ABSTRACT

Hart, William J. Effect of Computer Animation Instruction on Spatial Visualization Performance. (Under the direction of Dr. Theodore J. Branoff)

The purpose of this study was to determine the effect of a sixteen week long animation class on spatial visualization performance. The students in the treatment group were provided instruction consisting of four hours of lecture/lab each week. Lecture/Lab consisted of lessons on the fundamentals, history, and techniques of animation. The students were provided instruction in and opportunity to use three different animation packages (Flash ®, TrueSpace ®, and 3D Studio Max ®).

The spatial visualization performance of the students in the animation group was compared to a control group of students in a Foundation of Graphics (GC120) class.

A paired T-test was completed on each group to determine progress made within each group. An Independent Samples T-test was used to make a comparison between the animation test group and the control group.

When H_0: animation group = control group was tested, analysis indicated that no significant difference existed between the groups. This research requires a larger sample size and a different test instrument to repeat the study.

EFFECT OF COMPUTER ANIMATION INSTRUCTION ON SPATIAL VISUALIZATION PERFORMANCE

by

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DEDICATION

I dedicate this work to the three guiding people in my life. My loving wife, C. J. Hart, whose support and constant encouragement made this work possible. To my parents, my mother, Mildred C. Hart and my late father, Lewis W. Hart for their guidance and direction which provided me with the will and desire to endure and strive to beat the odds. I also dedicate this work to my children and grand children who provided me with inspiration to keep going.

BIOGRAPHY

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I also give my thanks to my co-workers and fellow students for their assistance in locating materials and for reminding me when materials were to be returned to the library.

Thanks to you all.

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CHAPTER ONE: INTRODUCTION

Summary of Relevant Research

The use of computer animation in computer-assisted instruction medium is a way of taking advantage of capabilities that computer technology has provided. From an instructional viewpoint, computer animation can be used as a visual aid to illustrate, provide meaning, and give organization to the material being taught. The advancements in computer animation allow realistic scenes to be generated and provide interactive tools that students are able to use to create an environment that they are able to control. This ability provides the opportunity for a better understanding, greater retention, and improved spatial performance of instructional material (Klein, 1985; Proffitt & Kaiser, 1986).

Although the idea presented in the previous paragraph is somewhat dated the concept is still valid for the current time frame. The relevant research presented in this study will cover major topics as: spatial abilities, the relationship between animation and spatial abilities, computer-aided design and spatial ability, and the cognitive interactionist/experiential learning theory. Review of previous research will provide the foundation for the utilization of animation as a viable form of instruction to improve spatial visualization performance.

Learning Theory

Cognitive Interaction Learning theories may be a better way to understand the learning process for obtaining and for improving spatial visualization ability. Within this cluster of theories, learning occurs when cognitive function interacts with the meaningful psychological environment around it. The cognitive interaction theories have two forms, linear and field (Bandura, 1993; Bigge & Shermis, 1998, p. 159). Under this premise, the followers of the adult learning philosophy of the Experiential Learning theory will learn (cognitive process) by experience (doing) (Fenwick, 2000; Knox, 1980) and would fall into the category with the Cognitive Interactionist philosophy.

The linear and field forms of the cognitive interaction theory are very similar in nature. The followers of the linear form of cognitive interaction believe that perception and behavioral changes [learning] occur in sequence. The followers of the field version of cognitive interaction believe that there is a simultaneous interaction occurring between the learner and their psychological environment (Bigge & Shermis, 1998).

This theory could explain the phenomena of the quick learning that children exhibit with video games. This theory indicates that the learner actually learns by doing and adapting to new conditions and perceptions. The same conditions would apply to the adult learner. Learning by doing provides the interaction that is present in the interaction learning theory. As shown in Figure 1.1, if the learner is able to interact with the computer animation environment, then according to the cognitive interaction theory by extrapolation the learner should be able to improve his/her spatial visualization performance.

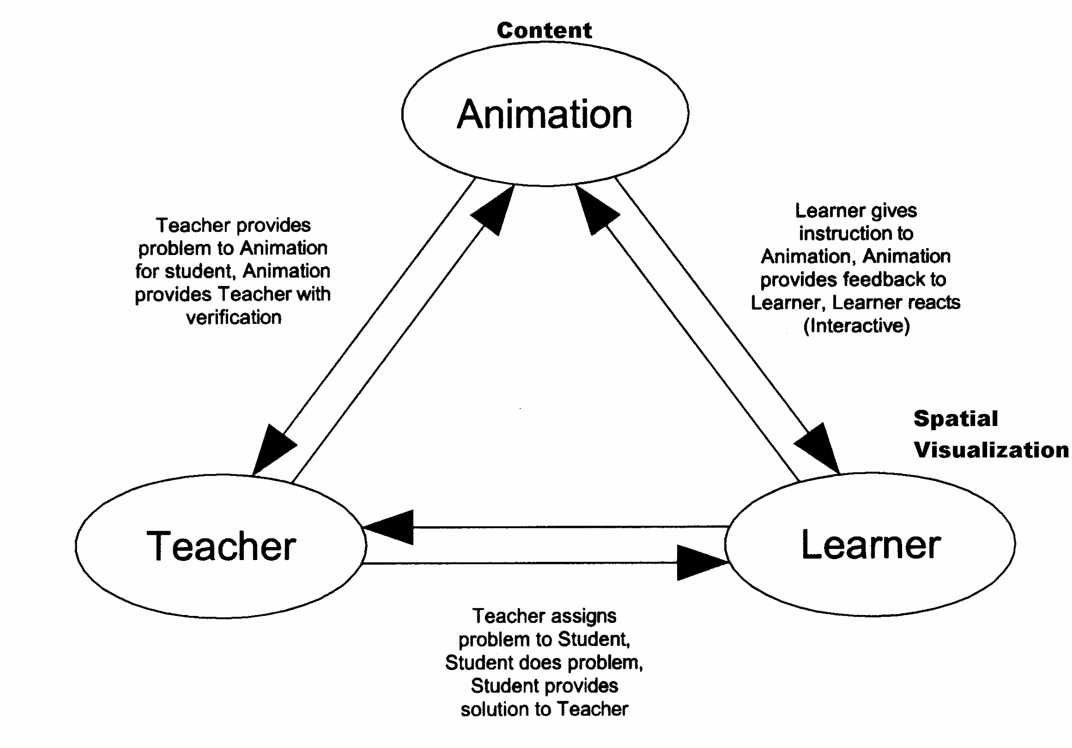

Figure 1.1. Theoretical Learning Model

The interaction between the learner and the animation provide immediate information to each other. When the learner provides commands to control the animation, the animation provides the learner with immediate feedback allowing the learner to see the results of his actions. The learner is then able to gain knowledge through experience. The function of the teacher in this model is to help control the learning situation and to act as a learning model for the student. The teacher is able to evaluate the action/reaction of the learner and provide the necessary stimulus for the continued education experience of the learner.

Purpose of Study

Previous work has indicated that spatial visualization can be taught and that there is a natural progression in learning and improving spatial visualization skills (Baartmans & Sorby, 1996; Klein, 1985; Proffitt and Kaiser, 1986). Thus the purpose of this study, from a theoretical standpoint, was to investigate whether instruction in computer animation improved spatial visualization skills. By comparing the results of the scores from the Purdue Spatial Visualization Test – Visualization of Rotations between students taking a Foundations of Graphics class with students taking a computer animation class, an attempt was made to determine which of the groups provided the most improvement in spatial performance. This study compared the difference in spatial performance between students taking the introductory Foundations of Graphics class and students taking the animation class. These classes are currently taught in the Department of Mathematics, Science, and Technology Education at North Carolina State University. The rotations section of the Purdue Spatial Visualization Test used in this research study was developed by Guay (1976), and has been widely used to assess students' spatial visualization ability (Branoff, 1998, 1999; Baartmans & Sorby, 1996).

The need for study in the area of spatial visualization performance can be summed in these words, "… in terms of cognitive development, researchers have pointed to spatial ability as playing a fundamental role in the formation of performance and understanding of concepts in mathematics, chemistry, and earth sciences" (Coleman & Gotch, 1998, p. 206).

Research Questions and Hypotheses

In order to create orthographic projections, the student must be able to perform 3 mental tasks: (1) rotate an object to another plane, (2) change the object from two-dimensional to three-dimensional, and (3) to change an object's size (Zavotka, 1987; Sorby, 2000). All three of these tasks are considered to be spatial in nature. Thus, the specific questions investigated by this study can be stated by means of the following questions:

1. Will instruction in a sixteen week computer animation course significantly improve spatial visualization performance in undergraduate students?
2. Will instruction in a sixteen week basic technical graphics course significantly improve spatial visualization in undergraduate students?
3. Will instruction in a sixteen week computer animation course provide higher scores indicating a higher development of spatial visualization than a sixteen week basic technical graphics course?

Questions 1 and 2 were answered by using a paired samples T-test between pretest and posttest scores on the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R) collected at the beginning and end of the sixteen week instruction period. The hypotheses for questions 1 through 3 were:

$H1_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2).

$H2_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a Foundations of Graphics class or introduction to engineering graphics class (Group 1).

To answer question 3 it was necessary to use the posttest data for both of the groups. Using the posttest results in an independent sample T-test was performed to see if there was a significant difference in mean scores between the animation group and the graphics group.

$H3_N$ – There will be no significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2) and students who take the Foundations of Graphics class or introduction to engineering graphics class (Group 1). G2=G1

Assumptions

The students used as the sample groups in this study were taught by two instructors. Group 1 was taught by the researcher and group 2 was taught by Dr. A. Clark. The assumptions made in this study were: (1) that conditions were the same for all students, (2) that the students performed to the best of their ability on the PSVT:R, and (3) that the instructors taught their respective materials in a similar manner as to all of their respective classes involved in the study.

Definition of Terms

1. Analytic skill: The ability to identify figures concealed in a complex background field (Stancil & Melear, 1991).
2. Computer animation: A series of rapidly changing computer screen displays presenting a geometrical shape and varying positions giving the impression of movement (Mayton, 1991).
3. Dependent variable: A dependent variable is a variable that is influenced by an independent variable. The dependent variable in this study was student performance on the posttest instrument.
4. Image and imagery: The terms image and imagery in this study refer to nonverbal modes of thought, where memory representations of concrete objects and events are actively generated and manipulated by an individual (Caraballo-Rios, 1985).
5. Independent variable: An independent variable is a variable that is manipulated by the researcher. The independent variable in this study was the treatment applied to the test group.
6. Instructional visual display or instructional graphical display: Displays that are presented during an instructional situation where the main message is presented by a drawing or illustration (Klein, 1985).
7. Interactiveness: When applied to mental images, interactiveness relates to learning activities that are associated with a picture. In the context of this study,

the term “interactiveness” refers to the two-way communication that can be carried out between the computer and its human operator.

8. Spatial visualization: Spatial visualization is "The ability to formulate mental images and to manipulate these images in the mind" (Lean and Clements, 1981 p. 286). Guay (1980) indicated that the defining element of spatial visualization is the ability to manipulate the mental image and not the perception of that image.

Summary

This chapter summarized relevant research concerning several instruments used to measure spatial visualization skills. Investigative studies that have examined spatial visualization as it applies to chemistry and other fields are also included. Animation and the effect on recall and several studies that use motion to test for improvement in spatial visualization abilities are discussed. Interactive learning theory is also summarized relative to the use of animation as a teaching tool. The purpose of this study was to investigate the effectiveness of computer animation in promoting spatial abilities in college students.

CHAPTER TWO: REVIEW OF LITERATURE

Spatial Visualization and Animation

The use of animation is employed in many fields of study. Reports and presentations of chemists, engineers, mathematicians, advertising agencies, commercial designers, and architects all use graphics to explain how things work (Bodner & Guay, 1997; Rieber, 1987, 1989; Strong & Smith, 2001). When appropriate, animation, a sequential series of images that gives motion to objects, is used to illustrate such presentations. The study being reported here deals with the effect of computer animation on the understanding and improvement of spatial performance.

Test for Measuring Spatial Abilities

There have been many test developed to measure spatial ability. The early attempts included the Minnesota Paper Form Board Test (MPFB) developed in the late 1920's. The present version was written by Likert and Quasha (1970) and is a 64-item test of general spatial aptitude. Each test item consists of a figure cut into two or more parts. Five other complete shapes are also displayed. One of these is equivalent to how the test figure would look if all its parts were joined together. The task is to choose the appropriate figure from the five options. The RMPFB was chosen as a standard test of general spatial ability. An example of the RMPFB is illustrated in Figure 2.1.

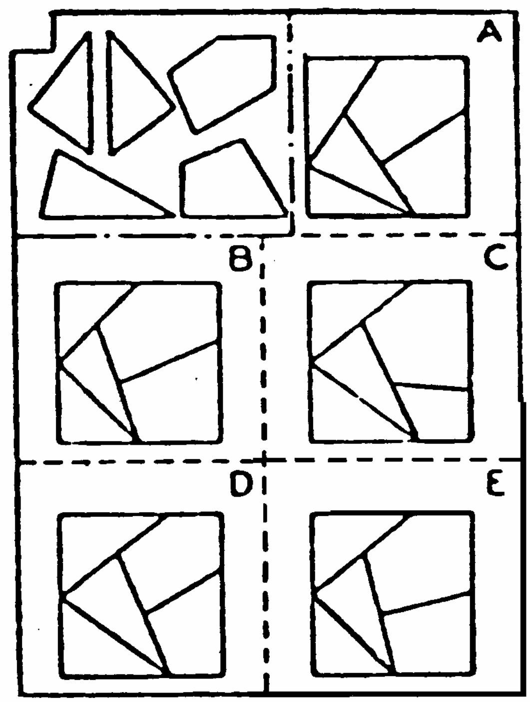

Figure 2.1. Revised Minnesota Paper Form Board Test

Shepard and Metzler (1971), developed a “mental rotations test” referred to as S-M (Figures 2.2, 2.3, & 2.4). This test used pairs of static images of the same object in different positions or mirror images of the same object in different positions. The study in which this test was developed provided a random sequence for one test group and provided the other test group with prior information about the rotation and sequencing of the images presented. The results of this study indicated the second group performed only slightly better than the first group (Shepard & Metzler, 1971). Their research with this test indicated that test subjects who had experience and advanced knowledge about the direction and axis of rotation performed only 20 percent better than the control group who were not given this information. This test was part of the early framework upon which later research and test instruments were based.

Figure 2.2. S-M Object Rotated in Plane

Figure 2.3. S-M Object Rotated in Depth

Figure 2.4. S-M Mirror Image of Same Object

The Mental Rotations Test (MRT) developed by Vandenberg and Kuse (1978) was a continuation of Shepard and Metzler's work with the S-M test.

The Purdue Spatial Visualization Test (PSVT) series was developed by Guay (1976). The actual test consists of three parts: Developments, Rotations, and Views. The Visualization of Developments (PSVT:D) tests the ability of subjects to visualize the folding of a development into a three-dimensional object as illustrated in Figure 2.5. The Visualization of Rotations (PSVT:R) portion tests the ability of the subjects to visualize the rotation of three-dimensional objects as shown in Figure 2.6. The Visualization of Views (PSVT:V) portion is used to test the ability of the subject to visualize what three-dimensional objects look like from different viewpoints (Figure 2.7). The series of subtests utilizes different processes to measure spatial ability.

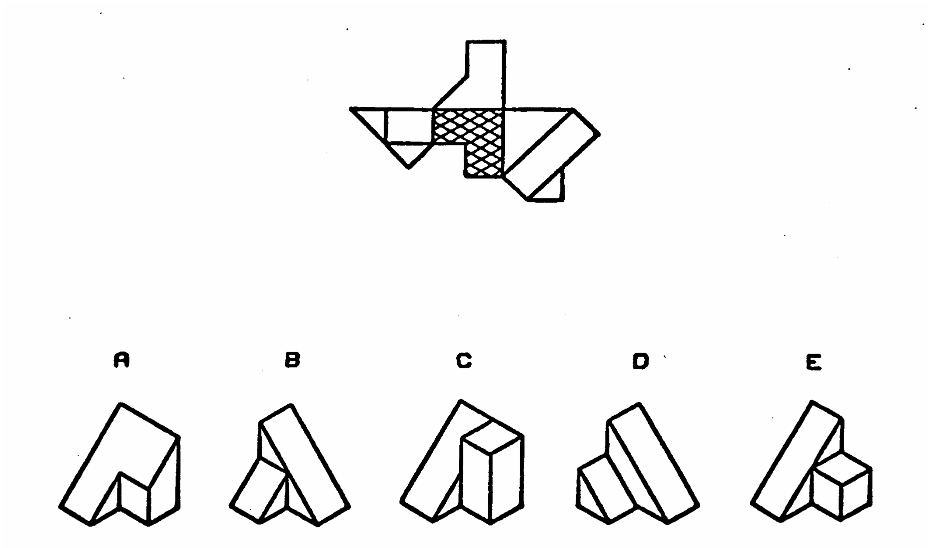

Figure 2.5. Visualization of Developments

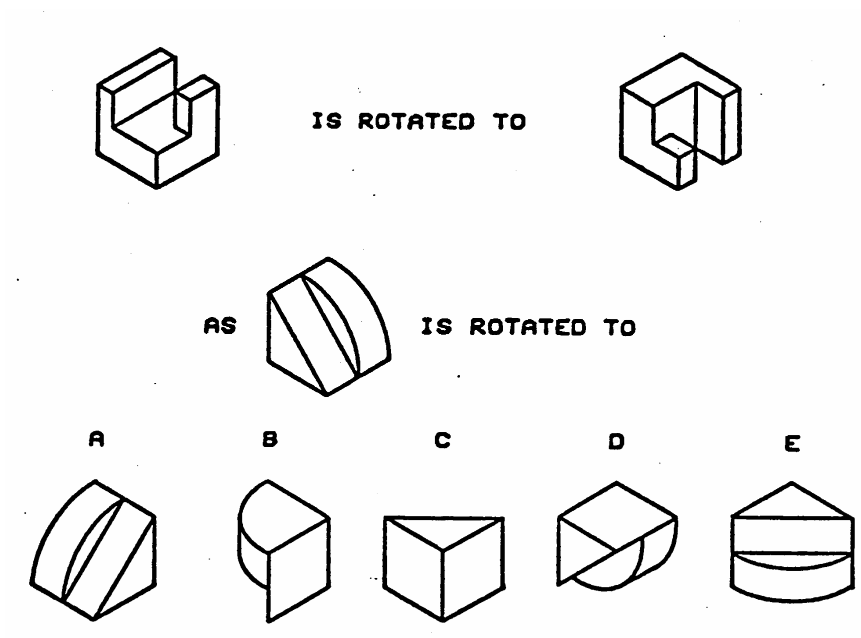

Figure 2.6. Visualization of Rotations

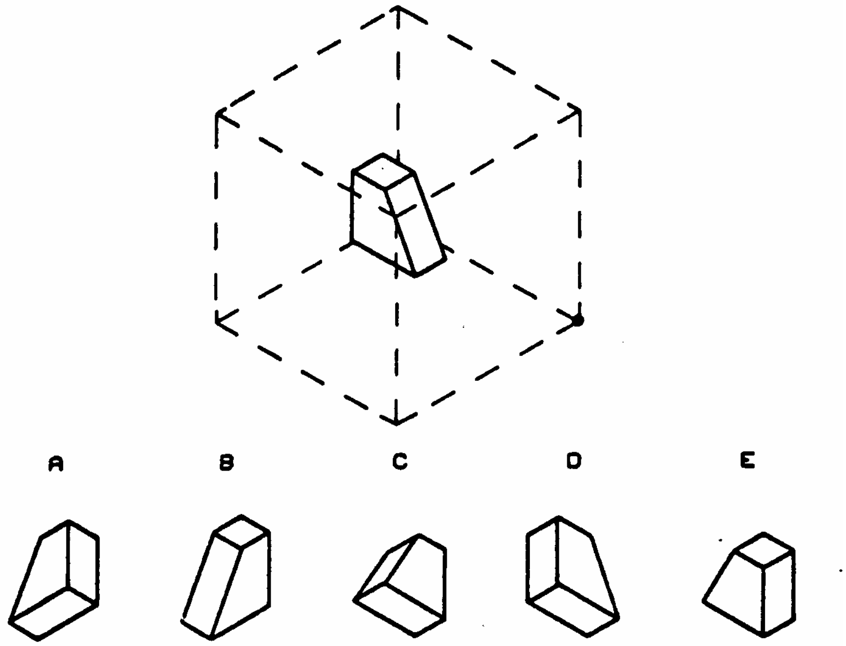

Figure 2.7. Visualization of Views

Guay & McDaniel (1978) completed a study on spatial performance tests. Comparisons of the RMPFB, S-M, and the three subtests of the PSVT were made. A categorization of these tests was made by Guay & McDaniel (1978). They divided the tests into groups by processing styles. The gestalt group (object processed as a whole) included the S-M, Visualization of Rotations and Visualization of Views. The analytical group included the RMPFB and the Visualization of Developments. This group was characterized by Guay & McDaniel (1978) as a trial and error method of processing.

Research presented by Branoff (1998 & 1999), addressed the lack of studies conducted by technical graphics and engineering educators in examining how spatial visualization ability is developed and measured in students. Branoff used the Purdue

Spatial Visualization Test – Visualization of Rotations and modified the test items by adding coordinate axes to the objects. The modified form (Figure 2.8.) of test questions had mixed results.

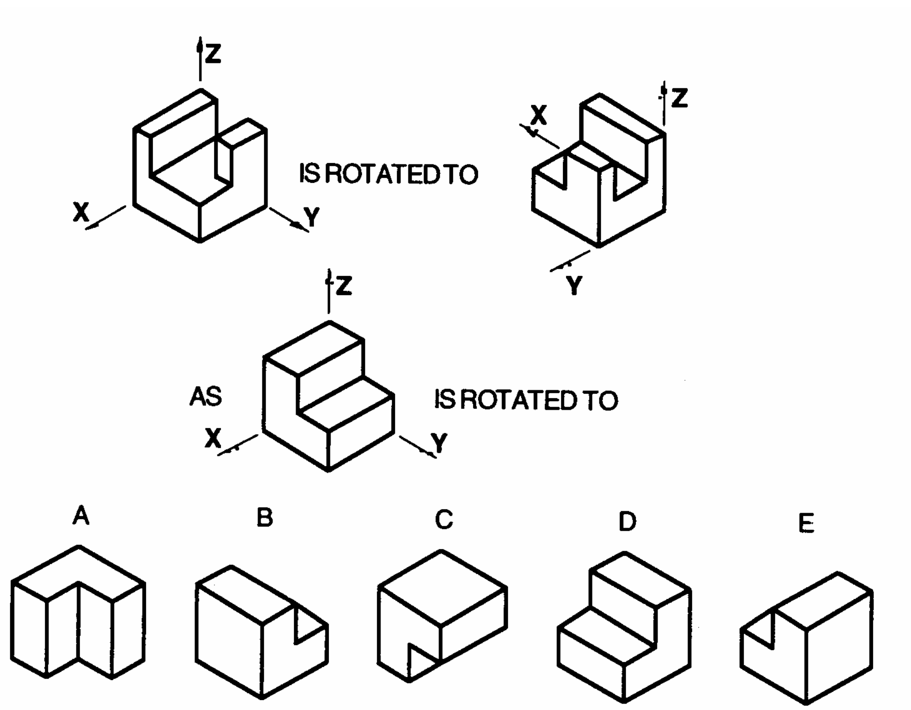

Figure 2.8. Visualization of Rotations with Coordinate Axes Added

Branoff determined that the addition of the axes only had a small influence on the scores for the PSVT:R between the treatment groups. The effect of the axes system indicated more time was required for the test subjects to process the test items. The addition of the coordinate axes indicated that there was no significant difference between male/female ability in rotation of the test items (Branoff, 1998). Branoff (1999) replicated previous findings but indicated that the practical significance on adding the coordinate axes needed to be examined. Recommendations made for this work include a larger sample size and replication at other universities with similar populations as well as different target populations.

In a study, by Seddon, Eniaiyeju, and Chia (1985), the ambiguity in results for visualization in rotations about the Z axis or the X and Y axes was thought to be in statistical methods used in research. They tested the effect of different figures and the cognitive functions that occurred with each type of figure. The figures that Seddon et al. (1985) used provided spatial information that required a different kind of thought process to analyze rotations in different axes. Using the test items illustrated in Figure 2.9, they concluded that the type of psychological reasoning used to understand rotations of the Z axis could not be used to understand rotations of the X and/or Y axes. This work was continued by Shubbar (1990).

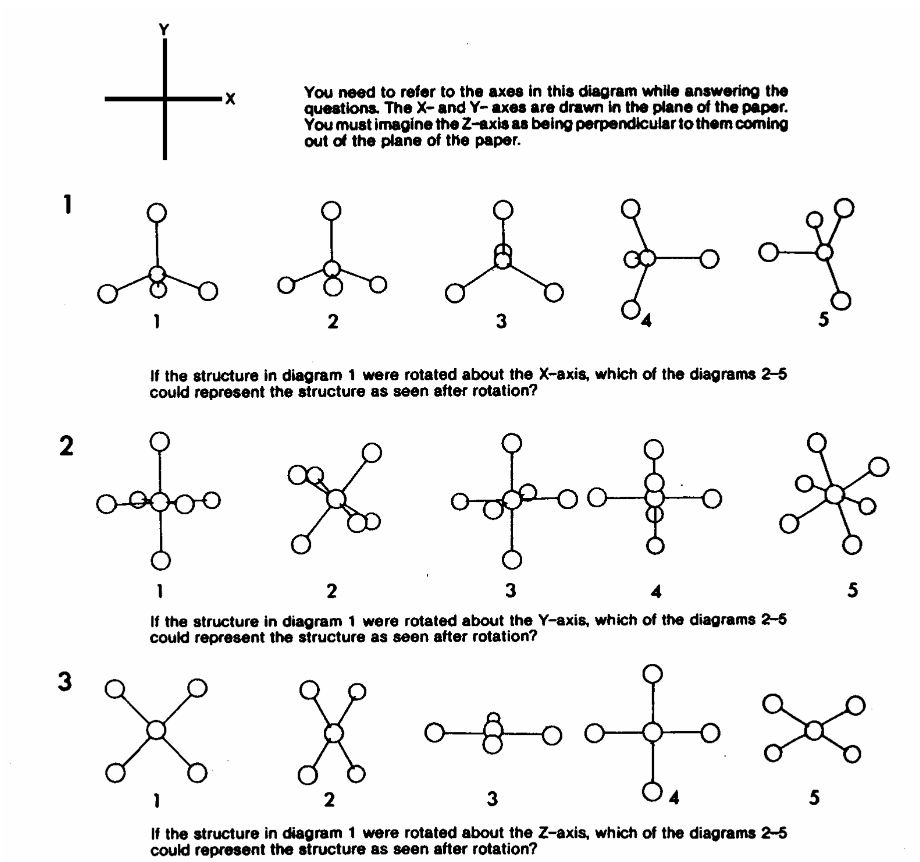

Figure 2.9. English Translation of Arabic Test figures developed by Seddon, Eniaiyeju, and Chia

Animation Studies and Spatial Ability

Blake (1977) investigated motion as an instructional media. In a study utilizing 84 subjects (42 males and 42 females) taken from undergraduate psychology courses, Blake tested the hypothesis that motion in visual media can enhance the learning of complex spatial relations. Blake determined that one of the most important factors in media selection was the degree of detail to be included in the visual presentation. Accordingly, Blake indicated that the increased signal-to-noise ratio in the information theory meant that learning would decrease as a function of the irrelevant cues that are presented simultaneously with the critical cues. Blake concluded that commercial instructional media was done in such detail that it was difficult to isolate the relevant cues because the detail was distracting. The increased detail would not necessarily be a critical portion of the presentation and thus it would cause interference and irrelevant cues (noise). The irrelevant cues impeded learning, by requiring the subject to devote additional time to scan the images, thus decreasing the amount of time available to focus on the relevant cues. "If motion is to be used to reduce the complexity of perceiving visual information, it follows that it should clarify critical information and not add any irrelevant cues" (Blake, 1977, p. 996). Thus it is necessary to clarify what critical information should be presented and not add irrelevant cues.

The manner in which real and apparent motions are presented is a matter of technique (Blake, 1977). In animation the object can be moving (real motion) or the background can be moving (apparent motion of the object), thus providing the illusion of motion.   He also stated that experimenters have failed to demonstrate the significant differences among the media presentations because of the large internal variance caused by individual differences in learning from different modes of instruction. Blake further noted that motion could only enhance learning if it adds significantly to the viewer's perception of the relations between objects. Blake's research determined "… viewers with sufficient spatial ability to perceive spatial relations presented without the use of motion should not show any improvement in learning with the addition of motion. For them, motion cues became extraneous or irrelevant" (Blake, 1977, p. 978).

Caraballo (1985) described research on motion in the following manner: "The research on motion as an instructional variable is neither as vast nor has been carried as systematically as the research assessing the instructional effectiveness of visuals" (p.14). According to Caraballo variations on this outlook have been made by researchers since the 1970s. .

Caraballo (1985) suggested that motion could be a relevant instructional tool in teaching if the concepts to be learned involved motion. While this research employed two different forms of media (slides and motion picture) to teach two concepts, only one of the concepts involved motion as a defining attribute. The college students in the study receiving the motion picture presentation were able to identify a significantly higher number of motion as well as non-motion concepts. The students were tested for learning concepts involving motion, time, and space. Study results indicated that the motion picture was far superior for teaching concepts involving time and was as effective as the slide presentation for teaching concepts involving motion.

Pictures, graphs, animations, or other types of graphics are considered a type of drawing or illustration (Klein, 1985). As a group, these graphics have been increasingly used in education as a tool in which concepts and detailed information can be presented (Klein, 1985). Klein felt that there were a considerable number of theories supporting the use of graphics as a learning tool, however, there is considerable disagreement in theoretical approach and the validity of the various theories among researchers. The perceptual efficiency theory (visuals are more readily perceived because they are a better communicator) had no empirical support according to Moore & Nawrocki (1978). Realism theories (people learn better if information is present in the most concrete manner) were supported by literature, but these views did not have the support of Moore & Nawrocki. “Generally speaking there is belief that pictures aid in learning because they are pleasing. … there is little evidence to support the notion that preferences for a particular stimuli … affect performance” (Moore & Nawrocki, 1978, p. 17).

Klein's (1985) work compared animated and non-animated displays and, in the process, established two classes of rules for describing motion. One of the classes depended heavily on the use of spatial location information (time and space) and the second relied heavily on the temporal sequence of events. Klein classified the first rule as “spatial” in nature and the other as “temporal.” He described the spatial rule as involving some pattern within the trajectory of a moving object. An example of the spatial rule, Klein said, might be the spatial pattern made as the result of skiing down a slope or a bent ray of light that passes through a lens (Klein, 1985, p. 30). The temporal rule was defined as “some regularity in association between motions or changes of at least two objects” (Klein, 1985, p. 30). This example for the temporal rule was the internal moving parts of an engine or clock. Klein simplified his temporal rule by stating that a motion in part A results in a motion in part B.

Caraballo (1985) completed a study in which he investigated types of presentations and the effect each had on learning. The study consisted of eighty college students who were randomly assigned to one of the following groups for a different treatment condition. His instruction conditions consisted of (1) no instruction, (2) text only, (3) text and still graphics, and (4) text plus still and animated graphics. Caraballo's study indicated that the text plus still graphics was as or more effective than text only or text plus still and animated graphics in promoting achievement. Another conclusion was that the decision to include an animated sequence must follow a careful analysis of its effectiveness in promoting specific goals and the effectiveness in reaching the schools. Additionally, his study showed that still graphics might be as effective as, or more effective than, the animated sequences.

A study performed by Bush and Gresham (1986) examined the effect of animations as a communications tool in advertising, questioning the effectiveness of the communication provided by the animation technique. The study consisted of 135 students. The participants were instructed to watch TV programs as if they were in their own homes. There were nine commercials placed in the programming in the normal spots – three each at the beginning, middle, and a few minutes before the end of the program. Each of the commercials was 30 seconds in length. The test subjects were broken into three groups of 45 subjects. Each group viewed all of the commercials, only the sequence of viewing was altered between groups to control for position and order bias. The difference in the commercials was the level of animation. The commercials that had total animation ranked higher than those that were a combination of animation and live action and totally non-animated. Their findings determined that animation, although traditionally popular with children as an attention getting device, provided the least amount of time for perception and recognition of the topic presented to occur. Bush and Gresham also looked into the use of animation as a training tool for military trainees. They found consistent increases in the amount that the trainees learned in situations involving animation. They determined that the use of animation was effective in facilitating comprehension and learning. They concluded that animation was a viable method of execution for advertisers, and that there were no negative perceptions toward advertisements that used animations. Additionally, Bush and Gresham determined that advertisements containing animation were perceived better than advertisements without animation and that brand recall was better for animated advertisements.

According to a paper by Proffitt and Kaiser (1986), the advantages of computer animation over other techniques are that programmed displays are more flexible and easier to create than are the actual physical mechanisms constructed to do the actual motion. However, the effectiveness of computer animation depends on several factors, such as the quality of the simulated motion, the object realism, the scaling perspective, and depth and size (p. 488). Additionally, Profitt and Kaiser

(1986) stated that the realism and quality of motion were limited by the amount of computing power available. Profitt and Kaiser concluded that computer generated displays allowed a greater freedom and control that were impossible with conventional methods. They also stated that computer simulation would rarely achieve a level of realism that would cause an observer to confuse a simulation with reality (p 491).

Shubbar (1990) investigated rotation and diagrams of three-dimensional structures using the rotation of molecules for chemistry visualization problems. In the study Shubbar used 96 boys aged 15-16 drawn at random from all of those following science courses in one senior high school in Bahrain. These students were classified as above average in terms of general education ability and achievement. From the results of this study, Shubbar determined that the ability to visualize molecular structure was dependent on understanding the significance of the tools used to illustrate the structure, and the cues which were used to portray depth. He discussed foreshortening of lines, overlapping of lines, and the representation of angles. According to Shubbar, the psychological importance of the visual cues demonstrated that a general level of spatial relationships in the diagrams for the structures of molecules needed to be understood. It was also stated that if the cues and their relationships were removed, the subject would have a decreased understanding of molecular structure.

Examples of Shubbar's (1990) rotations test appear in Figure 2.9. This test is an English translation of the Arabic material used by Seddon, Eniaiyeju, and Jusoh (1984) to verify learning outcomes after the class lectures were completed. The researchers required students to look at diagrams of a three-dimensional model and then select which of four other diagrams could represent the model. The student was always able to refer to diagrams showing the orientation of X and Y axes. The teaching method was used to assist the student in preparing for this test and employed animation with an explanation describing how to visualize the rotation of the molecular structure. The animation provided a shadow cue to assist in visualizing the rotation of the molecule. According to Shubbar, this particular method was proven to enable the students to visualize rotations in the molecular diagrams. According to test results, an increase in recognition did in fact occur. This increase in recognition was dependent upon the rotational speed of the shadow in the animations. Shubbar stated that, at the time of his study, computer aided animation technology was not advanced enough to allow the test subject to readily control rotational speed. Testing and training, therefore, was done by hand and recorded on video tape. Shubbar concluded the videotape provided an effective means of presenting the sequences of diagrams for instructional purposes.

Although Wiley (1990) does not reference any specific study, he proposed integrating computer graphics throughout the engineering graphics curriculum. Within his framework, he indicated that viewer controlled animation could increase visual perceptual skills. He proposed a change in the curricula to teach the higher level of cognitive skills (i.e. visualization) using computer generated animation. He stated, “Teaching higher level cognitive skills, such as visual perception, should take precedence in our curricula.” (1990, pg 40)

The fundamental logic behind this thought was, "that specific analysis of animations containing multiple depth cues significantly improved depth perception" (Wiley, p.41). Computers are capable of presenting objects in graphical three-dimensional form (model) that can be manipulated to provide different views and allow user control of the model. Wiley felt that the ability to control the movement of an object in real time allowed the learner to get more realistic visual information to promote visual learning and improve spatial ability.

Later, Williamson and Abraham (1995) investigated the effects of computer animation on particulate mental models. In order to determine the effect of animation on student visualization of chemistry concepts, Williamson and Abraham sought answers for the following questions:

1. Will computer animation of concepts improve the understanding of the particulate nature of matter?
2. Would computer animation improve course achievement?

The sample group for this research consisted of two sections of the first semester of general chemistry at a Midwestern university. These two sections were the only sections offered for this class and consisted of a total of approximately 400 students. One section was randomly assigned as the control group and the other as the treatment group. Part of this study used animations illustrating the ion bonding of iodine and hydrogen atoms and the resulting molecular compound. The conclusions reached by Williamson and Abraham (1995) were that animations may increase conceptual understanding through the formation of mental models.

Additionally, the quality of the animation may promote deeper encoding of information than that of static pictures (p. 532). Williamson and Abraham compared animation to static visuals such as transparencies or chart diagrams and determined that static visuals failed to provide an adequate understanding to allow formation of mental models.

Mayton (1991) completed a study in which he investigated the effects of animated visual information used in conjunction with text and static images. In his work, Mayton established three different treatment groups. These groups were composed of a total of 72 introductory psychology undergraduates at The Ohio State University. The first group used static images without cueing strategy; the second used static images with cueing strategy the third group used animated visuals with cueing strategy. The results indicated that both of the groups who were able to incorporate cueing outperformed the group that did not have cueing. The group that used the animated visual performed the best even after re-testing a week later. Mayton concluded that animated instruction could be used to teach a dynamic process.

In a study of spatial abilities and the effects of computer animation, Hays used 131 sixth, seventh, and eighth graders from a suburban middle school. These students were considered average to above average in educational ability. Hays (1996) made two assumptions. The first was "…spatial representations are the more appropriate form of memory representation for concepts involving time and motion …" (p.150). The second was "animation communicates those ideas involving time and motion better than text" (p.150). Hays concluded by noting that animations somehow managed to improve high spatial ability subjects and [allowed subjects] to make better use of their performance. The actual test results indicated that lower ability subjects improved more through the use of animation than through the use of text only or static pictures. The improvements shown by participants indicated that the students with lower ability were almost equal with the students of higher ability after the use of animation. This result agreed with Hays' contention that using three-dimensional objects moving in time and space could aid the lower spatial ability students, allowing them to reach the same degree of understanding that students with higher spatial ability could attain. Additionally, graphical representations in animated form help student construct knowledge in a shared domain and improve performance (Enyedy, 1997).

In an article written by Johns and Brander (1998), they stated that using interactive computer animation software during mechanical skills training leads to improved cognitive, perceptual, and motor skills, (p.8). Their article was written to illustrate how animation could be used in a teaching environment. The purpose of animation, as described by Johns and Brander, was to improve perception of mechanical mechanisms and how to make adjustments and alignments on those mechanisms. Through application of this idea, Johns and Brander felt animations create a three-dimensional simulated world in which spatial performance could be developed. This simulated construct provides an environment that allows experimentation and practice with the relationship between objects within the simulated environment. By interacting with the animated components, the students could practice manipulating the objects and thereby gain knowledge within the spatial concept of the object (Johns & Brander, 1998).

Computer-Aided Design and Spatial Abilities

Sexton (1992) attempted to evaluate computer aided design as an enhancement for teaching spatial visualization while teaching projection theory to students. A sample of 71 male undergraduate students enrolled at Ohio University in the College of Engineering formed the treatment (31) and control (40) groups. These students were taking IT101, an Engineering drawing course. Using the MRT, Sexton attempted to measure the difference in spatial visualization performance using three-dimensional CAD wireframe models versus traditional methods with two-dimensional CAD. Results from this study did not indicate significant improvement in spatial visualization performance by using three-dimensional CAD wireframe models. Sexton thought that more research should be completed using three-dimensional CAD.

Devon, Engel, Foster, Sathianathan, & Turner (1994) investigated the effect of solid modeling on spatial visualization. The sample group for this study consisted of thirteen of fifteen sections of a first year engineering course, EG 50, with approximately 900 students. The two sections that were eliminated from the study were "experimental in ways not relevant to the study". The research also used the MRT as the evaluation instrument. The data generally supported the inferences that solid modeling did help to improve spatial visualization skills. This research compared wireframe models to solid models. Their findings indicated that the students felt the solid modeling software was of more help than the wireframe software in helping them visualize objects in three dimensions.

Sorby (2000) presented the results of a study using three-dimensional solid modeling software and a two-dimensional drafting package in an engineering graphics class. Her sample consisted of 180 students taking GN135- Introduction to Computer Aided Drafting and Design at Michigan Technological University. Sorby used the PSVT:R (Guay, 1977), MCT, and the Differential Aptitude Test: Space Relations (DAT:SR) (Vandenberg & Kruse, 1978). Sorby's conclusions were that just working with 3-D modeling software does not improve spatial visualization skills as much as sketching and hand drawing. Additional findings indicated that the spatial skills measured were an indication of the person's ability to interact with the computer in a 3-D modeling environment. Sorby also indicated that spatial skills were not necessary for effective use of 2-D drafting software.

Cognitive Interaction Learning Theory

When comparing computer animated displays with static pictures, it must be remembered that the observer has a dual awareness. The first is an awareness of transforming two-dimensional patterns on the screen. The second is an awareness of the three-dimensional element that is being created or simulated (Proffitt and Kaiser, 1986). A perceived object in a computer-animated display appears to be somewhere behind the screen, rather than on the surface of the screen. The viewer provides the absolute depth for the object from his or her own knowledge. In order to make the object realistic, it is necessary to create a perspective projection that will appear natural in the simulation.

Pictures have played an important part in education. As such, the traditional theories on learning and the interaction of pictures [graphics] and text on retention have been questioned. Paivio's dual coding theory states that text is normally processed and encoded by the verbal system, and that pictures are processed and encoded by both the imaging and verbal systems (Paivio, 1986). As such Schnotz and Grzondziel (1996) investigated the effects of mental representations in picture comprehension and the effect of animation. Research supported the idea that animated pictures support the construction of a mental model as well as the respective mental simulations (Schnotz & Grzondziel, 1996, p.12). This cognitive function provides feedback and experience from the learning situation and is related to the Interactionist Learning theory.

The Cognitive Interactionist Learning theory and the Experiential Learning theory are very closely related. Both have the feedback from experience through trial and error learning and both also have the effect of a model's behavior to emulate. As shown in Figure 1.1, (pg 3), the interactive exchange of action and feedback provide a constant learning environment. Within the cluster of theories, learning occurs when cognitive function interacts with the meaningful psychological environment around it. The cognitive interaction theories have two forms, linear and field (Bandura, 1993; Bigge & Shermis, 1998, p. 159). Under this premise, the followers of the adult learning philosophy of the Experiential Learning theory will learn (cognitive process) by experience (doing) (Fenwick, 2000; Knox, 1980) and would fall into the category with the Cognitive Interactionist philosophy.

Within the experiential learning theory presented by Kolb, the process of learning is based on reflecting upon existing knowledge (experience) and then forming new concepts that are applied in an active experimentation phase. Experimentation determines which new conceptualization will provide the desired result. The process of experimentation then provides additional concrete experience (knowledge) from which the learner is able to use in the future (Kolb, 1984).

Summary

The effect of animation on spatial visualization has been investigated many times. Test instruments have been developed to measure spatial visualization. The tests have evolved and determinations have been made on the validity of each. The Mental Rotations Test and the Purdue Spatial Visualizations Tests are the most widely used to measure spatial visualization.

Animation has been hypothesized as a tool that could be used to improve spatial visualization. Research has indicated that static images provide cues which improve visualization. From this research, assumptions have been made which indicate that animated images should also be effective in improving spatial visualization (Blake, 1977; Klein, 1985; Wiley, 1990).

The results of this research have been mixed and as a result have not lead to any firm conclusions. Improvement in spatial visualization has been observed but the results of the research have not shown a significant change in spatial visualization. Each of the research articles have indicated that more study be completed to either confirm or expand previous work.

CHAPTER 3: RESEARCH METHODOLOGY

Introduction

The review of the literature led the researcher to conclude that there could be other factors (not yet examined) which influence spatial visualization ability. One factor is the effects of a technical animation class on spatial visualization. The learning theory presented in this study allows for the learner to control the animation environment and for the animation system to provide immediate feed back to the learner. This allows for continuous interaction between the animation system and the learner. The teacher in this learning theory provides the control and guidance so the learner can reap the maximum benefit from the learning situation. Additionally, this chapter describes the methodology used in devising and conducting a study investigating the effects of a technical animation class on the spatial visualization ability of undergraduate students.

Purpose of Study

The purpose of this study was to investigate whether computer animation improves spatial visualization skills. By comparing the results of the scores from the Purdue Spatial Visualization Test – Visualization of Rotation between students taking a Foundations of Graphics (technical graphics) with students taking a computer animation class, an attempt was made to determine which of the groups provided the most improvement in spatial performance.

Research Questions and Hypotheses

As indicated in the previous chapters, certain abilities are required in order to perform spatial tasks. Zavotka (1987) stated that the ability to (1) rotate an object to another plane, (2) change the object from two-dimensional to three-dimensional, and (3) to change an object's size are considered to be spatial in nature. As such, the questions to be investigated by this study can be stated by means of the following research questions:

1. Will instruction in a sixteen week computer animation course (group 2) significantly improve spatial visualization performance in undergraduate students?
2. Will instruction in a sixteen week basic technical graphics course (group 1) significantly improve spatial visualization in undergraduate students?
3. Will instruction in a computer animation course (group 2) provide higher scores indicating a higher development of spatial visualization than a basic technical graphics course (group 1)?

Null Hypotheses

To answer the research questions the following hypotheses were formed:

$H1_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take an undergraduate computer animation course (Group 2).

$H2_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take an undergraduate technical graphics course (Group 1).

$H3_N$ – There will be no significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for undergraduate students who take a computer animation course (Group 2) and students who take a technical graphics course (Group 1). G2=G1

Research Design

Since the researcher collected the data from two intact classes, this study used a non-equivalent control-group design (see Table 3.1). The purpose of selecting this design was to maximize the likelihood that measured differences between the experimental and control groups would reflect the actual differences. When conducted properly, this type of research design can control the following threats to internal validity: maturation, history, instrumentation, testing, statistical regression, and experimental mortality (Gall, Borg, & Gall, 1996).

Table 3.1. Research Design

Group	Pretest	Treatment	Posttest
1- Technical Graphics (control)	O1	X1	O2
2- Animation (experimental)	O1	X2	O2

Key

Group – 1-control , group2 experimental, Nominal level

Score – O1-score on pretest, O2-score on posttest, Interval level

Treatment – X1-treatment provided to control group, X2 – treatment for experimental group

X1 – 16 week course in technical graphics

X2 – 16 week course in animation

Instrumentation

The spatial abilities of individuals of almost all ages have been measured. Many tests have been developed for measuring different spatial factors in the abilities of students and people in various professions (Strong & Smith, 2002).

The instrument that was used in this study was developed from earlier tests. An early example of this test was questions that were part of the Air Force Officers Qualifying Test. These questions were used to evaluate the candidate's ability to determine flight maneuvers necessary to attack or avoid another aircraft. The maneuvers were indicated by pictures of aircraft in various orientations and were based on movement about three axes. The Purdue Spatial Visualization Test - Visualization of Rotations (PSVT:R) of today is very similar in that its test items asks what an object will look like after movements are applied about a combination of axes (Bodner & Guay, 1997).

The Purdue Spatial Visualization Test, designed by Guay, is a series of items that include three different tasks to test spatial ability. This research used the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R). The test contains thirty test items. Each test item provides an example set of figures and a test set of figures. The example set shows a new figure before and after it has been rotated about one or more axes.

> The PSVR test starts off with items requiring a rotation of 90 degrees on one axis. These test items are followed by items requiring a rotation of 180 degrees on one axis, then items requiring a 90 degree rotation on two axes, and finally items requiring a rotation of 90 degrees on one axis and 180 degrees on another axis (Guay, 1980, p. 10).

The test items also provide a view of a new figure and five possible views of this figure if it is rotated about the same axes as the example set. The rotation sub-test requires the most gestalt techniques in processing strategy. Because the gestalt processing method works with mental visual images of figures as a complete unit, the PSVT:R is the best method to measure the spatial ability without the inference of analytic methods changing the strategy used in visualization. With this in mind, the PSVT:R test was chosen to be used as the test instrument for this study.

In previous evaluations of this test, a correlation of 0.61 was obtained when compared to the Sheppard-Metzler test (Guay, 1980, Bodner & Guay, 1997). The first three studies to use the PSVT:R had a total of 217 university students. The reliability of the internal consistency coefficients was .87, .89, and .92 (Guay, 1980). Additional studies have indicated the validity of the PSVT:R (Guay & McDaniel, 1978, Bodner & Guay, 1997). The PSVT:R contains 30 items and is a paper and pencil test with a time limit of 20 minutes. The test is considered appropriate for ages thirteen (13) and older (Guay, 1980). The instructions are designed to be self-explanatory. The difficulty of test items is dependent on the number of axes the object is rotated around. Example items are rotated about one or more axes. The examples are used to indicate the amount of rotation and how the rotation is applied. The stimulus item [the object to be mentally rotated] for each of the questions is different and is in the form of "truncated hexahedrons, right circular cylinders, right rectangular prisms, or right triangular prisms" (Guay, 1980, p.10).

Target Population

The target population for this study is students in fields that require visualization skills for the mental manipulation of three dimensional objects. Professions in chemistry, mathematics, various fields in engineering, and technical graphics are the primary target groups considered for this study. However, this research could be applied to the general population in any area that has an interest in or requires improved spatial visualization requirements.

Sample

The sample groups used in this study were composed of students from two classes taught at NCSU. The groups varied in size due to equipment and software limitations. Group 1 – technical graphics, consisted of nineteen (19) students from a fall semester 2001 Foundations of Graphics class. Group 2 – animation, consisted of twelve (12) students that were enrolled in an animation class (a special topic class) also taught in the fall semester of 2001.

Procedures

Each class took the PSVT:R as a pre-test during the second week of the semester. This helped to eliminate students that dropped the class in the first week. The posttest was administered during the last week of class. The researcher administered the pretests and posttests to all of the classes that participated in the study.

The treatment provided to group 1 was that of the normal instruction and assignments for the Foundations of Graphics classes. Instruction included the topics of sketching, geometric relationships, multiview sketching, isometric sketching, dimensioning practices, and section and auxiliary views. Instruction in AutoCAD ® was also provided to acquaint the students with CAD applications. The students in group 1 were required to learn how to use the AutoCAD ® program by completing provided tutorials and completing two major projects that allowed the students to demonstrate their competency in technical graphic fundamentals and AutoCAD ® .

The treatment for group 2 was the normal course work and instruction in three different animation packages. The instruction included the history, terms and techniques used in animation. Instruction in Flash ® (a two-dimensional animation package), TrueSpace ® (a three-dimensional gaming animation package), and 3D Studios Max ® (a professional quality animation package) was also provided. The students were required to complete a project using each of the animation packages.

The projects consisted of simple animation actions for Flash ®, the animation of a cross sectional view of an internal combustion engine and in TrueSpace ®, objects rolling off a table and bouncing on the floor. Primary emphasis was placed on 3D Studio Max ® in which the students were required to create a one minute animation on any technical subject of their choosing.

Analysis of Data

Questions 1 and 2 were answered by using a paired samples T-test (small sample) for a difference in means between the pretest and posttest scores on the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R) collected at the beginning and end of the sixteen week instruction period.   Question 3 was answered by using an independent sample T-test for a difference in means between the posttest score of groups 1 and 2.

The pretest data was collected from each class in the second week and the posttest data was collected the last week of class for both groups. The pretest/posttest data collected for both sample groups appears in Table 4.1.

Dependent Variable

The dependent variable for this study was the actual score each student received for the posttest on the PSVT:R. The control variable was the score that each student made on the pretest. The score on the PSVT:R is an Interval level variable. The assumptions applied to the performance of the student were that they would do their best to answer all questions to the best of their ability.

Independent Variables

The independent variable for this study was the treatment provided to the classes. The technical graphics class was taught by the researcher and used as the control group. The animation class received the treatment of a sixteen week course in animation and was taught by another instructor. The instructors of both groups worked together as colleagues. The researcher acted as a substitute instructor in the animation classes.

Summary

The validity of the Purdue Spatial visualization of Rotations Test has been shown and identified as the most appropriate instrument for testing spatial visualization without the influence of analytical processes (Guay, 1980).

The sample groups used in this study consisted of thirty-one (31) students, and is considered to be a representative sample of the students taking the various Graphic Communications classes.

Additionally, the researcher administered the test to each of the sample groups and read the instructions with no variation as provided with the PSVT:R. The questions to be addressed by this research are:

1. Will instruction in a sixteen week computer animation course (group 2) significantly improve spatial visualization performance in undergraduate students?
2. Will instruction in a sixteen week basic technical graphics (group 1) significantly improve spatial visualization in undergraduate students?

3. Will instruction in a computer animation course (group 2) provide higher scores indicating a higher development of spatial visualization than basic technical graphics course (group 1)?

The research design for this study was a non-equivalent control-group design and used the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R) as the test instrument. The target group for this research is anyone in the professions in chemistry, mathematics, various fields in engineering, and technical graphics.

The sample groups consisted of 19 students in the control group and 12 students in the treatment group. Each group took the PSVT:R as a pre-test and posttest. Analysis to test for improvement within each group used a paired samples T-test (small sample) for a difference in means between the pretest and posttest scores. The test used for analysis between the groups was an independent sample T-test for a difference in means between the posttest score of groups 1 and 2.

CHAPTER FOUR: PRESENTATION OF DATA

Introduction

This chapter is divided into two sections. The first section presents demographic data on the participants. The second section presents the data related to the analysis of the scores for the PSVT:R.

Description of Participants

Group One – Technical Graphics (Control Group)

The Foundation of Graphics class is an introductory class in the technical graphics area. The emphasis of this class is to provide an orientation to the language of engineering graphics. This includes a knowledge base of the various types of drawings (perspective and parallel projections) with emphasis on the principles of orthographic projections (multiview), the need for sections and auxiliary drawings, and dimensioning and tolerancing standards, plus visualization techniques. Additional work is focused on the Concurrent Engineering Design Method. The principles learned are applied using a software package to produce a final project for the class.

The Foundation of Graphics class used in this research was taught in the fall semester of 2001. The students completed a demographics questionnaire at the beginning of the semester. Each student provided information about age, graphics background, class load, work status, and major. The students in group 1 ranged from eighteen to thirty-one years of age. More that 75% of the students had part time jobs and were taking a minimum of twelve credit hours of course work. The class started with twenty-four students but through attrition class size was reduced to nineteen (19) students by the end of the semester.

The final student makeup for the class taught in the fall semester of 2001 was 6 females and 14 males. These students were primarily electrical engineering, civil engineering, and mechanical engineering majors who were taking the class as a general education elective. Additionally, there was a Technology Education major and a Psychology major enrolled in the class. The former was required to take the class and the latter was taking the class as an elective. A summary of the demographic data appears in Table 4.1.

Group Two – Animation (Experimental Group)

The animation class was taught in the fall semester of 2001. The class had no pre-requisites and was open to all students. The treatment was that of a fifteen-week course, (consisting of four hours of lecture/lab each week) in which animation fundamentals, history, and techniques were taught. The students were shown how to use three different animation packages. These packages included: Flash ®, a two dimensional program for web page animation; TrueSpace ®, a three dimensional animation package for animated game creation; and 3D Studio Max ®, a professional animation package. As each animation package was discussed, the students developed a mini-project. At the end of the sixteen week course each student was required to create a one-minute animation presentation for a final project in order to show knowledge of the animation principles.

Table 4.1. Demographic Data

	Group 1 n = 19	Group 2 n = 12
Gender		
Female	6	1
Male	13	11
Age		
18-25	18	11
25-30	0	0
> 30	1	1
Work		
Yes	15	11
No	4	1
Class Load		
< 12 units	3	0
> 12 units	16	12
Major		
Design	0	1
Education	1	4
Engineering	17	0
Graphic Communications	0	7
Other	1	0

Demographic data was collected from each of the students by the researcher. The class started with sixteen students and finished with thirteen students. At the beginning of the semester, the class consisted of two females and fourteen males. By the end of the semester, three of the males had dropped out. The females in the class had no previous experience in technical graphics. However, one female was concurrently enrolled in a Foundation of Graphics class and as a consequence was eliminated from the study. All of the male students in the class had previously taken several of the technical graphics courses, and many of them had considerable experience in the technical graphics area. Four of the students in this class were Technology Education majors and seven were Graphic Communications majors. The only exception was the female who was a design major. The age of the students in this group ranged from twenty-four to twenty-nine and one student was forty-two. Eleven of the twelve students were employed in part time work and also had a minimum of twelve semester hours of course work. A summary of the demographic data appears in Table 4.1.

Analysis of Scores

Utilizing the data collected from the classes, the groups (technical graphics or animation) were analyzed by performing a paired sample T-test for questions 1 and 2 and an independent samples T-test for a difference in means for question 3. The scores for each group are provided in Appendix A.

Table 4.2 examines the scores obtained on the PSVT:R for both the control and experimental groups as seen in questions 1 and 2.

Table 4.2. Pretest and Posttest Scores by Treatment Group

	Control Group		Experimental Group	
Variable	Mean	Std Dev	Mean	Std Dev
Pretest	24.631	3.804	24.583	4.452
Posttest	24.947	4.249	25.083	3.965

Question 1

To investigate question 1, will training in computer animation significantly improve spatial visualization performance, the data collected for Group 2 (animation group) will be analyzed using the following hypothesis.

$H1_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2).

$H1_A$ – There will be a significant increase between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2).

The results of the paired sample T-test using the pretest and posttest for the Experimental group are given in Table 4.3. As shown the analysis failed to reveal a significant difference between the pretest and posttest groups. A T-score of 0.460 and a corresponding p value of 0.658 indicate that there is no significant difference between the pretest and post test score on the PVST:R for the Animation (experimental) group. Thus the analysis of the data leads to the conclusion that the null hypothesis cannot be rejected for Question 1.

Table 4.3. Analysis of Mean Gain Scores for the Experimental Group

Variable	N	Mean	Std Error	T	Pr > |T|
Diff	12	0.500	1.098	0.460	0.658

Question 2

To investigate question 2, will training in a Foundations of Graphics significantly improve spatial visualization performance, the data collected for Group1 and the second hypothesis will be used.

> $H2_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a foundation of graphics class (Group 1).
>
> $H2_A$ – There will be significant increase between the pre-test scores and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a foundation of graphics class (Group 1).

The results of the paired sample T-test using the pre-test and posttest for the Control group are given in Table 4.4. As shown, this analysis failed to reveal a significant difference between the two groups (pre-test and posttest), a t-score of 0.440 with a corresponding p-value of 0.669. The analysis of the data leads to the conclusion that the null hypothesis cannot be rejected for Question 2.

Table 4.4. Analysis of Mean Gain Scores for the Control Group

Variable	N	Mean	Std Error	T	Pr > |T|
Diff	19	0.316	0.726	0.440	0.669

Question 3

Investigation of question 3, will training in computer animation provide higher average scores on the PSVT:R than the Foundations of Graphics class and introduction to engineering graphics class, will be completed by using the data collected for the graphics group and the animation group and hypothesis 3.

> $H3_N$ – There will be no significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2 – Treatment) and students who take the Foundations of Graphics class or introduction to engineering graphics class (Group 1 – Control). G2 = G1
>
> $H3_A$ – There will be a significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2) and students who take the Foundations of Graphics class or introduction to engineering graphics class (Group 1). G2 ≠ G1

The independent samples T-test conducted compared the animation group posttest score to the average posttest score made by the graphics group (G2=G1). The data in Table 4.5 indicates that the difference in means test resulted in a t-score of 0.09 with a corresponding p-value of 0.929. The high p-value would indicate that no significant difference existed between the groups. Analysis indicates sufficient evidence to support the null hypothesis. Additionally, a test on variation was made by the statistical software; this test indicated that there was no significant difference between the variations of the posttest scores.

Table 4.5. Analysis of Posttest Scores between Treatment Groups

Variable	DF	T	Pr > |T|
Posttest	24.8	0.090	0.929

Summary

This chapter has presented the demographic data on the participants, presented mean scores, tested the research hypotheses, and reported the results. When analyzing mean scores for the control group, no significant difference existed between the pretest and posttest. There was no significant difference between the pretest and posttest when examining mean scores for the experimental group. No significant difference was found when analyzing the posttest mean scores between the experimental and control groups.

CHAPTER FIVE: SUMMARY, CONCLUSIONS, DISCUSSION, RECOMMENDATIONS

Introduction

The purpose of this study was to investigate the effect of using computer animation as a tool for improving spatial visualization performance in college students. The researcher investigated whether the use of computer animation and computerized modules of instruction can produce beneficial results on the understanding and improvement of spatial visualization abilities. The results of this study are expected to be important in the advancement of the use of computer animation in teaching.

Animation is capable of providing both real and apparent motion which provides realism and results in improved viewer perceptions of the relations between objects (Blake, 1977). Computer animation takes advantage of the ability to provide meaning, illustrate, and give organization to the material being taught (Klein, 1985; Profit & Kaiser, 1986). As such, animation is used in many fields of study (Bodner & Guay, 1997; Strong & Smith, 2001).

Research on animation includes work that has compared animation to still images, text only, still images with text, and motion pictures (video). Prior to the current standards of computer animation, motion pictures were consider by some researchers as "far superior" compared with still images with or with text (Caraballo, 1985; Klein, 1985; Shubbar, 1990). Bush and Gresham (1986) found consistent increases in the amount trainees learned when the learning situation included animation. Animated visuals allowed better retention in student learning and communicated ideas involving time and space better than text (Hays, 1996; Mayton, 1991).

Viewer controlled animation provides significantly improved depth perception and can increase conceptual ideas through the development of mental models (Williamson & Abraham, 1995; Wiley, 1990). Additionally, viewer controlled animation leads to improvement in cognitive, perceptual, and motor skills and allows the creation of a three-dimensional simulated world in which spatial performance can be developed, assisting in anchoring the student into reality for the use of visual objects (Johns & Brander, 1998).

In order to develop animation tools that improve spatial visualization, previously developed tests have been used as measurement instruments. These tests have been developed and validated over time and usage. The list of tests include the Revised Minnesota Paper Form Board (Likert & Quasha, 1970), the S-M mental rotations test (Shepard & Metzler, 1971) later revised by Vandenberg and Kuse (1978), The Purdue Spatial Visualization Test (a series of three tests) developed by Guay (1976) and later experimentally modified by Branoff (1998, 1999) with coordinate axes added and a molecular rotations test developed by Seddon, Eniaiyeju, and Chia that was later translated to English by Shubbar (1990). Of these tests the Visualization of Rotations portion of the Purdue Spatial Visualization Test was deemed the best test for measuring spatial visualization performance (Guay & McDaniel, 1978, Sorby, 2000).

Statement of Problem

The purpose of this study was to determine whether instruction in technical animation improves spatial visualization in undergraduate students more than instruction in technical graphics. A sample of 31 students was used as a control and experimental group. The research design was a non-equivalent control-group design to maximize the likelihood that measured differences would reflect real differences and to improve validity. A pretest and posttest were administered to each group using the PSVT:R.

Research Questions and Hypothesis

To study the possibility of improving spatial visualization skills, the investigation asked the following questions:

1. Will instruction in a sixteen week computer animation course (group 2) significantly improve spatial visualization performance in undergraduate students?
2. Will instruction in a sixteen week basic technical graphics (group 1) significantly improve spatial visualization performance in undergraduate students?
3. Will instruction in a computer animation course (group 2) provide higher scores indicating a higher development of spatial visualization than basic technical graphics course (group 1)?

Questions 1 and 2 were answered by using a difference in means test between pretest and posttest scores on the Purdue Spatial Visualization Test – Visualization of Rotations (PSVT:R) collected at the beginning and end of the sixteen week instruction period. The hypotheses for questions 1 and 2 were:

$H1_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Group 2).

The results of the paired sample T-test for the animation group using the pre-test and posttest are given in Table 4.3. This analysis failed to reveal a significant difference between the two groups (pre-test and posttest), a t-score of 0.460 with a corresponding p-value of 0.658. The high p-value as seen in Table 4.3 would indicate that no significant improvement in spatial visualization performance had occurred over the period of the course and the students had not collectively improved their spatial visualization performance.

$H2_N$ – There will be no significant difference between the pre-test and posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a foundation of graphics class (Group 1).

The results of the paired sample T-test for the technical graphics group using the pre-test and posttest are given in Table 4.4. The high p-value would indicate that no significant improvement in spatial visualization performance had occurred over the period of the course and the students had not collectively improved their spatial visualization performance.

To answer question 3 it was necessary to use the posttest data for both of the groups. Using the posttest results, a difference in means test was performed to see if there was a significant difference in mean scores between the animation group and the graphics group.

$H3_N$ There will be no significant difference between the posttest mean scores on the Purdue Spatial Visualization Test – Visualization of Rotations for students who take a computer animation class (Treatment) and students who take the Foundations of Graphics class (Control). G2 = G1

Procedures

The sample groups were administered the thirty question PSVT:R as a pretest during the second week of a sixteen week class in either animation (group 2) or in a beginning technical graphics class (group 1).

Treatment for the experimental group was provided in the form of instruction. The instruction included animation history, theory, and techniques. The students were provided hands on experience with three different animation packages and were required to produce short animations with each.

Treatment for the control group consisted of the normal Foundations of Graphics class. The students were instructed in sketching, isometric sketching, multiview sketching, dimensioning, and section and auxiliary views. Additional training was provided in a CAD package.

A posttest was administered to each class during the last week of class. The students were not provided with scores from the pretest and were encouraged to do their best. The researcher administered the pretest and post test to both of the sample groups. The instructions from the PSVT:R were read to the students prior to the start of the evaluation and no other form of instruction was given. All groups received the same instructions. Scores for students that took the pretest but not the posttest were removed from the sample group to prevent skewing of the results of mean calculations.

The pretest and posttest scores collected were used to perform comparisons within each group to determine if any significant difference existed in the before and after test scores or between the groups in the posttest scores. The researcher taught the students in the technical graphics group. Dr. A. Clark taught the students in the animation group.

Demographic Data on Participants

The choice of this population was made for practical considerations that involved the availability of subjects, the willingness of their instructor to participate, and cooperativeness of the students to work with the educational research efforts of the university.

The sample groups in this study consisted of students from two classes in the Graphic Communications Program area group of the Department of Mathematics, Science and Technology Education. The treatment groups consisted of a total of thirty-one (31) students, seven (7) females and twenty-four (24) males. The ages of the students ranged from nineteen to 42. The treatment groups were comprised of a Foundation of Graphics class (group 1) and an animation class (group

2). Group 1 consisted of 6 females and 13 males for a total sample size of 19. The students in group 1 were primarily biological and chemical engineering students, with a few electrical and civil engineering students who were taking the class as a general education elective. Group 2 consisted of 1 female and 11 males for a sample size of 12 students. The female in the class had no previous experience in technical graphics. All of the male students in the class had previously taken several of the technical graphics courses, and many of them had considerable experience in the technical graphics area. Most of the students in this class were either Technology Education or Graphic Communications majors. The only exception was the female who was a design major.

Analyses

Question 1 – Will instruction in a sixteen week computer animation class (group 2) significantly improve spatial visualization scores on the Purdue Spatial Visualizations Test – Visualization of Rotations? It was hypothesized that there would be no significant difference between the pretest – posttest scores on the PSVT:R for the treatment group. Analysis using a paired samples T-test between the pretest/posttest indicated there was no significant difference in scores between the pretest and posttest ($t = 0.30$, $p = 0.7698$). The failure to reject the null hypothesis indicated there was no significant difference between the pretest and posttest scores on the Purdue Spatial Visualizations Test – Visualization of Rotations. This indicates that there was no significant improvement in the spatial visualization scores of the students that took part in the sixteen week animation class. The findings support Null Hypothesis #1.

Question 2 – Will instruction in a sixteen week basic technical graphics class (group 1) significantly improve spatial visualization scores on the Purdue Spatial Visualizations Test – Visualization of Rotations? It was hypothesized that there would be no significant difference between the pretest – posttest scores on the PSVT:R for the treatment group. Analysis using a paired samples T-test between the pretest/posttest indicated there was no significant difference in scores between the pretest and posttest ($t = 0.44$, $p = 0.6686$). The failure to reject the null hypothesis indicated there was no significant difference between the pretest and posttest scores on the Purdue Spatial Visualizations Test – Visualization of Rotations for the technical graphics group. This indicates that there was no significant improvement in the spatial visualization scores of the students that took part in the sixteen week technical graphics class. The findings support Null Hypothesis #2.

Question 3 – Will training in a sixteen week computer animation class (group 2) provide higher scores on the Purdue Spatial Visualizations Test – Visualization of Rotations than instruction in a sixteen week basic technical graphics class (group 1)? It was hypothesized that there would be no significant difference between the posttest scores on the PSVT:R for the animation and the technical graphics groups. Analysis using an independent samples T-test between the posttest scores of the test groups indicated there was no significant difference in scores between the posttest of each group ($t = 0.09$, $p = 0.929$). The failure to reject the null hypothesis indicated there was no significant difference between the posttest scores on the Purdue Spatial Visualizations Test – Visualization of Rotations for the animation and technical graphics groups. The findings support Null Hypothesis #3.

Conclusions and Discussion

Although the results of this study cannot be generalized to populations other than the ones that are similar to those that were used in this study, the results indicated the following:

A. The students in the animation group did not significantly improve their spatial visualization. A possible explanation for the lack of significant improvement is that the spatial visualization of these students were previously developed and that no further improvement in scores could be measured with the PSVT:R.

B. The students in the technical graphics class did not significantly improve their spatial visualization. A possible explanation for the lack of significant improvement is that the spatial visualization of these students were previously developed and that no further improvement in scores could be measured with the PSVT:R.

C. The lack of significant difference in spatial visualization performance between the test groups is surprising. It had been noted that animation should improve spatial visualization performance.

Based on the results, the following explanations could be made. The first of these is that animation does not have any significant effect on spatial visualization performance. Animation may only provide motion cues and not really provide the necessary information for the visualization of spatial relationships. Secondly, significant improvement in spatial visualization of these students could not be measured with the PSVT:R, and a different test instrument should have been used. The change in spatial visualization ability may have been too small for the instrument to measure. It may well be necessary to use a combination of instruments to measure the change in spatial visualization. A third explanation is that the technical graphics classes were provided with ample learning techniques that brought them to a level equal to the students in the animation group. The students in the animation class, with one exception, had taken the same Foundations of Graphics class. Many of these same students had taken additional advanced graphics courses. These classes may have only provided for further improvement in design and technical techniques, not improvement in spatial visualization skills. A fourth explanation is that there was no real improvement in either of the test groups so no difference existed. The level of spatial visualization may have already been developed by the students' life experiences. A fifth possible cause for no difference is the instruction provided to the test groups. The instruction provided to the students may have only improved technical skills and not been geared towards improving spatial visualization skills. Additionally, students in engineering and technical majors are suspected of having developed spatial visualization skills through previous life experiences. That ability would tend to attract students to the engineering and technical fields of study. Finally, it is possible that a single course in animation is not sufficient to improve spatial visualization.

The biggest factor affecting the results of this research is the small size of the sample. This study is inconclusive due to the limited sample size and should be completed with a larger sample and a different instrument or combination of instruments to measure the spatial visualization of the students.

Implications for Teaching

Educators in technical animation and engineering and technical graphic should consider the results of this study before integrating animation activities into the curriculum if the sole purpose is to increase spatial visualization over the course of one semester. It appears that neither instruction in animation nor technical graphics had any significant effect on students' spatial visualization ability as measured by the PSVT:R. Teachers should use animation to some extent in classroom activities if the opportunity presents itself. Student exposure to animation should only enhance the learning experience by providing the student with new knowledge and experience.

Recommendations for Future Research

The results of this research suggest that further study in the area of spatial visualization be conducted. The significance of spatial visualization performance has been noted from many sources and indicated throughout this research. The need to find the best method or combination of methods to assist the student in learning and improving his/her spatial visualization is paramount. This research should be redone using a larger sample size and should include samples from other learning institutions (secondary and post-secondary). As new technology is made available, this work should be completed again to determine whether more improvement in student spatial visualization can be accomplished.

REFERENCES

Baartmans, B. G., & Sorby, S. A. (1996). *Introduction to 3-d spatial visualization*. Englewood Cliffs, NJ: Prentice Hall Inc., chap. 1,2.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28(2)*, 117-148.

Bigge, M. L., & Shermis, S. S. (1998). *Learning theories for teachers* (6^{th} ed.). New York: Longman, pp. 154-210.

Blake, T. (1977). Motion in instructional media: Some subject-display mode interactions. *Perceptual and Motor Skills*, *44*, 975-985.

Bodner, G. M., & Guay, R. B. (1997). The purdue visualization of rotations test. *The Chemical Educator*, *2(4)*, 1-18.

Branoff, T. J. (1998). The effects of adding coordinate axes to a mental rotations task in measuring spatial visualization ability in introductory undergraduate technical graphics courses, *Engineering Design Graphics Journal, 62(2)*, 16-34.

Branoff, T. J. (1999). Coordinate axes and mental rotations tasks: A solomon four group design, *Engineering Design Graphics Journal, 63(3)*, 4-14.

Bush, A. J., & Gresham, L. G. (1986) Research note the communication effects of animation. *Journal of Applied Communication Research*, *14(1)*, 59-65.

Caraballo, J. N. (1985). *The effect of various visual display modes in computer-based instruction and language background upon achievement of selected educational objectives.* Unpublished doctoral dissertation, Pennsylvania State University.

Coleman, S. L., & Gotch, A. J. (1998). Spatial perception skills of chemistry students. *Journal of Chemical Education*, *35(2),* 206-206.

Devon, R., Engel, R. S., Foster, R. J., Sathianathan, D., & Turner, G. F. W. (1994). The effect of solid modeling software on 3-d visualization skills, *Engineering Design Graphics Journal, 58(2)*, 4-11.

Enyedy, N. (1997). *Constructing understanding: The role of animation in interpreting representations.* (ERIC Document Reproduction Service No. ED409349)

Fenwick, T. J. (2000). Expanding conceptions of experiential learning: A review of the five contemporary perspectives on cognition. *Adult Education Quarterly*, *50(4),* 243-272.

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research: An introduction.* (6th ed.). White Plains, NY: Longman

Guay, R. B. (1976). *Purdue spatial visualization tests*. (Tests on Microfiche No. TC009199)

Guay, R. B. (1978). *Factors affecting spatial test performance: Sex, handedness, birth order, and experience.* (ERIC Document Reproduction Service No. ED167612)

Guay, R. B. (1980). *Spatial ability measurement: A critique and an alternative*. (ERIC Document Reproduction Service No. ED189166)

Guay, R. B., & McDaniel, E.D. (1978). *Correlates of performance on spatial aptitude tests*. Purdue University, U.S. Army Research Institute for the Behavioral and Social Sciences, Grant No. DAHC 19-77-G-0019

Hays, T. A. (1996). Spatial abilities and the effects of computer animation on the short-term and long-term comprehension. *Journal of Educational Computing Research*, *14(2)*, 139-155.

Johns, J. F., & Brander, J. M. (1998). Improving perceptual skills with 3-dimensional animations. *Journal of Instruction Delivery Systems*, *Winter*, 8-19.

Klein, D. (1985). *Conditions influencing the effectiveness of animated and non-animated displays in computer assisted instruction.* Unpublished doctoral dissertation, University of Illinois in Urbana-Champaign.

Knox, A. B. (1980), Proficiency theory of adult learning. *Contempory Educational Psychology, 5,* 378- 404.

Kolb, D. A. (1984). *Experiential learning: Experience as a source of learning and development*. Englewood Cliffs, New Jersey: Prentice-Hall.

Lean, G. A., & Clements, M. A. (1981). Spatial ability, visual imagery, and mathematical performance. *Educational Studies in Mathematics*, *12 (3)*, 267-299.

Likert, R. & Quasha, W. H. (1970). *Revised minnesota paper form board test*. New York: The Psychological Corporation.

Mayton, G. B. (1991). *Learning dynamic processes from animated visuals in microcomputer-based instruction*. (ERIC Document Reproduction Service No. ED334999)

Moore, M.V., & Nawrocki, L.H. (1978). *The educational effectiveness of graphic displays for computer assisted instruction*. Alexandria, VA.: Army Research Institute for the Behavioral and Social Sciences. (ERIC Document Reproduction Service No. ED169197).

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.

Proffitt, D. R., & Kaiser, M. K. (1986). The use of computer graphics animation in motion perception research. *Behavior Research Methods, Instruments, & Computers*, *18(6)*, 487-492.

Rieber, L. P. (1987). Animation in computer-based instruction. *Educational Technology Research and Development*, *10(4)*, 77-86.

Rieber, L. P. (1989). *A review of animation research in computer-based instruction*. (ERIC Document Reproduction Service No. ED308832)

Schnotz, W., & Grzondziel, H. (1996*). Knowledge acquisition with static and animated pictures in computer-based learning*. (ERIC Document Reproduction Service No. ED401878)

Seddon, G.M., Eniaiyeju, P.A., & Chia, L. H. L. (1985). The factor structure for mental rotations of three-dimensional structures represented in diagrams. *Research in Science & Technology Education*, *3(1),* 29-42.

Seddon, G.M., Eniaiyeju, P.A., & Jusoh, I. (1984). The visualization of rotation in diagrams of three-dimensional structures, *American Educational Research Journal*, *21*, 25-38.

Sexton, T. J. (1992). Effect of spatial visualization: Introducing basic engineering graphic concepts using 3d cad technology, *Engineering Design Graphics Journal, 56(3)*, 36-43.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, *171*, 701-703.

Shubbar, K. E. (1990). Learning the visualization of rotations in diagrams of three dimensional structures. *Research in Science & Technological Education*, *8(2)*, 145-1554.

Sorby, S. A. (2000). Spatial abilities and their relationship to effective learning of 3-d solid modeling software. *Engineering Design Graphics Journal, 64(3)*, 30-35.

Stancil, J. S., & Melear, C. T. (1991). *Paper and cube interventions preceded by a three dimensional computer graphics animation to improve spatial ability among elementary education majors*. (ERIC Document Reproduction Service No. ED334071)

Strong, S., & Smith, Roger (2001). Spatial visualization: Fundamentals and trends in engineering graphics. *Journal of Industrial Technology*, *18(1)*, 2-6.

Strong, S., & Smith, R. (2002). The development of a computerized version of vandenberg's mental rotation test and the effect of visuo-spatial working memory loading. *The Engineering Design Graphics Journal*, *66(2)*, 6-16.

Vandenberg, G. S. & Kuse, R. A. (1978). Mental rotation, a group test of three-dimensional spatial visualization. *Perceptual and Motor Skills, 47*, 599-604.

Wiley, S. E. (1990). Computer graphics and the development of visual perception in engineering graphics curricula, *Engineering Design Graphics Journal, 54(2)*, 39-43.

Williamson, V. M., & Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching*, *32(5)*, 521-534.

Zavotka, S. L. (1987). Three-dimensional computer animated graphics: A tool for spatial skill instruction. *Educational Communication and Technology Journal*, *35(3),* 133-144.

Appendix

Pretest/Posttest Scores on the PSVT:R

Technical Graphics		Animation	
Pre	Post	Pre	Post
25	25	29	29
29	27	28	28
18	25	30	26
27	27	21	17
26	26	27	27
27	29	23	23
15	17	20	28
29	28	30	30
22	28	27	25
25	25	21	19
24	23	16	23
24	18	23	26
28	26		
19	14		
25	26		
26	26		
25	25		
25	29		
29	30		