional treatment, while the mean values for the three-dimensional treatment ranged from 17.00 to 31.00. The data for the *t* test of the means of Group A are presented in Table 2.

Table 2
Statistical Values: t Test Results for Group A

Statistic	N	Mean Difference	StDev	SEMean	T	P-Value
Value	10	2.00	4.19	1.32	1.51	0.17

The difference between the means of the two-dimensional treatment and the three-dimensional treatment was found to be 2.00. That is, the mean number of spatial cues in the drawings, using the combined score of the evaluators, was found to be less in the second treatment when a three-dimensional stimulus was used.

The difference in means was found not to be statistically significant, t (9) = 1.51, p = 0.17. Consequently, hypotheses 1 and 2 were rejected. It could not be confirmed that there was a significantly greater number of spatial cues found in the drawings when the stimulus was three-dimensional. The descriptive statistics for Group B (3-D→ 2-D) are presented in Table 3.

Table 3
Descriptive Statistics for Group B

Stimulus	N	Mean	Min	Max	Median	TrMean	StDev
3-D	18	26.00	12.00	34.00	28.50	26.37	6.49
2-D	18	22.17	13.00	33.00	22.50	22.06	5.53

Table 3 contains the data for the descriptive analysis of Group B (3-D→2-D). The class identified as Group B (3-D→2-D) had an enrollment of 24; however, only 18 students participated in the study. A combined score of 36, or a score of 12 from each of the three evaluators, was possible for each treatment. The mean number of spatial cues present in each drawing completed during the three-dimensional treatment was determined to be 26.00. The two-dimensional treatment resulted in a mean of 22.17. The mean values ranged from 12.00 to 34.00 for the three-dimensional treatment, while the mean values for the two-dimensional treatment ranged from 13.00 to 33.00. The data for the *t* test of the means of Group B (3-D→2-D) are presented in Table 4.

Table 4
Statistical Values: t Test Results for Group B

Statistic	N	Mean	StDev	SEMean	T	P-Value
Value	18	-3.83	6.35	1.50	-2.56*	0.020*

The difference between the means of treatment 1 (three-dimensional) and treatment 2 (two-dimensional) was found to be -3.83. That is, the mean number of spatial cues in the drawings, using the combined score of the evaluators, was found to be less when a two-dimensional stimulus was used.

The difference in means was found to be statistically significant, t (17) = -2.56, p = 0.02 indicating that hypotheses 1 and 3 can be accepted. It was confirmed that there was a greater number of spatial cues present in drawings when the stimulus was three-dimensional and that the number of spatial cues decreased when the subsequent stimulus was two-dimensional.

An analysis was performed on Groups C and D, with group C being subjected to a two-dimensional stimulus only and group D being subjected to a three-dimensional stimulus only. An *F* test was performed to determine if the variances in the two samples were equal. The difference in the variances was found not to be significant, F (14,24) = 1.68, p>.05; therefore, it was determined that a pooled variance should be used in the calculation. The descriptive statistics for Groups C (2-D only) and D (3-D only) are reported in table 5.

Table 5
Descriptive Statistics for Independent Groups C and D

Stimulus	N	Mean	Min	Max	Median	TrMean	StDev
2-D Only	15	25.93	18.00	31.00	26.00	26.15	3.71
3-D Only	25	23.92	11.00	35.00	24.00	24.00	4.82

Table 5 contains the data for the descriptive analysis and *t* test for independent Groups C (2-D only) and D (3-D only). The class identified as Group C (2-D only) had an enrollment of 29; however, only 15 students were included in the study. Group D (3-D only) was comprised of a class of 32; however, only 25 students participated in the study. A combined score of 36, or a score of 12 from each of the three evaluators, was possible for each treatment. The mean number of spatial cues present in each drawing completed by Group C (2-D only) was determined to be 25.93. Group D (3-D only) was found to have a mean of 23.92. The mean values for Group C (2-D only) ranged from 18.00 to 31.00, while the mean values for Group D (3-D only) ranged from 11.00 to 35.00. A two (independent) sample *t* test was performed on Groups C (2-D only) and D (3-D only) and the data are reported in Table 6.

Table 6
Statistical Values: t Test Results for Independent Groups C and D

Statistic	DF	Mean Difference	T	P-Value
Value	35	2.01	1.48	0.15

The differences in means was found not to be significant, $\underline{t}$ (35) = 1.48, $\underline{p}$ = 0.15; therefore, research hypothesis 1 was rejected. It could not be confirmed that drawing from a three-dimensional stimulus resulted in a greater number of spatial cues.

An analysis was performed on Groups A and C, with Group A being subjected to a two-dimensional stimulus in treatment one and a three-dimensional stimulus in treatment two. Group C was subjected to a two-dimensional stimulus only. An *F* test was performed to determine if the variances in the two samples were equal. The difference in the variances was found not to be significant, $\underline{F}$ (9, 14) = 2.00, $\underline{p}>.05$; therefore, it was determined that a pooled variance should be used in the calculation. The descriptive statistics for Groups A (2D→3-D) and C (2-D only) are reported in Table 7.

Table 7
Descriptive Statistics for Independent Groups A and C

Stimulus	N	Mean	Min	Max	Median	TrMean	StDev
2-D→3-D	10	27.60	16.00	34.00	28.50	28.25	5.25
2-D Only	15	25.93	18.00	31.00	26.00	26.15	3.71

Table 7 contains the data for the descriptive analysis for independent groups A (2-D→3-D) and C (2-D only). A combined score of 36 or a score of 12 from each of the three evaluators was possible for each treatment. The mean number of spatial cues present in each drawing completed by Group A (2-D→3-D) was determined to be 27.60. Group C (2-D only) was found to have a mean of 25.93. The mean values for Group A (2-D→3-D) ranged from 16.00 to 34.00, while the mean values for Group C (2-D only) ranged from 18 to 31. A two (independent) sample *t* test was performed on Groups A (2-D → 3-D) and C (2-D only) and the data are reported in Table 8.

Table 8
Statistical Values: t Test Results for Independent Groups A and C

Statistic	DF	Mean Difference	T	P-Value
Value	23	1.67	0.93	0.36

The differences in means was found not to be significant, t (23) = 0.93, p = 0.36; therefore, research hypotheses 1 and 2 were rejected. It could not be confirmed that drawing from a three-dimensional stimulus resulted in a greater number of spatial cues.

An analysis was performed on Groups B and D, with Group B being subjected to a three-dimensional stimulus in treatment one and a two-dimensional stimulus in treatment two. Group D was subjected to a three-dimensional stimulus only. An *F* test was performed to determine if the variances in the two samples were equal. The difference in the variances was found not to be significant, F (17, 24) = 1.81, p>.05; therefore, it was determined that a pooled variance should be used in the calculation. The descriptive statistics for Groups B (3D → 2-D) and D (3-D only) are reported in Table 9.

Table 9
Descriptive Statistics for Independent Groups B and D

Stimulus	N	Mean	Min	Max	Median	TrMean	StDev
3-D → 2-D	18	26.00	12.00	34.00	28.50	26.37	6.49
3-D Only	25	23.92	11.00	35.00	24.00	24.00	4.82

Table 9 contains the data for the descriptive analysis for independent groups B (3-D → 2-D) and D (3-D only). The mean number of spatial cues present in each drawing completed by Group B (3-D → 2-D) was determined to be 26.00. Group D (3-D only) was found to have a mean of 23.92. The mean values for Group B (3-D → 2-D) ranged from 12.00 to 34.00, while the mean values for Group D ranged from 11.00 to 35.00. A two (independent) sample *t* test was performed on Groups B(3-D → 2-D) and D (3-D only) and the data are reported in Table 10.

Table 10
Statistical Values: t Test Results for Independent Groups B and D

Statistic	DF	Mean Difference	T	P-Value
Value	41	2.08	1.21	0.23

The differences in means was found not to be significant, t (41) = 1.21, p = 0.23; therefore, research hypotheses 1 and 3 were rejected. It could not be confirmed that drawing from a three-dimensional stimulus resulted in a greater number of spatial cues.

Discussion

It should be noted that in groups A and B where two treatments were involved, the mean scores were lower on the second treatment. This suggests that the influence of training was not a consideration in interpreting these results and that training did not increase the number of spatial cues present in subsequent drawings. It also suggests that the first treatment did not sensitize the participants to the second treatment.

One possible explanation for the decrease in mean scores after the first treatment might be a novelty effect. The cooperating teachers in the experiment reported that students had little experience drawing from photographic slides. It is possible that they performed better during the first treatment because it was a new, and possibly exciting task for them.

The decrease in mean scores after the first treatment might also be explained by the students becoming bored with drawing the same image again only after a period of one week. It is important to note that the decrease was less when the second image was three-dimensional. This might suggest that, although they did not respond well to drawing the image a second time, they were intrigued with the three-dimensional image and responded to the spatial cues present in the scene.

It can be concluded that the students in Group B (3D→2D) depicted more spatial cues when exposed to a three-dimensional stimulus than when exposed to a two-dimensional stimulus of the same scene. Furthermore, it seems probable that the significant decrease in the means of Group B (3D→2D) when the stimulus in the first treatment was three-dimensional and the stimulus in the second treatment was two-dimensional cannot be completely explained by students becoming bored with the task.

It is possible that the comparison of Groups A and C might offer insight into the effects of the two-dimensional stimulus on these groups; however, the obtained value was found not to be significant. The comparison of Groups B and D, in which the stimulus was three-dimensional, also resulted in a finding of no significance. It is interesting to note, however, that the mean for Group A (27.60) and the mean for Group B (26.00) was higher than Groups C (25.933) and D (23.92), thus making it possible to consider that groups with fewer participants had a greater mean number of spatial cues than the larger groups.

It is difficult to determine what, if any, effect the teachers might have had on this experiment. It is important to note that there was a considerable difference in the percentage of students who elected to participate in the study from each of the two teachers' classes. Teacher 1 had participation from 41% of his students in period 1 which comprised Group A (2D→3D) and 51% of his students in period 2 which comprised Group C (2D only). Teacher 2 had participation from 75% of her students in period 1 which comprised Group B (3D→2D) and 78% of her students in period 2 which comprised Group D (3D only). Additionally, the teachers differed in the assignment made to students not wishing to participate in the study. Teacher 2 requested that a writing assignment be completed in lieu of the drawing activity; while teacher 1 allowed those electing not to participate to choose an activity of their choice. Again, while it is difficult to ascertain the effect of the teacher on this experiment, the relatively small sample sizes of teacher 1 are clearly a possible factor in these results.

Conclusions

With respect to the findings in this investigation, the following conclusions can be drawn: This experiment utilized intact groups which limits the degree to which generalizations can be made from these results. In this instance, it is difficult to determine if drawing from a three-dimensional scene resulted in a more realistic depiction of space; however, it appears that children perceive and respond to two-dimensional and three-dimensional stimuli differently.

It is probable that the teacher was a contributing factor in this investigation. Although areas of concern were noted, it is unclear to what extent this variable had any effect on the results.

Recommendations for Further Research

It is recommended that a larger sample be used in any replication of this study to eliminate the concerns previously expressed in relation to the small group sizes. It would also be reasonable to consider selecting students who are, preferably, at the eighth grade level or older and under the direction of a single teacher. This would ensure that all students have been exposed to similar instruction as it pertains to drawing, and specifically, the representation of space. It would also ensure that their formal knowledge of each of the twelve spatial cues is comparable.

It is recommended that in replicating this study, the investigator consider reducing the number of spatial cues to be identified in the evaluation of the drawings. It was discovered that it was difficult to distinguish among spatial cues such as foreshortening and shape constancy as well as modeling and shadows. It seems probable that there would be a greater difference in the mean number of spatial cues present in the drawings if distinctly different spatial cues were used in the rating device.

While generalizations cannot be made based on these preliminary findings, the investigator hopes that additional research will be conducted to examine the effects of two-dimensional and three-dimensional stimuli on children’s perception and representation of spatial information.

BIBLIOGRAPHY

BIBLIOGRAPHY

Allen, B. S. (1991). Virtualities. Educational Media and Technology: The Year in Review, 17, 47-53.

Andolsek, D. L. (1995). Virtual reality in education and training. International Journal of Instructional Media, 22 (2), 145-155.

Auld, L. W. S., & Pantelidis, V. S. (1994). Exploring virtual reality for classroom use. Tech Trends, January/February, 29-31.

Chen, M. J., & Cook, M. (1984). Representational drawings of solid objects by young children. Perception, 13, 377-385.

Chen, M. J. (1985). Young children's representational drawings of solid objects: a comparison of drawing and copying. In N. H. Freeman & M. V. Cox (Eds.), Visual order: The nature and development of pictorial representation (pp. 157-175). Cambridge, UK: Cambridge University Press.

Cox, M. V. (1978). Spatial relationships in young children's drawings. Journal of Experimental Child Psychology, 26, 551-554.

Cox, M. V. (1991). The child's point of view. NewYork: The Guilford Press.

Crook, C. (1985). Knowledge and appearance. In N. H. Freeman & M. V. Cox (Eds.), Visual Order: The nature and development of pictorial representation (pp. 248-265). Cambridge, UK: Cambridge University Press.

Dalton, K., & Burton, D. (1995). Children's use of baselines: Influences of a circular format. Studies in Art Education, 36 (2), 105-113.

Dowell, M. (1990). Effects of visual referents upon representational drawing of the human figure. Studies in Art Education, 31 (2), 78-85.

Ferwerda, J. G. (1987). The world of 3-D: A practical guide to stereo photography. Netherlands: 3-D Book Productions.

Freeman, N., & Eiser, C. (1977). Children's strategies in producing three-dimensional relationships on a two-dimensional surface. Journal of Experimental Child Psychology, 23, 305-314.

Frisby, J. P. (1979). Seeing: Illusion, brain and mind. Oxford: Oxford University Press.

Gibson, J. (1960). Pictures, perspective, and perception. DAEDALUS, 89, 216-227.

Golomb, C. (1992). The child's creation of a pictorial world. Berkley: University of California Press.

Graham, C. H. (1965). Vision and visual perception. New York: John Wiley & Sons, Inc.

Griffen, J. R. (1982). Binocular anomalies: Procedures for vision therapy. New York: Professional Press Books, Fairfield Publications.

Guthrie, P., & Su, C. M. (1992). The significance of young children's visual skills in graphic depiction of spatial representations: Testimony from two drawing researchers. Paper presented in the symposium, Making Meaning Through Art: Art in the Early Childhood Education Conference. Urbana, Illinois.

Hagen, M. A. (1985). There is no development in art. In N. H. Freeman & M. V. Cox (Eds.), Visual Order: The nature and development of pictorial representation (pp. 59-77). Cambridge, UK: Cambridge University Press.

Harris, D. B. (1963). Children's drawings as measures of intellectual maturity. New York: Harcourt, Brace & World.

Hedgerg, J., & Alexander, S. (1994). Virtual reality in education: Defining researchable issues. Educational Media International, 31 (4), 214-220.

Helsel, S. (1992). Virtual reality and education. Educational Technology, 32 (5), 38-42.

Hochberg, J. (1978). Art in Perception. In E. C. Carterette, & M. P. Friedman (Eds.), Handbook of perception (pp. 225-258). New York: Academic Press, Inc.

Homan, W. J. (1994). Virtual reality: Real promises and false expectations. Educational Media International 31, (4), 224-227.

Ingram, N., & Butterworth, G. (1989). The young child's representation of depth in drawing: Process and product. Journal of Experimental Child Psychology 47, 356-369.

Ireson, J., & McGurk, H. (1985). Perception of depth in photographs: A study of young Malawians. International Journal of Behavioral Development, 8, 345-353.

Ittelson, W. H. (1960). Visual space perception. New York: Springer Publishing Company, Inc.

Kazdin, A. E. (1982). Single-case research designs. New York: Oxford University Press.

Kose, G. (1983). Children's conceptions of spatial relationships in drawings and photographs. Paper presented at the Annual Meeting of the American Educational Research Association, Montreal Quebec.

Leeds, A., Dirlam, D., & Brannigan, G. C. (1983). The development of spatial representation in children from five to thirteen years of age. Genetic Psychology Monographs, 108, 137-165.

Lowenfeld, V., & Brittain, W. L. (1982). Creative and mental growth. New York: MacMillian.

Luckiesh, M. (1965). Visual illusions. New York: Dover Publications, Inc.

Mandes, E. (1985). Interposition and size constancy: A developmental study. Perceptual and Motor Skills, 61, 196-198.

Milheim, W. D. (1995). Instructional utilization of three dimensional graphics. International Journal of Instructional Media, 21, (1), 93-99.

Mshelia, A. Y., & Lapidus, L. B. (1990). Depth picture perception in relation to cognitive style and training in non-western children. Journal of Cross-Cultural Psychology, 21 (4), 414-433.

O'Donnell, L. M. & Smith, A. J. (1994). Visual cues for enhancing depth perception. Journal of Visual Impairment & Blindness, May-June, 258-265.

Okoshi, T. (1976). Three-dimensional imaging techniques. New York: Academic Press.

Olson, D. R. & Bialystok, E. (1983). Spatial cognition: The structure and development of mental representations of spatial relations. Hillsdale, NJ: Lawrence Erlbaum Associates.

Piaget, J., & Inhelder, B. (1967). The child's conception of space. (F. J. Landon & J. L. Lunzer, Trans.). London: Routledge & Kegan Paul.

Pirenne, M. H. (1970). Optics, painting & photography. Cambridge: University Press.

Rock, I. (1984). Perception. New York: Scientific American Library.

Rock, I. (Ed.). (1990). The perceptual world. New York: W. H. Freeman and Company.

Smarr, L. From "The marvels of virtual reality." Fortune Magazine, June 1991, 138-150.

Smith, N. R. (1983, September). Drawing conclusions: So children draw from observation? Art Education, pp. 22-25.

Teske, J. A., Waltz, C. R., & Shenk, C. C. (1992). The effects of object alignment on the representation of depth in young children's drawings. Journal of Experimental Child Psychology, 54, 19-36.

Thwaites, H. (Ed.). (1990). Three-dimensional media technology: Proceedings of the 1989 International Conference, Canada.

Ullmer, E. J. (1994). Media and learning: Are there two kinds of truths? Educational Technology Research and Development, 42, (1), 21-32.

West, T. (1991). In the mind's eye: Visual thinkers, gifted people with learning difficulties, computer images, and the ironies of creativity. Buffalo: Prometheus Books.

Whalley, P. (1995). Imagining with multimedia. British Journal of Educational Technology, 26, (3), 190-204.

Willats, J. (1977). How children learn to draw realistic pictures. Quarterly Journal of Experimental Psychology, 29, 367-382.

Willats, J. (1985). Drawing systems revisited: The role of denotation systems in children's figure drawings. In N. H. Freeman, & M. V. Cox (Eds.), Visual order: The nature and development of pictorial representation (pp. 78-100). Cambridge, UK: Cambridge University Press.

APPENDIX A

A Comparison of Developmental Stages Proposed by Piaget and Lowenfeld

A Comparison of Developmental Stages Proposed by Piaget and Lowenfeld

Age	Piaget's Spatial Representation Development	Piaget's Cognitive Development	Lowenfeld's Creative and Mental Growth
0		Sensorimotor	
1			
2			Scribbling
3	Synthetic incapacity	Preoperational	
4			
5	Intellectual realism		Preschematic
6			
7			
8		Concrete operational	Schematic
9	Visual realism		
10			Gang age
11			
12		Formal operational	
13			Pseudo-naturalistic
14			
15			Period of decision
16			
17			
18			
19			
20			
Early Adulthood			
Middle Adulthood			
Late Adulthood			

APPENDIX B

Group Composition

Group Composition

Group Identification	A	B	C	D
Group Size	10	18	15	25
Gender	Male 50% Female 50%	Male 44% Female 56%	Male 80% Female 20%	Male 60% Female 40%
Age	Mean 13.82 years	Mean 13.60 years	Mean 13.60 years	Male 13.86 years
Ethnic Categories	White 80% Black 20%	White 83% Black 17%	White 86% Black 7% Asian 7%	White 92% Black 8%
Special Services	Special Ed. 10% Gifted 10%	Special Ed. 6% Gifted 6%	Special Ed.13% Gifted 0%	Special Ed.12% Gifted 12%
Free or Reduced Meals	40%	33%	26%	28%

APPENDIX C

Pola-Mirror Test

Pola-Mirror Test

The Pola Mirror-Test was devised by John Griffen (1982) to determine the status of binocularity. Subjects view themselves in an ordinary flat mirror at a distance of ten inches, while wearing polarizing glasses. The objective is for the subject to determine whether both eyes can be seen. Good binocularity is indicated when the subject can see both eyes; whereas poor binocularity is indicated by the subjects' ability to see only one eye at a given moment. In instances of poor binocularity, one eye appears blackened. Griffen states, "The blacking-out occurs in the suppressed eye because it cannot see itself under binocular conditions. The fixating or nonsuppressing eye, cannot see the other eye because of the effect of crossed polarization. Light traveling from the suppressing eye to the mirror and on to the fixating eye is excluded."

Griffen provides the following specific instructions for administering the test:

1. "Look at yourself in the mirror and tell me what you can see." If the response is that both eyes can be seen at the same time, suppression is not indicated. If only one eye can be seen at a time while the other looks black, suppression is present.
2. "Close one eye and tell me what you see." This confirms the response. The closed eye should be reported as appearing black.
3. "Open both eyes and tell me if you see one eye that looks black." If one eye is black, suppression is indicated. Good binocularity is present if both eyes are seen at the same time.

APPENDIX D

Kazdin's Point-by-Point Agreement Ratio

Point-by-Point Agreement Ratio

A. Kazdin

Interrater agreement=

[agreements/(agreements+disagreements)] X 100

APPENDIX E

Experimental Design

Experimental Design

Solomon Four-Group Design

Group	Treatment 1	Observation	Treatment 2	Observation
A	2-D	O	3-D	O
B	3-D	O	2-D	O
C	2-D	O	____________	____________
D	3-D	O	____________	____________

APPENDIX F

Rating Device

Drawing Identification Number ________

Evaluator ________

Please evaluate the drawing for the following spatial cues. Assign one point for each spatial cue present in the drawing.

occlusion	________	familiar size	________
linear perspective	________	size constancy	________
atmospheric perspective	________	foreshortening	________
texture gradient	________	shape constancy	________
modeling	________	vertical positioning	________
shadows	________	spatial icon	________

________ **Total**

Operational Definitions

1. **occlusion**--the partial covering of one object by another.
2. **linear perspective**--parallel lines that recede from the subject appear to converge.
3. **atmospheric perspective**--the tendency of objects to appear tinged with blue because of impurities in the atmosphere. It also refers to the loss of visible detail in distant objects.
4. **texture gradient**--nearer elements in a texture are represented larger than distant elements of the same apparent size.
5. **modeling**--reproducing in a drawing, the effect of light and shadow on a three-dimensional form to create a realistic, three-dimensional appearance of the form.
6. **shadows**--shading that results from the depth within the object itself and from that which falls on surrounding surfaces.
7. **familiar size**--if we are familiar with an object's typical size, our memory of its visual angle at varying distances could allow us to estimate its distance.
8. **size constancy**--objects of equal size at varying distances project images whose visual angles are inversely proportional to their distance.
9. **foreshortening**--the difference in the projection of equal distances in the third dimension.
10. **shape constancy**--the tendency to compute the shape of an object based on our perception of the distinct distances of parts of the object.
11. **vertical positioning**--representing space in such a way that distant objects appear higher on the picture plane.
12. **spatial icon**--a symbol or convention used to indicate the relative distance of the viewer from the object, for example, "m" birds or "lollipop" people.

VITA

Tammy M. McGraw

Education

- Doctor of Education
  Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1997.
  Instructional Technology

- Master of Art Education
  Virginia Commonwealth University, Richmond, Virginia. 1990.
  Art Education

- Bachelor of Science
  Concord College, Athens, West Virginia. 1984.
  Art Education

Employment History

- Franklin County Public Schools, Rocky Mount, Virginia. Instructional Systems Specialist since November, 1995.

- Franklin County Public Schools, Rocky Mount, Virginia. Assistant to the Director of Secondary Education during the summer of 1995.

- Benjamin Franklin Middle School, Rocky Mount, Virginia. Art teacher for grades 6-8 from 1990 to 1995.

- Mullens High School, Mullens, West Virginia. Art teacher for grades 9-12 from 1984 to 1990.

Honors/Awards

- Virginia's Region VI Teacher of the Year, 1996.

- Franklin County's Teacher of the Year, 1995-1996.

- Benjamin Franklin Middle School's Teacher of the Year, 1993-1994; 1995-1996.

- Southwest Regional Virginia Art Education Association's Middle School Art Teacher of the Year, 1993.

Grants

- 1996 Technology Innovation Challenge Grant. Co-author of a project to provide staff development and support services for staff, develop a regional training center, and provide telecommunications access to Franklin County Public Schools ($1,478,355).

- Serving as project director for the development of an Integrated Curriculum Development Laboratory, a collaborative project with Ferrum College and funded by the Arthur Vining Davis Foundations ($125,000).

- Toyota TAPESTRY Award for excellence in science education, 1995 ($10,000).

- Directed an Arts and Rural Communities Grant from the Virginia Commission for the Arts and the National Endowment for the Arts ($13,000).

Presentations/Publications

- Presented a paper entitled *Using NIH Image to Generate Specifications for A Ceramic Tile Mosaic* at the 1996 Image Processing in Teaching conference in Orlando, Florida.

- Participated in a panel discussion entitled *Utilizing Community Resources to Strengthen the Arts Curriculum* at the Virginia Elementary School Principal's 1996 conference.

- Published an article entitled *Beastly Plants* in the May 1995 issue of *Arts and Activities* magazine.

- Participated in a panel discussion entitled *Out of the Classroom Experiences* at the Virginia Art Education Association's 1994 conference.

- Participated in a panel discussion entitled *Classroom Management for Beginning Teachers* at the Virginia Art Education Association's 1993 conference.

- Presented a workshop at the Virginia Art Education Association's 1992 conference about the use of stereoscopic slides to teach drawing.

- Participated in a regional rural arts forum sponsored by the National Assembly of Local Arts Agencies and the National Endowment for the Arts. Approximately 100 people from New Jersey, Pennsylvania, Virginia, and West Virginia were invited to discuss rural and/or arts issues.

Professional Activities

- Designed the Integrated Curriculum Development Laboratory at Ferrum College.

- Taught a week-long intensive summer workshop entitled *New and Emerging Technologies for Instruction* in 1996.

- Chairperson of the arts module curriculum planning team for the Center for Applied Technology and Career Exploration.

- Taught a 15-week course entitled *Education Applications of Microcomputers* as part of an internship at Virginia Tech in 1996.

- Studied image processing at Harvard University during the summer of 1995.

- Developed a staff development plan for Franklin County Public Schools to facilitate the integration of technology into the curriculum.

- Participated in training in Problem-Based Learning, Socratic conferencing methods, and process writing.

- Review and revise division technology plans.

- Developed the homepage for Franklin County Public Schools.

- Served on a division assessment team which developed alternative assessments for student learning.

- Conduct a workshop each summer about fiber-reactive dyes for the National Science Foundation Young Scholars Program--Science Adventure in Research and Career Exploration Camp at Ferrum College.

- Gateway (gifted and talented) instructor for summer and after-school programs. Courses include stereo photography, stained glass, silk painting, and fused glass jewelry.

- Developed assessment materials for identifying gifted students in art.

- Developed curriculum materials for students identified gifted in language arts.

- Served on an integrated curriculum planning team.

- Served as a mentor in the division's teacher mentor program.

- Served as a cooperating teacher for student interns/teachers for local colleges.

- Coordinate artist-in-residence projects. Jeff Fetty, a nationally recognized sculptor worked with students to create a giant metal daffodil which stands on the front lawn of Benjamin Franklin Middle School. J. Plunky Branch, a nationally recognized jazz musician, spent two weeks working with students at all grade levels in activities as diverse as creating handmade instruments at the elementary level to conducting workshops with older students about electronically recording and editing music.

- Coordinate with the Virginia Museum of Fine Arts to bring visual art exhibits to Franklin County Schools. Past exhibits include *The Making of Virginia Architecture, The Artful Cat, Radical Realism,* and *The Art of Mapmaking.*

- Worked with students to design and create original puppets, construct a puppet theatre and plan and deliver performances for elementary school children.

Professional Association Memberships

- International Society for Technology in Education

- Virginia Society for Technology in Education

- International Visual Literacy Association

- National Art Education Association

- Association for Supervision and Curriculum Development

- Phi Delta Kappa