The Effect of Training in Computer-Aided Design on the Spatial Visualization Ability in Selected Gifted Adolescents

by

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Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of DOCTOR OF EDUCATION in Vocational and Technical Education

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March, 1992
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Abstract

This research was undertaken to determine the effect that computer-aided design (CAD) had on the spatial visualization abilities of selected gifted adolescents. The following hypotheses was tested: Subjects receiving instruction in CAD will show improvement in spatial visualization ability, as measured by the Revised Minnesota Paper Form Board (RMPFB) test, when compared to the subjects not receiving CAD instruction.

The experimental group consisted of 20 students enrolled in the CAD course offered in the 1991 Virginia Governor's School of Technology. The control group consisted of 20 Governor's School students not enrolled in the CAD course. Both groups were pretested using the RMPFB test Form AA to measure entry level spatial visualization. A treatment consisting of three weeks of CAD instruction using CADKEY 3.5 was given to the experimental group. Following the treatment both groups were posttested using the RMPFB test Form B8 to determine their existing level of spatial visualization ability.

The nonequivalent control group design was used in this study since the experimental group was an intact group and therefore not randomly assigned. ANCOVA statistical analysis was used to determine if there was statistical significance of the posttest scores.
Acknowledgements

The author would like to thank his committee for all their help and encouragement throughout the writing and research process. He would especially like to thank Dr. E. Allen Bame for recruiting him to pursue his degree at Virginia Polytechnic Institute and State University. A special thank you goes to Drs. Charles A. Pinder and Donald E. Elson for giving him flexibility in his assistantships so he could concentrate on his studies.

All of this would not have been possible without his parents Ruth E. Mack and the late Elmer W. Mack, who would have been proud.

Finally, the author is grateful to his wife, Darlene, who did the typing and editing, and displayed continuous support, understanding, and patience throughout this adventure.
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CHAPTER 1

Introduction

Spatial visualization ability has been recognized as a distinct and important dimension of human abilities for more than half a century. Although spatial ability has never attained the level of recognition afforded verbal and numeric ability, it has long been recognized as important for success in many occupations and school subjects, such as engineering drafting, and art (Guay, 1980).

Blade (1949) found that visualization, or a person's ability to think in three dimensions, can be improved through training and practice. Visualization is developed through experience in relating what an individual sees to what is felt with the sense muscles. Spatial visualization skills are important to doctors, dentists, biochemists and mathematicians alike. This study will attempt to show that through the use of computer-aided design training a student's visualization skills can be improved.

Background

Gifted Education

Gifted and talented children are those identified by professionally qualified persons as students who, by virtue of outstanding abilities, are capable of high performance. These are children who need unique educational programs and
services beyond those normally provided to realize their contribution to self and society. Children capable of high performance include those with demonstrated achievement and/or potential ability in any of the following areas: (a) General intellectual ability, (b) Specific academic aptitude, (c) Creative or productive thinking, (d) Leadership ability, (e) Visual and performing arts.

Since the beginning of gifted education, there have been research studies conducted to ascertain in which areas, and to what extent, gifted children are superior to other children of the same age group. The results of these investigations have contributed to the knowledge in the field of gifted education. These studies have led to further research, and impacted on the definition of giftedness. With the growing awareness that quality education is an enhancement both for the individual and for society comes the realization that there remains much to learn about the nature of giftedness (Wright, 1984).

During the researcher's review of literature it was found that the gifted and talented student is often unchallenged in today's high school program. Many teachers insist on giving the gifted student more work to complete rather than giving the student quality assignments. These quality assignments should allow the gifted students to dig deeper into the subject rather that give them more of the same material.

The approach to gifted teaching models and curriculum was once limited to acceleration, grouping, early admissions, or grade skipping. The current emphasis is on how gifted students learn best and what goes on in the classroom. More emphasis is placed upon skills, divergent thinking, and the learning environment. Educators have become increasingly aware that the key elements in planning for gifted children are: (a) a definition of giftedness that
includes a suitable procedure for identification, (b) an assessment of the
child's needs, (c) a clearly stated goal or purpose, (d) a means of achieving
the goal, (e) a plan of action that addresses teaching strategies, content and
skills, and (f) an evaluation plan (Johnson, 1987).

The gifted student is not always challenged. Even though they may have
highly developed abilities, like spatial visualization skills, they may never have
had the chance to put those abilities to work. In this study the researcher strived
to make the students reach for the outer boundaries and put their spatial
visualization skills to practice.

Spatial Abilities

Spatial Visualization -- is the ability to imagine the rotation of depicted
objects, the folding or unfolding of flat patterns, the relative changes in position
of an object in space, or the motion of machinery (Guilford & Lacey, 1947).
Spatial ability is discussed in psychometric factors and information-processing
research. Review of major psychometric studies suggests two major spatial
factors: spatial relations and spatial visualization ability. In this study, the
researcher will concentrate on spatial visualization skills.

The effective use of spatial information is one aspect of human cognition,
and is manifested in situations ranging from navigating through one's
environment to determining the trajectories of approaching objects. These skills
are also required in intellectual endeavors ranging from problem solving in
engineering and design to physics and mathematics. Some argue that the ability
to think in three dimensions is essential to be a successful engineer or scientist.
Others see the gradual implementation of computers taking over the three-dimensional work and gradually phasing out the need for human intervention. Still others see the ability to utilize three dimensions to be too difficult for many working drafters and engineers.

Research has shown that spatial skills can be taught by formal instructional processes. In high school geometry, one typically teaches two-dimensional spatial relationships, and occasionally three-dimensional material is used. Studies indicate that exposure to geometric relationships and concepts improves the spatial skills of students (Brinkmann, 1968). Other studies have shown that the teaching of spatial skills in other disciplines such as science (Cohen 1982) and mathematics (Anglin, 1982) improves the student's spatial abilities. There appears to be a strong correlation between spatial skills and success in science, mathematics, and problem solving (Fennama, 1983).

The research indicates that developing spatial skills is important to students. Improving the instructional setting used to teach these skills is, therefore, equally important. Two-dimensional representations of the world abound in books, magazines, on television and computer screens. Teaching students the spatial skills to move conceptually from the two-dimensional to the three-dimensional world is important. Of equal importance is moving from the three-dimensional world to its two-dimensional representation.

Bodner, McMillen & Greenbowe (1983) examined the relationship between students' relative ability in visual-spatial tasks, their verbal and numerical skills and to their performance in various phases of an introductory college chemistry course. The findings suggest that visualization skills play a positive role in chemistry achievement.
Spatial visualization is a critical ability that is latent in everyone. This ability is essential for individuals desiring to enter the fields of engineering and design, medicine and other occupations that require a person to visualize spatially.

Computer-Aided Design

Computer-aided design (CAD) involves using computer hardware and software to manipulate visual stimuli on the computer screen. CAD can refer to any kind of activity that uses a computer to aid in the creation, modification, presentation, and analysis of a design. Also, a CAD system is defined as a design software/hardware package that uses interactive computer graphics (Majchrzak, Chang, Barfield, Eberts & Salvendy, 1987). This manipulation was, and still is done to some degree using traditional drafting equipment. With traditional drafting it was nearly impossible for someone who was not a trained drafter or engineer to visualize how an object might look if it was modified in length or height. With the advent of CAD nearly everyone can look at a computer generated image and get a better understanding of how the image would look if it were modified in some way. CAD can help people gain a better understanding of complex shapes through the use of dynamic rotation (spinning the object about a center point), level management and attribute modification (changing the entities color or line weight, etc.).

Before the development of modern 3-D CAD programs, a physical model was difficult to make and to modify. The most effective way to convey the designer's idea was through a drawing. Since a designer was limited to working
in 2-D, engineers developed drafting rules to represent details of 3-D objects on paper by presenting three projected views. Long lead times for manual drawing preparation were an accepted fact. Inevitably there was always the potential for human error in conveying and interpreting the sketches and the final drawings (Majchrzak et al., 1987).

One of the main advantages of a CAD system is to shorten the lead time for drafting. It is much faster and easier for a draftsperson to enter, modify, and plot a drawing with CAD. However, for CAD to be most effective, it must result in improved performance, improved human interactive system design, improved organizational factors, and reduced stress.

The way the CAD operator processes information can be summarized as occurring in four steps: (a) attending to graphic stimuli and alphanumeric information which appears on the screen. (b) recognizing familiar patterns such as geometrical shapes, and acquiring and integrating new information. (c) assessing the design with respect to the needed alterations. (d) deciding on a response such to change or keep the design.

Not only has CAD cut the production time required to complete set of drawings, it also has enabled draftsmen, designers and other individuals to process visual information faster. By processing this visual information faster the individual can decide on drawing modifications without having to modify the existing paper copy each time a change is made.
Drawing Training and Spatial Visualization

In engineering and architectural education, formal drawing skills have traditionally been taught—both for visual communication and to improve spatial visualization. Also, design tasks are a more efficient and relevant way of achieving the latter goal.

Studies have demonstrated improvement in spatial ability with training. Training by routine offerings of mechanical drawing or solid geometry courses does not have the desired effect on space visualization test scores. There has been, however, no attempt to relate a specific training task to improvement in one rather than another of the sub-factors of spatial ability. Only in one study conducted in 1964 were two instructional procedures compared, in an attempt to determine which would lead to the greatest improvement in spatial ability.

Brown (1954) conducted a study with the broad hypothesis that increases in spatial ability test scores—associated with training in drawing skills are specific, and closely related to test item and training content similarity. Subjects were divided into experimental and comparison groups. The Experimental Group followed a six-week drawing course, while the comparison group completed a program of the analysis of architectural form. The two groups were compared on their posttest scores for five levels of spatial ability. The reported results did not indicate that a training exercise specifically intended to improve drawing skills was superior for improving visualization and spatial orientation over a conventional architectural design program—except in relation to material highly specific to the training situation. There has been a tendency to imply that because some spatial tests measure visualization and because visualization is a
highly desirable ability in engineers, architects and other designers, then any method of training that produces increments in scores on these spatial tests also produces improvements in powers of visualization. This is a broad inference which only holds up if visualization is all that the spatial tests in question measure.

Training and practice is crucial to developing the critical spatial visualization skills a person needs to survive in today's technological society. Training in specific spatial visualization exercises will help the students in this study to picture and comprehend complex visual stimuli found in many of today's jobs and occupations.

Purpose of the Study

The purpose of this study was to determine the effect of training in computer-aided design (CAD) on the spatial visualization abilities of selected gifted adolescents. Previous research findings (Blade & Watson, 1955; Brinkman, 1966; Carpenter, Brinkman & Lirones, 1966; Myers, 1951) have all reported significant gains in test results when training for spatial visualization ability.

Research Hypothesis

The following major research hypothesis was tested: Subjects receiving instruction in Computer-Aided Design will show improvement in spatial
visualization skills, as measured by the Revised Minnesota Paper Form Board (RMPFB) test, when compared to the subjects not receiving CAD instruction.

Significance of Study

Researchers have identified and studied spatial skills, and used this information to predict job success. Spatial skills can also be correlated with relative expertise in disciplines like mathematics and science. Spatial skills can be improved, and these abilities have been correlated with problem-solving abilities in other disciplines.

Studies have shown that lack of spatial abilities can hinder a person’s vocational pursuits and may hinder a subject’s creative potential. Thus, spatial skills are important to an individual’s success at negotiating the world at both the microspatial and macrospatial level. Because of their importance, further study of spatial skills, particularly in the areas of their acquisition and refinement in an educational setting, is of fundamental importance (Yates, 1988).

How well can one visualize solid objects from looking at flat paper plans? How well can one think in three dimensions? Spatial visualization measures the ability to "see" a finished object before it is built, just by looking at the drawings. This ability makes some kinds of mathematics (solid geometry for example) easier.

People who have limited spatial visualization ability, may view an architect’s plans for a house, or an engineer’s plans for a bridge as nothing more than several flat drawings. However, a person who does well in this area could look at those same plans and "see" the finished house, bridge, or machine. He
or she could probably "walk" around the finished structure mentally, and "see" it from various angles.

People who do well in spatial visualization will have an advantage in jobs such as drafting, architecture, mechanical engineering, die-making, and building construction. A good machinist, carpenter, dentist, or surgeon also needs this skill.

The utilization of visual imagery as an intellectual mode of thought processing has been suggested as the most viable method of mental information processing for dealing with spatially manipulated objects and events or nonverbal modes of thought (Loll, 1973). Many teachers, if not all, are unaware of how to effectively teach spatial visualization skills. The field of education abounds with information and activities relevant to the area of spatial visualization and is an appropriate area to initiate a study of this type.

Assumptions of the Study

The following methodological assumptions are implicit to this study:

a) The instrument was reliable and valid for the purpose of this study.

b) The treatment had an equal effect on all subjects.

c) The pretest accounted for the differences in the subjects that existed before the onset of the study.

d) The variability in time in which the students completed the exercises did not have an effect on the outcome of this study.
Limitation of the Study

The following limitation must be considered for all data derived from this study:

a) The length of the treatment was for two hours a day, five days per week for three weeks.

Delimitation of the Study

The following delimitation imposes constraints upon the ability to generalize from this study:

a) This study was delimited to the population of 50 males and females students participating in the 1991 Virginia Governor's School of Technology at Virginia Polytechnic Institute and State University.

Definition of Terms

The following terms were used in this study to assist the reader:

Gifted -- means children and, whenever applicable, youth who are identified at the preschool, elementary or secondary level as possessing demonstrated or potential abilities that give evidence of high performance capabilities in areas such as intellectual, creative, specific academic, or leadership ability, or in the performing or visual arts, or who by reason thereof, require services or activities not ordinarily provided by the school (PL 95-561, Section 902).
RMPFB -- is an aptitude test designed to measure mechanical aptitude and the related spatial abilities generally required in mechanical oriented vocations (The Psychological Corporation, 1970).

CAD -- Computer-aided design describes any system that uses a computer to assist in the creation or modification of a design.

Three-Dimensional -- is an image or object which has height, width, and depth.

Two-Dimensional -- is an image or object which has height and width.

Spatial Relations -- is the capacity to transform objects rapidly "in the minds eye" as is required when one "mentally rotates" an object about its center (Shepard & Cooper, 1982).

Spatial Visualization -- is the ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative changes in position of an object in space, or the motion of machinery (Guilford & Lacey, 1947).

Spatial Orientation -- is the comprehension of the arrangement elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientations in which spatial configuration may be presented, and the ability to determine spatial orientation with respect to one's body (McGee, 1979).
CHAPTER 2

Review of Related Research and Literature

Introduction

The three parts of this study are the gifted student, spatial visualization ability, and computer-aided design. Each of these parts makes up an integral and interrelated part of the study. Can computer-aided design improve spatial visualization? Specifically, can it accomplish this in gifted students, who may already have a high degree of spatial visualization ability? What is computer-aided design? How important are spatial visualization skills?

In this chapter the researcher will relate the applicable literature pertaining to these three components.

The Gifted Child

The gifted student is attracting an increasing amount of recognition as a distinct student subpopulation (Porter, 1982). A 1971 report on the gifted and talented by the U.S. Office of Education reviewed related research on the gifted and talented. It documented the special needs of this group and offered a conservative estimate that there were 1.5 to 2.5 million gifted and talented children out of a total elementary and secondary population of 51.6 million. At that time, fewer than 4 percent of those gifted were benefiting from the existent school services (Correll, 1978). In the late 1980s, the gifted estimate was placed
at 300,000 to 450,000. The population was still without appropriate educational identification and programming efforts (Davis & Rimm, 1985; Whitmore & Maker, 1985).

Students recognized as gifted display a number of traits indicative of high-potential. Wright (1984) outlines some general characteristics associated with gifted and talented students.

1. Shows superior reasoning powers and marked ability to handle ideas; can generalize readily from specific facts and can see subtle relationships; has outstanding problem-solving ability.

2. Shows persistent intellectual curiosity; asks searching questions; shows exceptional interest in the nature of man and the universe.

3. Has a wide range of interests, often of an intellectual kind; develops one or more interests to considerable depth.

4. Is markedly superior in quality and quantity of written and/or spoken vocabulary; is interested in the subtleties of words and their uses.

5. Reads avidly and absorbs books well beyond his or her years.

6. Learns quickly and easily and retains what is learned; recalls important details, concepts and principles; comprehends readily.

7. Shows insight into arithmetical problems that require careful reasoning and grasps mathematical concepts readily.

8. Shows creative ability or imaginative expression in such things as music, art, dance, drama; shows sensitivity and finesse in rhythm, movement, and bodily control.

9. Sustains concentration for lengthy periods and shows outstanding responsibility and independence in classroom work.
10. Sets realistically high standards for self; is self-critical in evaluating and correcting his or her own efforts.

11. Shows initiative and originality in intellectual work; shows flexibility in thinking and considers problems from a number of viewpoints.

12. Observes keenly and is responsive to new ideas.

13. Shows social poise and an ability to communicate with adults in a mature way.

14. Gets excitement and pleasure from intellectual challenge; shows an alert and subtle sense of humor.

Research on creative/productive individuals has shown consistently that although no single criterion can be used to measure giftedness, persons who have achieved recognition because of their unique accomplishments and creative contributions possess a relatively well-defined set of three interlocking clusters of traits. These clusters consist of general ability, creativity, and task commitment (Renzulli, Reis & Smith, 1981). It is important to point out that, according to Renzulli, Reis, and Smith, no single cluster makes giftedness - but it is the interaction of the clusters that makes one gifted.

Giftedness is a biologically rooted concept, a label for a high level of intelligence that results from the advanced and accelerated integration of functions within the brain, including physical sensing, emotions, cognition, and intuition. Such advanced and accelerated functions may be expressed through abilities such as those involved in cognition, creativity, academic aptitude, leadership, or the visual and performing arts. Therefore, with this definition of intelligence, gifted individuals are those who are performing, or who show promise of performing, at high levels of intelligence (Clark, 1983).
Giftedness has expanded in terms of skill, intellectual ability and talent. There still remains a strong emphasis on IQ tests and some new emphasis on the ability of the teacher to identify the gifted child. IQ tests are acceptable in all circles because they are well-developed in terms of measurement and tap the memory, association and reasoning abilities crucial to high performance in school-related activities. Experts in the field such as Guilford (1968) and Getzes and Jackson (1962) expressed concern about the use of IQ tests as the single measure for identification of the gifted. Gallagher (1975) points out that IQ scores actually yield two different kinds of measures, both of importance. First they give some indication of the current mental level of the child in comparison with the child's own age group; second, they make a prediction of the rate of the child's mental growth in the future. The predictive power of the IQ score for future academic attainment remains impressive and influential in educational circles (Johnsor, 1987). Thus, students identified as exceptionally gifted intellectually, traditionally are evaluated by means of IQ or achievement tests.

Gifted and talented children are those identified by professionally qualified persons who by virtue of outstanding abilities are capable of high performance. These are children and youth who require differentiated educational programs and services beyond those normally provided by the regular program in order to realize their contribution to self and society. Children capable of high performance include those with demonstrated achievement and/or potential ability in any of the following areas:

1. General intellectual ability
2. Specific academic aptitude
3. Creative or productive thinking
4. Leadership ability
5. Visual and performing arts
6. Psychomotor ability (Marland Report 1972)

General intellectual ability or talent is defined in terms of a high intelligence test score, usually two standard deviations above the mean, on individual or group measures. Parents and teachers often recognize students with general intellectual talent by their wide-ranging fund of general information and high levels of vocabulary, memory, abstract word knowledge, and abstract reasoning. Specific academic aptitude or talent is identified as outstanding performance on an achievement or aptitude test in one area such as mathematics or language arts.

Creative and productive thinking is the ability to produce new ideas by bringing together elements usually thought of as independent or dissimilar, the aptitude for developing new meanings that have social value. Characteristics of creative and productive students include openness to experience, setting personal standards for evaluation, ability to play with ideas, willingness to take risks, preference for complexity, tolerance for ambiguity, positive self-image, and the ability to become submerged in a task.

Leadership ability can be defined as the ability to direct individuals or groups to a common decision or action. Students who demonstrate giftedness in leadership ability use group skills and negotiate in difficult situations. Many teachers recognize leadership through a student's keen interest and skill in problem solving. Leadership characteristics include self-confidence, responsibility, cooperation, a tendency to dominate, and the ability to adapt readily to new situations.
Students gifted in the visual and performing arts demonstrate special talents in visual art, music, dance, drama, or other related studies. Psychomotor ability involves kinesthetic motor abilities such as practical, spatial, mechanical, and physical skills. It is seldom used as a criterion in gifted programs.

There are many proponents who feel that a statistically exceptional IQ score is in itself sufficient manifestation of giftedness (National Report on Identification, NRI, 1982). Many others, however, feel that there are restrictions associated with the reliance on a single test score as a definition of giftedness. In the National Report on Identification (1982), the authors stated that "giftedness is not a single isolated phenomenon, but a complex interpretation of many factors . . . Certainly it should not be reduced to merely a score on a test" (p.22).

Guilford (1968, p.22) wrote that high IQ scores "select in" children but also "select out" children. He further stated that IQ tests have led us into complacency as they sample little more than routine mental operations and give students little opportunity to show what they can do in creative ways. Guilford's concern about the restrictive nature of IQ tests is echoed by Getzels and Jackson (1962) who state there are three severe limitations to be kept in mind.

First, the common intelligence test does not sample the complete range of cognitive abilities. In fact, the items on the intelligence test seem to represent a rather narrow bank of intellectual tasks, relying chiefly on those tasks requiring "convergent thinking" rather than those tasks requiring "divergent thinking." Students must be able to recall and to recognize, perhaps even to solve, but need not be able to invent or create.
Second, Getzels and Jackson state it is commonly observed that many children who are very high in intelligence as measured by IQ, are not concomitantly high in such other intellectual functions as creativity and many children who are not concomitantly high in intelligence as measured by IQ, are high in creativity.

Third, the IQ metric has been particularly immune to advancement in our thinking and behavior. The conceptual base of the intelligence test is often measured by its correlation with an old intelligence test. That is, "the new test must measure the same mental processes as the old test" (p.3).

There is a more fundamental problem with the reliance on IQ scores to define exceptional intellectual ability. There are those who believe that the culturally different, disadvantaged, underachieving, and handicapped students are screened out by this process (Hillard, 1983; Richert, 1983). Studies of the Stanford-Binet show that the test is weighted heavily with verbal reasoning ability (Davis & Lesser, 1959; French, 1951). In practice, children who are selected for admission to an intellectually gifted program are outstanding in regard to verbal reasoning ability.

Smith (1965) in a research project for the U.S. Office of Education investigated relationships of IQ, achievement, sex and race to socioeconomic position and found that upper socioeconomic status children are more efficient when a verbal product is expected. Lower socioeconomic status white children are most effective when the product is nonverbal. Consultants convened for a conference on identification procedures in May, 1981, stated that intelligence tests represent an indication of ability to do academic work. They also stated that the tests tend to be weighted toward verbal competence and as a result,
cultural and language backgrounds could negatively affect IQ scores (Wright, 1984).

Hallahan and Kauffman (1982) report that when IQ is used as the sole or primary criterion for giftedness, it has been found that more gifted children will come from homes of higher socio-economic status, have fewer siblings, and have better educated parents. Although giftedness occurs in all socioeconomic strata, it is clear that gifted children are not distributed equally across all social classes at least when IQ is the primary means of identification (p. 380).

Harrington (1982) wrote that approximately 95% of all children presently identified as gifted can be subsumed under the category of "intellectually gifted" or "children with specific academic abilities." In part, this may be due to the efficiency of the definition. That is, children may be identified via this method due to the relative accuracy of the instruments commonly used - the Stanford-Binet and the WISC-R. As Hallahan and Kauffman (1982) relate, the individually administered intelligence tests remain the most reliable, definable single means of identifying the gifted. IQ, too, seems to be a reliable indication of rate of academic learning as found in the Talent Search conducted through John Hopkins University.

The Scientific and Mathematically Precocious Youth (SMPY) program allows students to proceed as fast as they wish. The rate of learning is highly accelerated and students demonstrated continued high levels of academic achievement (George, 1979). The rate of learning finding is collaborated by Petzold (1959) who compared children of average musical ability with sixth grade musically gifted children. Petzold found that the gifted students learn the tasks at a superior rate. Osen (1973) conducted a study to determine if there
was a direct relationship between IQ and reading achievement and found that reading achievement increased in direct relationship to IQ.

Yet another definition of giftedness is put forth by Robert Sternberg (1984) suggests that giftedness is a kind of mental self-management. The mental management of one's life in a constructive, purposeful way has three basic elements: adapting to environments, selecting new environments, and shaping environments. According to Sternberg, the key psychological basis of intellectual giftedness resides in insight skills that include three main processes: 1) separating relevant from irrelevant information, 2) combining isolated pieces of information into a unified whole, and 3) relating newly acquired information to information acquired in the past.

Sternberg emphasized problem-solving abilities and viewed the gifted student as one who processes information rapidly and uses insight abilities. Howarc Gardner (1983) also suggested a concept of multiple intelligences, stating that there are several ways of viewing the world: linguistic, logical/mathematical, spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal intelligence. Joseph Renzulli (1960) stated that gifted behavior reflects an interaction among three basic clusters of human traits: above-average general and/or specific abilities, high levels of task commitment (motivation), and high levels of creativity. According to Renzulli, gifted and talented children are those who possess or are capable of developing this composite of traits and applying them to any potentially valuable area of human performance. Growing Up Gifted listed characteristics under five major headings: cognitive (thinking), affective (feeling), physical, intuitive, and societal (Clark, 1983).
With the new research in brain/mind function, a different definition for
giftedness becomes possible. Intelligence can no longer be confined to
cognitive function, but clearly must include all of the functions of the brain and
their efficient and integrated use.

**Gifted Learning Styles**

The improvement of learning and the educative process has been and still
is the focus of various theories, strategies, and research studies. Learning style
theories and approaches are among attempts for improvement that were
examined in the early 1980's (Allioti, 1981; Cafferty, 1980; Dunn & Price, 1980;
learning styles refers to the modes and/or environment(s) in which individuals
learn most effectively and efficiently.

Lewin's (1935) formula derived for behavior, \( B = f(P,E) \), states that
behavior is a function of the person and the environment. Hunt's (1971)
translation of this formula into educational terms is that the accomplishment of
the educational objective depends upon the effect of the educational approach
on the individual learner. The focus of the "educational approach" is viewed
differently in various theories. Kolb (1976) and Allioti (1981), Olson (1978),
Torrance and Mourard (1979) among others consider learning styles as a
cognitive function. Renzulli and Smith (1978) and others consider learning styles
as an instructional strategy function.

The instructional strategy approach has appeal for teachers because of its
possible application in the classroom. Several research studies related to the
teaching strategy approach (Domino, 1971; Dowaliby & Schumer, 1973; Smith, 1976; Yando & Kagan, 1968) indicate that students do achieve significantly better when taught in a manner consistent with their preferred learning styles. Even though the learning style strategies used in these research studies were varied and selective, the results are significant and show the need to select the most effective strategies as the basis for learning style identification.

Stewart (1981) discovered that learning style preferences were influenced by certain other factors - grade level, gender, favorite subject, IQ, and strongest achievement area and that there was some preference among gifted children for instructional methods which emphasized independence (independent study, discussion).

With an increased national interest in education of the gifted (Passow, 1981) have brought changes not only in the definition and methods of identification of the gifted but also in the planning of curriculum and instruction (Treffinger, 1982). Since the current educational and social view tends to emphasize the multifaceted dimensions of giftedness in interaction with the environment and the learning process, the gifted are no longer viewed as a single homogenous group. Thus, it has become necessary to view their needs differently and relate indicators of behavior to educational planning (Feldhusen, 1982, Treffinger, 1982).

A study by Ricca (1984) investigated unique patterns in learning style preferences among gifted students. The results of this study yielded significant differences between gifted and general population students pertaining to preferences for learning styles utilizing The Learning Style Inventory of Dunn, Dunn, and Price (1981). The gifted students, more than the general population,
were found to be more highly motivated, persistent, responsible, adult and teacher motivated, preferred learning alone and tactile learning. The general population, as compared to the gifted students, demonstrated a greater preference for structure, peer oriented learning, learning in several ways, auditory learning, visual learning, mobility, and learning with authority figures present. The general population also demonstrated a greater tolerance for late morning learning and more neutrality to time needs than did gifted subjects.

Learning Style and Classroom Implications

Those who favor a learning style approach have found many specific classroom applications for their work. One of the most noteworthy is Bernice McCarthy (1980), who developed the 4Mat system of teaching based on the work of David Kolb (1976). McCarthy recognized classroom reality by acknowledging that no one teacher can accommodate the styles of all students simultaneously. Instead, she developed an eight-step teaching sequence that addressed Kolb’s (1976) four quadrants and, additionally, right and left hemispheric functioning. In 4Mat, the lesson is, like treatment, introduced through an experiential activity that is designed to integrate the new material with previous experience (the affective, personal application needs of Kolb’s diverger type are best served by this phase). Facts and concepts are then presented (the lecture phase) to expand on the introduction and address the assimilator’s “watching” needs. The third phase consists of hands-on practice and application, which best suit the converger. Finally, analyzing the concept and applying it in new, more complex situations matches the strength of the
accommodator group. While persons in each style group are most comfortable and like best those activities aimed at their group, they are able to function quite well with the two adjacent styles. It is only when the activities of the opposite styles (i.e., diverger-converger and assimilator-accommodator) are in progress, that lack of interest or difficulty may arise. It is McCarthy's contention that accommodating all of the people three-quarters of the time is preferable to teaching primarily in and two one's own style and neglecting the needs of the other three quadrant types.

Myers and McCaulley (1985) reporting on The Myers-Briggs Type Indicator (MBTI) (Briggs & Myers, 1977) suggested that optimum classroom learning can take place when teachers and students are aware of their own types and when classroom options are developed for each. This was also supported by Silver and Hanson (1980) in interpreting their own instrument, the Learning Preference Inventory (LPI) (Silver & Hanson, 1978). Teachers can accommodate type variations in the classroom by providing opportunities for different working conditions and a variety of assignments or reporting methods. Comparing introverts and extroverts, the former would tend to choose individual projects and working alone, while the latter would prefer group-oriented tasks and discussions. Sensors prefer practical, hands-on activities, while intuiters want imaginative, open-ended, more complex challenges. Thinkers are attracted by routine, logic, theories, and structure, while feelers need people-oriented, interactive projects. Finally, judgers need structure, routine, and self-control, while perceivers prefer spontaneity and many activities progressing at once.
Functioning With and Against Type

In addition to providing varying classroom opportunities, two other questions arise when dealing with the gifted. First, to what extent should children be required to function against type? Second, if teachers and students are very different in style, is it possible that children are labeled as uncooperative and unrealistic if they rebel when consistently confronted with "against type" activities and assignments?

The former question was a concern after research revealed that the predominant type for gifted children is NF (intuitive, feeling) (Hoehn & Bireley, 1988). Given the ST practical, precise nature of the basic skills curriculum and the percentage of teachers who are sensors (nearly half of elementary and about 42% of high school instructors, according to Myers & McCaulley, 1985), it is little wonder that a frequent complaint about gifted students is that they resist completing basic skill assignments. Indeed, releasing some students from regular classes for attendance in gifted pullout programs causes dissension because regular class teachers perceive these children as "lazy," resistive non-workers, who could not possibly be "gifted." In the gifted classroom, these same children often become highly creative dynamos. From a learning style framework, the better match of the typical gifted child's style preferences and the more open-ended, individualized curriculum of the pullout program are understandable explanations for difference. Nevertheless, around 80% of the typical gifted child's school time and much of adult life consists of against type (that is, routine) action. Gifted children need to be counseled about this phenomenon and the necessity for all of us to learn tolerance for "boring"
activities. On the other hand, denying such a child access to the gifted program on the basis of non-productivity in the regular class should be considered carefully and applied in only the most extreme cases.

Secondary students appear to be less at risk for the scenario described above. Through a wider selection of courses and extracurricular activities, most style differences can be accommodated, given reasonably good teaching. However, if experiences in elementary school have been negative, attitudes toward education and learning may continue to have implications during the high school years. Turned-off underachievers may not develop the academic record and knowledge base needed to pursue later career choices without remediation. Others may continue to struggle against the system and go unrecognized as gifted throughout their secondary school years.

While the general population is about 75% extraverted, the reverse is true of gifted persons (Myers & McCaulley, 1985). Introverted gifted persons can, predictably, become their own worst enemies. Similarly, the sensing predominance of the general population (75%) contrasts with a similarly high percentage of gifted intuitors. This practical, "now" orientation of the sensers versus the possibility, future orientation of the intuiters can provide the basis for a productive team effort or can be a significantly diverse force. The gifted student who feels different or who can find few people who "understand what I'm talking about" may be reflecting frustration associated with the rarity of intuitive peers.
Fight and Left Brain Dominance

Research on the right and left brain function began on animals with Dr. Roger Sperry during the 1950s. Human brain operations were conducted in the 1960s by neurosurgeons Vogel and Bogen in cooperation with Sperry. A series of subtle and ingenious tests were devised to attempt to find out what was going on in the separate hemispheres. The results showed that the two hemispheres process information differently. It has long been known that the functions of the two hemispheres were different. Speech resides in the left brain and spatial ability in the right (McCarthy, 1980). But what was not known was that in processing information and stimuli, the left brain does a lineal type of processing, a sequential type, while the right brain uses global process in which data is perceived, absorbed, and processed even while it is in the process of changing. As Bogen (1975) stated, these differences in how the two brains process information are the most significant differences between the right and left hemispheres. Another equally important finding was that in the split-brained patient, there seems to be two different people up there, each with his or her favorite ways of processing information, each with a different way of thinking. That means that rather than being a half-brained species, we are two-brained species, each having its special mind (Levy, 1980).

What we as educators need to do is develop teaching methodologies which effectively teach to both modes (McCarthy, 1980). The brain dominance researchers have pointed the way. Sperry (1973) stated that there appear to be two modes of thinking, verbal and non-verbal, represented rather separately in the left and right hemisphere. Our educational system, as well as science in
general, tends to neglect the nonverbal form of intellect. What it comes down to is that modern society discriminates against right hemispheres (Sperry, 1973). According to McCarthy (1980) school is for the left brain, schools do not teach to the right brain.

Spatial Visualization

Spatial visualization is the ability to deal with complex visual problems that require imagining the relative movements of internal parts of an image (Pellegrino, Hunt, Abate, & Farr, 1987). What people "see" when they look at an external object is dependent upon who they are and what they are interested in at the moment. A layman "sees" a metal cube as a solid. This is one level of reality, a reality based on sensory model. Experience in relating what an individual "sees" to what he feels with this sense muscles, as well as training, and practice can all improve visualization.

Visualization. We often hear this word in the descriptive geometry classroom as well as in engineering work. What does it mean? We cannot ask this question without also thinking of several others. Is the ability to visualize subject to training or is it something unchangeable, like the length of your arm? What relation exists between this ability and a course in descriptive geometry or other engineering subjects? Finally, how is visualization ability measured? The answers to these questions are necessary if our students are to get the greatest possible benefit from their study of descriptive geometry, engineering drawing, and computer-aided design (Blade, 1949).
Webster says that to visualize is to form a mental image of something not before the eye; to picture mentally. To engineers the word means not only to form a mental picture but also to manipulate these pictures mentally. Therefore, visualization means a dynamic as well as a static mental picture.

The ability to rotate objects mentally and change their dimension and scale requires a person to have developed some type of spatial schema. This schema or framework, as described by Minsky (1975), would carry a data structure based on a stereotyped situation including default assignments. Adjustments, according to Piaget & Inhelder (1971), are either in the form of accommodations (transformations induced in the subject's existing framework) or assimilation (transformation of the object to correspond with the existing framework).

Ekstrom, French and Harman (1979) defines spatial visualization as the ability to manipulate or transform the image of spatial patterns into other arrangements. It requires either the mental restructuring of a figure into components for manipulation or the mental rotation of a spatial configuration in short term memory. It also requires performance of serial operations, perhaps involving an analytic strategy.

To prove this, a person is shown a two-dimensional representation of a box, and each trace of the box has a figure on it. The subject is then asked to fold mentally and rotate the box. This skill requires visualization abilities. Tests used to evaluate this skill often require a person to mentally fold a two-dimensional representation of a box and compare it to several other boxes that are shown as three-dimensional representations.
French (1965) defines spatial orientation as an ability to perceive spatial patterns accurately, to compare them with each other, and to remain unconfused by the varying orientations in which a pattern may be presented. For example, a person may be asked to compare the spatial orientation of a table in one picture to that of the same table in another picture where the table is in a different position. The person is asked to indicate the difference between the two pictures. This requires the ability to see a change in the relative pattern or orientation of objects in the two pictures.

Persons differ in their skill to manage spatial information. The level of sophistication of a person's spatial skills, according to Piaget and Inhelder (1971), depends on a person's ability to (a) think abstractly, (b) operate within a coordinate (XYZ) system of reference, and (c) use Euclidean measurements. Bruner, Oliver and Greenfield (1966) say it also requires an iconic mode of mental representation.

The studies done by Piaget, involving his own children, indicate three spatial stages during the development period: practical, subjective, and objective (Piaget, 1971). Piaget believed that the child progressed from a categorical to a relativistic concept of objects in space. In the Piagetian view, a child at one stage recognizes "larger" and "smaller" as mutually exclusive attributes. Therefore, the child cannot solve inference problems based upon the constructs of larger and smaller. Only after children have entered a relativistic stage can they solve such problems. However, Bryant and Trabasso (1971) have shown that children at the categorical stage can solve problems thought only to be solvable by children at the relativistic stage. Paris and Mahoney (1977) have demonstrated that children derive inferred spatial relationships
among linguistically and pictorially presented objects and then integrate these relationships into memory. At what age, however, they acquire such abilities is not clear and the conflicting views expressed by Piaget (1971), Bryant and Trabasso (1971), Paris and Mahoney (1977) and others have not been resolved (Cohen, 1985).

Currently there are three general theories as to how the brain sees mental representations of spatial relations (McNamara, 1986). The first general theory is a "nonhierarchical theory." It proposes that networks or image-like formats portray spatial representations. The essence of this view is that there is no hierarchical structure to mental representations but that each image, however it is stored, has the same representational value. This means that the representational structure of mental images has the same priority in the visual network.

The second general theory is the "strongly hierarchical theory." It suggests that different representational levels exist in the propositional network such that a lower level represents a finer grained representation than a higher level. In this type of propositional network the spatial relations between images stored in mental networks must be inferred from higher order spatial knowledge. For example, the representation of spatial relations between two rooms in a house is a subset of an image of the entire house. Stored are only the spatial relations needed to represent the layout of the house. The specific details of the locations of each room relative to other rooms are inferred and then reconstructed.

The final spatial theory is a "partially hierarchical theory." It suggests a redundancy in the representation such that many relationships analyzed or
inferred are also represented explicitly in the brain. According to this theory, the rooms of the house may be inferred as in the strongly hierarchical theory or may be stored as images and retrieved directly, without first needing to infer the relative positions of the rooms (Yates, 1988).

Although a clear resolution concerning these three different views is not yet forthcoming, the bulk of current research leans toward the partially hierarchical theory (McNamara, 1986). This means that information is encoded at nodes of a decision tree in explicit formats that are similar to external spatial states. Information is also retrieved through inference. For example, imagine taking a two-dimensional representation of a three-dimensional object and in the mind's eye rotating it to a new spatial configuration. McNamara, however, cautions that while the theoretical problems are important, much more work needs to be done to determine the organization of general problem knowledge in many different domains, and how it is integrated in our cognitive network. Additional research will help clarify the complex interconnections associated with spatial abilities and other representational schemas.

Engineers especially need to visualize because they must solve problems about objects which they do not have actually before them or in their hands. To solve their problems, engineers must produce and interpret abstract symbols. It is not enough, however, for engineers simply to visualize their problems. They also have to communicate their solutions and to understand the solutions of others. The means of communication is the language of graphic symbols that is, drawing. Thus, engineers must visualize (form mental pictures), draw pictures of objects in space according to a conventional system they learn, and understand the pictures of other engineers in this conventional language.
Can a student learn to visualize? In engineering and architectural education formal drawing skills have traditionally been taught, both as a measure of visual communication and in order to improve spatial visualization (Blade, 1949). It is also claimed that design tasks are a more efficient and relevant way of achieving the latter goal (Stringer, 1975).

In four previous studies which demonstrate improvement of spatial ability with training (Blade & Watson, 1955; Brinkmann, 1966; Churchill, Combs & Harrell, 1942; Van Voorhis, 1941) specificity in training, in relation to the criterion task, appears to be crucial. Training by routing offerings of mechanical drawing (Faubion, Cleveland & Harrell, 1942; Mendicino, 1956; Myers, 1958) or solid geometry (Ranucci, 1952; Brown, 1954) does not have the desired effect on space visualization test scores.

Other research has shown that students can learn spatial skills by formal instructional processes. Studies show that exposure to geometric relationships and concepts improves the spatial skills of students (Brinkmann, 1966). Other studies have shown that the teaching of spatial skills in other disciplines such as science (Cohen, 1982) and mathematics (Anglin, 1982) improves the students spatial abilities. Fennema (1983) and others have shown a strong correlation between spatial skills and success in science, mathematics, and problem solving.

Piaget and Inhelder (1971) suggested that daily experiences cause accommodations in visualization ability to occur. Theoretically, therefore, planned spatial experiences could induce changes in a person's spatial ability. Specifically, research in both environmental and cognitive psychology has reported improvements in spatial skills after training. Brinkmann (1966)
maintained that while genetics may influence some aspects of perceptual organization, other factors, such as discrimination and judgment, are influenced by learning. He found that college students who had participated in a three-week programmed instruction course on spatial skills scored significantly higher on a test of spatial relations than a Control Group. Others (Evans, Marrero, & Butler, 1981; Evans & Pezdek, 1980; Gibson, 1953; Lord, 1985; Siegel & Schadler, 1977) have found similar results. There is some indication that persons at the formal operational level may benefit more from training than those at a concrete level (Battista, Talsm & Wheatley, 1973; Hill & Ovenauf, 1979).

In using spatial skills in large-scale environments, Evans and Pezdek (1980) found that multiple experiences in an environment led to more flexible use of spatial relations and more accurate placement of objects within an environment. The mobile experience as explained by Spencer and Darvizeh (1981) could be by (a) active movement in the environment, (b) object manipulation, or (c) film.

Earlier studies reported that active movement was the most effective means of gaining spatial information. Mandler (1962) reported that actions and movements repeated endlessly become transformed into spatial images. However, Salomon (1979) more recently found that film could simulate the multiview experience, and therefore is a good instructional medium for spatial cognition.

Olson and Bialystok (1983), using objects similar to those in a mental rotation test developed by Vandenberg and Kuse (1978), found that partial rotations were nearly as effective in teaching mental rotations as experiences. In
their study, subjects viewed film of objects rotating. The researchers then asked
the subjects to identify views of those same objects on paper.

Recent concerns in the areas of brain hemisphere specialization, male
and female differences in math-related fields of study, and various aspects of
computer programming have brought the study of spatial cognition to the
forefront. However, as pointed out by Arnheim (1974), public educators have
overlooked spatial skills for a long time. Although standardized tests often
contain a spatial skills section, there is little formal training in this area. Zavotka
(1987) noted a lack of spatial training while teaching interior design to college
students. Many of the students lacked the spatial skills necessary to design and
analyze simple orthographic drawings.

Wood and Beck (1976) demonstrated that these skills are susceptible to
instruction and change developmentally. The study also showed a correlation
between mapping ability and spatial ability. Lord (1985) also undertook a study
to see if spatial skills could be taught. The results suggest that the intervention
has a positive effect on spatial awareness. The ability to teach spatial skills is
also demonstrated in geometry (Brinkmann, 1966), and science (Cohen, 1983)

In the Cohen (1983) study, fifth grade science students were randomly
assigned to two groups. Each group was given activities from Science
Curriculum Improvement Study and received the same content instruction. The
Experimental Group was encouraged to move around and manipulate the
apparatus and materials provided in the different lessons. The Control Group
was not given similar encouragement. Instead they were directed not to move
around or manipulate the apparatus. The results show that the Experimental
Group did statistically better on a test of spatial skills. This research, coupled
with the research described above, adds strong support to the claim that spatial skills can be taught and can improve problem-solving skills.

According to Stea and Blaunt (1973), to draw or fully interpret orthographic views, the student must perform three tasks mentally: (a) rotate the object to another plane, (b) change the object from two to three dimensions, and (c) change the object's size. An interest in three-dimensional computer-animated graphics leads us to question if they can improve one's ability to perform these tasks and, if so, which visual stimuli would be more effective.

There is also a significant difference in spatial abilities between the sexes. When the results of spatial tests are taken together, a difference appears between the scores for boys and girls. The higher scores attained by the boys' group may be due to the radical difference between the games, hobbies, outlook and training of the boys, as distinguished from the girls. The difference is significant because it may indicate that spatial ability can be organized and developed through training. Linn (1985) in her meta-analysis concluded that the sex differences in spatial ability for mental rotation are large (one-quarter to one standard deviation). However, less of a sex difference exists for spatial perception and spatial visualization. Why such a wide variation in ability exists is unclear but the gender gap appears to widen during puberty (Best & Rabinowitz, 1982). There are, however, a few studies indicating a possibility of narrowing the differences in spatial abilities between the sexes (Brinkmann, 1966).

Using computers to teach spatial skills is another way to improve instruction. A study done by McClurg and Chaille (1987) indicates that the computer can be used to improve spatial skills. This study, conducted over an eight week period, involved computer games. It showed that students made
significant improvement in their spatial abilities. This study used a Control Group that was given no direct instruction in spatial skill development. By contrast, a study done by Yates (1988) examined an alternative method of teaching spatial skills. The study investigated the use of paper and pencil and commercially available materials, with a computer program called Super Factory. Super Factory uses a strong problem-solving format to teach two and three-dimensional spatial problem-solving skills. In this study, the use of the computer in an instruction setting contrasted directly with an alternative method of instruction to determine which method led to the greatest improvement in the student's spatial abilities.

The playing of video games is also associated with improvement of spatial skills. McClurg and Chaille (1987) found that tracking objects, along with skill in compensating for the movement of the object in space, improves when using Atari's Air Combat video game. Scores on video games correlated with scores on spatial visualization tests and visual pursuit tests. That same study also showed that using computer games could improve the spatial ability of fifth, seventh, and ninth grade students.

Spatial skills have been identified, studied, used to predict success on jobs, and correlated with relative expertise in disciplines like mathematics and science. Spatial skills can be improved, and these abilities have been correlated with problem-solving abilities in other disciplines. Lack of spatial abilities can hinder a person's vocational pursuits and may even hinder a subject's creative potential (Paivio, 1970). Thus spatial skills are important to an individual's success at negotiating the world. Because of their importance, further study of
spatial skills, particularly in the areas of their acquisition and refinement in an educational setting, is of fundamental importance.

There are several different theories on how spatial visualization skills are best learned. Some think training and practice will improve the ability (Blade, 1949). Others believe that repeated visual stimuli will accomplish it (Stea & Blaunt, 1973). Finally, still others believe a computer can be used to teach spatial skills (McClurg & Chaille, 1987).

Computer-Aided Design

Computer-Aided Design (CAD) systems allow the user or designer (the terms will be used interchangeably) to use the capabilities of the computer to aid in the process of design. CAD, together with computer-aided manufacturing (CAM) commonly called CAD-CAM is revolutionizing the way we design and manufacture products. More and more CAD systems are implemented as industry makes a concerted effort to raise the quality of products and the cost effectiveness of the manufacturing process.

The CAD system consists of a user and a CAD workstation which typically includes a color graphics display terminal, a digitizing tablet, an input device, a printer/plotter, and a local graphics processor. The CAD workstation provides the user with the option to perform several transformations on the figure displayed on the CAD graphics screen (Majchrzak et al., 1987).

A frequently-used CAD option is the rotation transformation. The CAD designer uses rotation transformation primarily to assist in visualizing the figure being designed. Typically, a designer will rotate a figure to perform a visual
interference check or to evaluate the overall aesthetic qualities of the design. The task of rotating a figure and making inferences based on that rotation requires the processing of visual information and decisions based on how the processed information is represented (Majchrzak et al., 1987). Spatial reasoning, the ability to make inferences based on the information contained within a spatial representation (Perricone, 1983), is an important aspect of the visual information processing task for CAD.

Many everyday problem-solving tasks depend on knowledge of spatial structures and relationships, either explicitly or implicitly. Perceptual and cognitive processing skills are especially important for CAD tasks. This is because the interaction between the designer and CAD system is primarily visual and cognitive. That is, the designer must look at a figure appearing on the CAD screen, process the information within the figure and make design decisions based on how the figure is represented. The importance of spatial reasoning abilities for CAD, and manufacturing in general, are noted by several researchers (Nau, 1983; Reggia, 1983). One characteristic of good designers is that they can think in three-dimensions and manipulate objects in their mind.

The term "computer-aided design" describes any system that uses a computer to aid in the creation or modification of a design. In general, a CAD workstation consists of a color graphics display terminal, a digitizing tablet, a keyboard, a printer/ploter, and a local graphics processor. A user can design a part, build an assembly, and conduct an engineering analysis directly and interactively on the CAD system (Majchrzak et al., 1987).

Although the use of CAD systems can save up to about 70 percent of the total manual design time the real benefits of using CAD is a reduction in product
lead time, better product quality and design documentation, and reported increases in the creativity and productivity of the designer.

A CAD system integrates the functions of drafting and analysis by storing a design in the computer electronically. The results of the engineering analysis can be shown graphically by displaying the design on the CAD terminal, thus, providing immediate visual feedback to the designer. Also, the use of CAD allows the designer to go through many design iterations in a reasonably short time. The quality of the final product is usually much higher and the lead time much shorter when using CAD.

Another advantage of using CAD systems is the ability to interface CAD with computer aided manufacturing (CAM). When CAD is interfaced with CAM, the total design-production cycle is shortened. CAD becomes not only a tool to save costs, but more importantly, a means to survive in the high competition marketplace of manufacturing. Today there are more than ten thousand CAD workstations delivered for use each year. With the price of these systems decreasing and the performance improving, we will see increasing numbers of CAD workstations being used by industry (Barfield, Chang, Majchrzak, Ebert & Salvendy, 1987).

For CAD to be effectively used it must result in improved performance (Salvendy, 1982), improved human interactive system design (Salvendy, 1984, 1987), improved organizational factors (Dunnette, 1976) and reduced stress (Salvendy, 1982). Although the use of CAD systems can save up to about 70 percent of the total manual design time, the real benefit of using CAD is a reduction in product lead time, better product quality and design documentation, and reported increases in the creativity and productivity of the designer. It is
much faster and easier for a draftsperson to enter, modify, and plot a drawing with CAD (Majchrzak et al., 1987).

The way the CAD operator processes information is summarized as occurring in four steps. First, attending to graphic stimuli and alphanumeric information which appears on the screen. Second, recognizing familiar patterns such as geometrical shapes, and acquiring and integrating new information. Third, assessing the design with respect to the needed alternations. Fourth, deciding on a response such to change or keep the design.

There are many human factors issues involved in the design and use of CAD systems. The primary goal of designing the human-CAD interface is to create a system which increases the designer's creativity and decision-making abilities, both cognitive and visual. To accomplish this objective, the hardware and software components of the CAD system should be compatible with the designer's cognitive and perceptual processes and physical requirements for interacting with the system. Such a system should result in an increase in design creativity and productivity, an increase in the quality of design decision making and greater job satisfaction (Barfield & Salvendy, 1985).

The human-CAD system is called a hybrid intelligent system because the creative and decision-making abilities of the human are coupled with the information processing capabilities of the computer. The resulting system exceeds the capabilities of either system component when the interaction between the two is synergistic (Majchrzak et al., 1987).

Groover and Zimmers (1984) and Pao (1984) have discussed several reasons for implementing CAD. These include the following:
1. CAD may result in significant productivity increases. The graphic features of a CAD system offer the designer the capabilities to visualize the product and to synthesize, analyze, and document the design interactively. Productivity improvements for CAD, in comparison to manual design, are reported to range from 3:1 (Gold, 1983), and 4:1 (Krouse, 1982; Sheldon, 1983) to 10:1 (Rosenbaum, 1983). Productivity improvements largely depend on the complexity of the drawing, level of design detail required, and repetitiveness of the designed parts (Groover & Zimmers, 1984; Krouse, 1981). In a survey of 33 current CAD users by Datapro (1984) the following results were noted. Seventy-eight percent of the respondents reported increased productivity, and 76 percent reported shortened cycle time. Seventy percent of the respondents said that the CAD system did what they expected it to do. Finally, 75 percent stated that they would recommend the particular system they were using to a colleague.

2. The use of CAD may lead to an improvement in design quality and accuracy. The survey by Datapro indicated that 85 percent of the designers reported an improvement in the accuracy of their drawings.

3. CAD may improve the communication among designers due to use of a common database, standardization, usage of common graphic symbols, and greater legibility of drawings (Groover & Zimmers, 1984).

4. CAD may aid the manufacturing process. For example, a CAD user can define a part shape, analyze stresses and deflections for the part, and check its mechanical action. Furthermore, the geometric description of the part provided by the CAD user can generate CNC tapes, instruct robots, and manage plant operations (Krouse, 1980).
As improvements continue in the areas of software, hardware, and the human-CAD interface, further benefits can be expected to occur from the use of CAD. The use of a CAD system has changed the range of skills required to perform design. The most obvious change is they require a certain amount of knowledge about computers and how to interact with them. A human-factored system, however, should minimize the need for computer knowledge. The introduction of CAD into the workplace may also affect the skill requirements for performing design. Computer-based systems are well suited for performing analytical work, especially when algorithmic solutions are necessary. They are, at present, ill-suited for creative decision making, though. For example, CAD may aid designers whose work requires geometric modeling and an engineering analysis. However, these designers may experience more stress as a result of increased levels of computer-paced decision making (Cooley, 1981). On the other hand, there may be a reduced need for designers performing tasks which require routine drawing skills, rather than engineering skills, as CAD systems proliferate into the design workplace (Arnold & Senker, 1982).

Summary

As this research was undertaken, the three aspects of the study merged together. Spatial visualization skills, the gifted student, and computer-aided design are each equally important. Spatial visualization skills are important to everyone as we wind our way through life. Without spatial visualization skills, how would we hit a softball or make a left-hand turn in traffic? As our country moves more and more away from an industrialized economy and more and more
towards an information-based economy, we will need our best and brightest to keep us at the forefront of technology and the world. It's possible that our best and brightest of today will have to work to regain that status, already lost to Japan. Computer-aided design is just one key to our future success.
CHAPTER 3

Methodology

This chapter describes the research design, subject selection, treatment, instrument administration and analysis of data.

Research Design

The primary purpose of this study was to determine if CAD training can increase student’s spatial visualization skills as measured by the Revised Minnesota Paper Form Board (RMPFB) test. The study used a pretest-posttest nonequivalent Control Group design model as depicted below from Campbell and Stanley (1963, p. 47).

\[ \begin{array}{ccc}
\cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot \\
\end{array} \]

This design was selected because the Experimental Group was self-selected and not randomly assigned. The Control Group, however, was randomly assigned from the balance of the available population.

The pretest using the RMPFB (Form AA) was given to both groups to measure their entry level in spatial visualization abilities. A posttest using (Form BB) of the RMPFB was given to both groups after the treatment to measure their
level of spatial abilities after the treatment. The alpha was set at the .05 level of significance for the study.

**Selection of Subjects**

The Experimental and Control groups were comprised of participants in the 1991 Governor's School of Technology program at Virginia Polytechnic Institute and State University. The Governor's School was an intense three week summer program for students currently in the 10th or 11th grades. The students had the opportunity for acceleration in pace and level of curriculum, exploration of a theme in depth and breadth, enrichment in learning and career direction and enlightenment. These opportunities were completed in three phases. Phase 1, the residential program, is where the students were involved in the development of process skills through problem solving activities in informational technology, biotechnology, physical technology, and the future impact of technology. During Phase 2, at their home schools, the students had the opportunity for completion of self-initiated problem solving activities, interdisciplinary involvement, support and participation of business and industry, regional presentation and discussion of student work and finally evaluation of student work. During Phase 3 a small group from the original students had the chance to pursue further experiences which included rational and international activities.

A selection committee selected students to participate in the program based on a composite score system. The composite scores (maximum total of 1000 points) were derived from the following categories: Extra curricular and
personal activities (360), Student interest essay (200), Teacher ratings (200), GPA (60), PSAT/SAT and DAT test scores (180). A Likert scale was used in each category to determine each nominee's score. The scores were compiled and the nominees were ranked in order of their scores. Fifty students were selected to participate in the 1991 Virginia Governor's School of Technology program.

The Experimental Group consisted of twenty students enrolled in the CAD class. These students elected to be in this class, and therefore were not randomly assigned to the Experimental Group. A Control Group was comprised of twenty students randomly selected from the remaining thirty students of the Governor's School population. In order to achieve statistical equality the Control group was designed to have the same ratio of males and females.

The average student participating in the 1991 Virginia Governor's School of Technology program was one who had completed the 11th grade with a GPA of approximately 3.5. The average student had taken both Algebra I and II along with a mixture of technology courses such as drafting and computer application or programming courses.

Instrument

Based upon careful review of instruments designed to measure spatial ability, the researcher chose the RMPFB because it is normed for the high school student and for working adults. The test has a higher level of difficulty and the researcher expects the subjects in this study to receive a more accurate and sensitive score in relation to their ability thus giving the study a lower starting
benchmark and a larger area of measure in which to show improvement in scores. Previous research into how gifted students score on the DAT showed that the students were scoring at the extreme high end of the scale. This indicated that the DAT was not an appropriate test to measure the change in the subject's spatial visualization abilities.

The DAT measures for spatial relations ability whereas the RMPFB measures for spatial visualization ability. According to Pellegrino, Alderton, and Shute (1984) spatial relations problems, although varying among themselves in complexity, involve less complex stimuli than spatial visualization problems. In terms of cognitive processing complexity or effort, an intuitive analysis suggests that more mental operations and coordination are required to solve spatial visualization problems. The spatial visualization ability is measured by tests that are relatively speeded and complex. Such tasks frequently require a manipulation in which there is movement among the internal parts of a complex configuration and/or the folding and unfolding of flat patterns.

The differences between spatial relations and visualization tasks seem to represent two correlated dimensions of performance. One of these is a speed-power dimension. Individual spatial relation problems are solved more rapidly than spatial visualization problems, and the tests themselves are administered in a format that emphasizes speed in the former case and both speed and accuracy in the latter case.

The original Minnesota Paper Form Board Test (MPFB) was developed in the late 1920's by Paterson, Elliott, Anderson, Toops, and Heidbreder (1930) as part of their extensive study of the measurement of mechanical ability. This test proved to be one of the most valid of the tests developed and was the most valic
tests employing only paper and pencil. However, in spite of its relatively high validity, it had serious limitation and needed improvement (The Psychological Corporation, 1970).

The Revised Minnesota Paper Form Board Test (RMPFB) was a revision by Likert and Quasha of the original paper form board test. This revision, first published in 1934, was designed to refine the test and make it more practical. The directions and scoring were simplified, practice problems were added, and items were arranged in order of difficulty. Two alternate forms of the original test were constructed. These are called Series AA and Series BB, each consisting of a booklet that is marked by the subjects and cannot be used again.

The RMPFB is a 20-minute speeded test consisting of 64 two-dimensional diagrams cut into separate parts. For each diagram there are five figures with lines indicating the different shapes out of which they are made. From these, the subject chooses the one figure which is composed of the exact parts that are shown in the original diagram.

![Figure 1. Sample RMPFB Test Question.](image-url)
Figure 1 shows two parts in the upper left-hand corner. By looking at the five figures labeled A, B, C, D, and E, the subject is to decide which figure shows how these parts can fit together. Looking at figure A one will notice that it does not look like the parts in the upper left-hand corner would look when fitted together. Neither do figures B, C, D. Figure E does look like the parts in the upper left-hand corner would look when fitted together. Therefore, E would be the correct response.

There were considerable individual differences in the ability or abilities measured by this test. The nature of these differences and the specific kinds of abilities measured are discussed more fully in the section on validity. In brief, the test seems to measure those aspects of mechanical ability requiring the capacity to visualize and manipulate objects in space.

The test has a long history of effective prediction in many academic and industrial fields, particularly those with a mechanical orientation. The studies summarized in the validity section of the test manual (Jkert, 1934; Paterson, et al, 1933; Quasha, 1935; Quasha & Likert, 1937) strongly suggest that the test is a valuable tool for use in educational and vocational guidance and in employee selection. Equivalence of forms AA and BB were constructed as part of the revision of the original Minnesota Paper Form Board Test. A pool of 128 items was administered to college and high school students. The items were then ranked in order of difficulty and systematically assigned to Series AA or BB (Quasha & Likert, 1937). Logically, therefore, the forms are equivalent, and the authors of the test have observed that norms for Series AA and BB are almost identical when the two forms are administered to comparable groups.
Reliability

There is no one statistic that can be said to be a measure of the reliability of this particular test. Estimates of reliability coefficients are dependent on both the range and the level of ability within a sample being tested. For example, a sample with a wide range of ability will generally yield a higher reliability coefficient than a sample with limited range (Likert & Quasha, 1970). However, good estimates of a test's reliability can be obtained by evaluating the results of a number of reliability studies using a variety of samples.

In their developmental work with the Revised Minnesota Paper Form Board Test, Quasha and Likert (1937) found the interform reliability of Series AA and BB was .85, based on the results of 290 high school seniors applying for admission to New York University. The reliability coefficient and standard error of measurement for several groups of students (high school and college freshmen), who were administered alternate equivalent forms of the RMPFB in 1969, were found to be .75 with 3 to 4 raw score points as the margin of error (The Psychological Corporation, 1970).

Validity

The validation of the Minnesota Paper Form Board Test goes back to the original studies by Paterson, et al. (1930), and the development of the RMPFB as reported by Likert (1934), Quasha (1935), and Quasha and Likert (1937). The original Minnesota Paper Form Board Test was the most valid paper and pencil test of the criterion of mechanical ability developed in the study. In a
series of studies, the Revised Edition correlated .75 or better with the original test. When corrected for attenuation, these correlation coefficients became .94 or better. In addition to validating the revised test against the original, Quasha and Likert found that their first revision correlated .49 with grades in mechanical drawing and .32 with grades in descriptive geometry. These grades were semester grades for freshman engineering courses.

Research from the 1940's on, pertaining to the validity of the test, are presented below in support of its usefulness as a measure of mechanical-spatial ability. One type of evidence of validity is afforded by the comparison of the mean test scores of groups who are logically and psychologically expected to differ in mechanical-spatial ability. For example, one would expect engineers and draftsmen to obtain higher mean scores than factory workers. Moore (1941) presents data for different groups in the form of graphs. That study showed that the average score of adult men to be 34 points; engineering school freshmen scored 43 points; and of 7,844 enrollees in engineering defense training (EDT) evening classes at Pennsylvania State College the average score was 41 points. In the same study mechanical draftsmen who were in the EDT group, had considerably higher rankings, approximately 75 percent were above the 90th percentile.

An examination of the normative groups presented in the manual also confirms the validity of the MPFB in differentiating between groups that logically should differ in spatial and mechanical ability. For example, the manual shows mean scores of two groups of engineering students exceeding the means of the other educational groups by about 4-8 raw score points. This is to be expected since the engineering students in this study were older, at a higher educational
level, and more highly selected than the other groups. This is because, according to the literature as a person increases in age and is exposed to new spatial experiences, their ability to perceive objects spatially also increases.

Correlations with other Tests

The manual summarizes the studies in which scores on the MPFB have been correlated with scores on various measures of general intelligence and specific aptitudes. Spatial ability tests had a range of coefficients from .38 to .70, with the mean coefficient being .58. The coefficient of correlation in the manual offered strong support that the test is (1) a valid measure of mechanical-spatial ability, and (2) clearly related to general intelligence.

Test Administration

The RMPFB test was used in this study to measure the students spatial visualization skills before and after the treatment. Both forms of the RMPFB (AA and BB) were administered to both of the groups, each of these tests were administered in their unaltered format. After a brief explanation of the test, subjects were given test booklets to review the sample questions. After all subjects have read the introductory information, they were given 20 minutes to complete as many problems as possible on each test.

The subjects were reminded that it is a speed test, and a test for accuracy as described in the test administrator's handbook. The researcher stayed in the
classroom with the subjects to answer questions. This procedure was followed for both administrations of the tests.

All materials (test booklets and answer sheets) were collected after the pretest and posttest, and evaluated using the RMPFB scoring sheet. The pretest was administered to the Experimental Group during the first twenty-five minutes of the first class meeting (July 8, 1991) and the posttest was administered on the second to the last class meeting (July 25, 1991). The Control Group was administered the pretest during the first day of the Governor's School program and they were administered the posttest during the second to the last day of the program.

Treatment

The treatment consisted of CAD instruction using CADKEY 3.5 software. The instructional time was two hours per day, five days per week for three weeks. The instructional methods were lecture, demonstration, and self-paced learning exercises. The eighteen exercises were taken from the Basic Mechanical Design Training Manual by CADKEY, Inc. This instructional manual was selected for two reasons. First, the manual has been used successfully for five years as a training manual in industry. Second, the manual is graduated in level of difficulty. Therefore, as the student's knowledge increases, the level of difficulty of the exercises also increases.
Analysis of Data

ANCOVA was used to determine if there was a difference in gain scores from pretest to posttest on the RMPFB between the Experimental and Control Groups and to adjust group means of the posttest for the two groups for any preexisting differences in the pretest scores. ANCOVA was also used to account for initial differences between groups on the pretest scores using the pretest as the covariate.

Summary

This chapter delineated the design and methods of this study, including the population composition, research methodology, general procedures, hypothesis testing, and analysis of data. This study used a population of 40 gifted high school students (from a total population of 50) from the Governor’s School for Technology at Virginia Polytechnic Institute and State University. A nonequivalent Control Group design employing pretest and posttest was used. Students were tested using multiple forms of the Revised Minnesota Paper Form Board test. The hypothesis in this study was tested using ANCOVA.
CHAPTER 4

Results

Introduction

This chapter is divided into two parts. In the first part, descriptive
statistics are presented which describe the demographic characteristics of the
Experimental and Control Groups. In the second part, data pertaining to the
testing of the hypothesis are presented. To conclude the chapter, there is a
summary of the findings.

The research hypothesis for this study was: subjects receiving instruction
in computer-aided design (CAD) will show improvement in spatial visualization
skills, as measured by the Revised Minnesota Paper Form Board (RMPFB) test,
when compared to the subjects not receiving CAD instruction.

In this study two different groups were contrasted to determine if the
Experimental Group, the group taking the computer-aided design course, had a
different demographic makeup than the Control Group (the ones not enrolled in
the CAD class).

Six demographic variables were analyzed: gender, grade level, number
of exercises completed, GPA, semesters of computer courses, and semesters of
drafting courses. This information was then processed using t-Tests for
independent samples and ANCOVA to determine if any significant statistical
differences existed between the groups.
Descriptive Data

A majority of both the Control Group (70%) and the Experimental Group (55%) had no previous course work in computers. Ten percent of the Experimental Group and 5% of the Control Group had a maximum of two semesters of course work in computers. No significant difference was found between the Experimental and Control groups with respect to the number of semesters of computer courses. These data are reported in Table 1.

Table 1:
Number of Semesters of Computer Courses

<table>
<thead>
<tr>
<th>Semesters</th>
<th>Experimental Group η (%)</th>
<th>Control Group η (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11 (55)</td>
<td>14 (70)</td>
</tr>
<tr>
<td>1</td>
<td>7 (35)</td>
<td>5 (25)</td>
</tr>
<tr>
<td>2</td>
<td>2 (10)</td>
<td>1 (5)</td>
</tr>
</tbody>
</table>

Total Sample 20 (100) 20 (100)

MEAN .55 .35
SD .69 .59
t Value - Prob. .33 .59
A majority of the Experimental Group (60%) and the Control Group (80%) had never received formal drafting training. Twenty percent of the Experimental Group as compared to 5% of the Control Group had three to five semesters of formal drafting training. No significant difference was found between the Experimental and Control groups with respect to the number of semesters of drafting courses. These data are reported in Table 2.

Table 2
Number of Semesters of Drafting Courses

<table>
<thead>
<tr>
<th>Semesters</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>η (%)</td>
<td>η (%)</td>
</tr>
<tr>
<td>0</td>
<td>12 (60)</td>
<td>16 (80)</td>
</tr>
<tr>
<td>1</td>
<td>3 (15)</td>
<td>3 (15)</td>
</tr>
<tr>
<td>2</td>
<td>1 (5)</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>3 (15)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>5</td>
<td>1 (5)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total Sample</strong></td>
<td><strong>20 (100)</strong></td>
<td><strong>20 (100)</strong></td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN</td>
<td>.95</td>
<td>.90</td>
</tr>
<tr>
<td>SD</td>
<td>1.46</td>
<td>.73</td>
</tr>
<tr>
<td>t Value - Prob.</td>
<td>.09</td>
<td></td>
</tr>
</tbody>
</table>
Both groups were very similar in their grade level composition. Between 25 - 30% were Juniors and 70 - 75% were Seniors. The Seniors were represented by approximately three times the amount of the subjects than the Juniors. No significant difference was found between the Experimental and Control groups with respect to grade level. These data are reported in Table 3.

Table 3
Subject Breakdown by Grade Level

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Experimental Group N (%)</th>
<th>Control Group N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11th</td>
<td>6 (30)</td>
<td>5 (25)</td>
</tr>
<tr>
<td>12th</td>
<td>14 (70)</td>
<td>15 (75)</td>
</tr>
<tr>
<td>Total Sample</td>
<td>20 (100)</td>
<td>20 (100)</td>
</tr>
<tr>
<td>t Value - Prob.</td>
<td>.73</td>
<td></td>
</tr>
</tbody>
</table>
A majority of the subjects in the Experimental Group (85%) completed fourteen exercises before the posttest was administered. Only 3 (15%) of the students completed fifteen or more exercises. These data are reported in Table 4.

Table 4

<table>
<thead>
<tr>
<th>Number of Exercises Completed at the Time of the Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise Number</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>Total Sample</td>
</tr>
</tbody>
</table>

X = (MEAN)  
SD  
13.6  
1.6
Twelve (60%) of the Experimental Group and 13 (65%) of the Control Group had a GPA between 3.7 and 4.0. Conversely 4 (20%) of the Experimental Group and only 2 (10%) of the Control Group had a GPA of less than 3.4. No significant difference as found between the Experimental and Control groups with respect to their grade point averages. These data are reported in Table 5.

Table 5

Subject Breakdown of GPA (4.0 Scale)

<table>
<thead>
<tr>
<th>GPA</th>
<th>Experimental Group Ω (%)</th>
<th>Control Group Ω (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 to 3.4</td>
<td>4 (20)</td>
<td>2 (10)</td>
</tr>
<tr>
<td>3.5 to 3.7</td>
<td>4 (20)</td>
<td>5 (25)</td>
</tr>
<tr>
<td>3.8 to 4.0</td>
<td>12 (5)</td>
<td>13 (25)</td>
</tr>
<tr>
<td>Total Sample</td>
<td>20 (100)</td>
<td>20 (100)</td>
</tr>
</tbody>
</table>

X = (MEAN) 3.74 3.63
SD .25 .26
 t Value - Prob. .91
Testing of the Hypothesis

Using ANCOVA (Analysis of Covariance), and combining the Experimental and Control Group pretest scores on the Revised Minnesota Paper Form Board test (RMPFB), posttest scores on the RMPFB were analyzed. One ANCOVA was applied testing the significance of the group’s scores on the posttest covarying for the pretest scores. The results from this ANCOVA revealed that there was no significant difference in the posttest scores between the groups \( F = 1.79, \text{df} = 1.37, p = .19 \) indicating the Experimental and Control Groups were equivalent in spatial visualization ability at the onset and at the completion of this study.

Using ANCOVA (Analysis of Covariance), it was determined that there was no statistical significance related to which group, Experimental or Control, that the students were in. ANCOVA showed that the scores of both groups increased from the pretest to the posttest. The ANCOVA technique was also used to assess the individual contributions attributed to group membership (Control vs. Experimental), and to the interaction between group membership and the pretest spatial visualization ability, after controlling for pretest spatial visualization ability. In examining the results of the ANCOVA, it was determined that the two groups did not have additional unexplained variations in their pretest spatial visualization scores.

The next step in analyzing the results from ANCOVA was to consider the contribution of group membership to the statistical equation, after controlling for the pretest spatial visualization ability. The hypothesis of this study was that group membership would contribute significantly to the statistical equation,
indicating that the CAD training improved spatial visualization ability. The results of the ANCOVA did not support the hypothesis of this study, causing the researcher to accept the null hypothesis. These data are reported in Table 6.

Table 6
ANCOVA for Posttest, Controlling for Pretest

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>Degrees of Freedom</th>
<th>Mean Squares</th>
<th>F Ratio</th>
<th>F Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>1078.9</td>
<td>1</td>
<td>1078.9</td>
<td>76.7</td>
<td>.0000</td>
</tr>
<tr>
<td>Group</td>
<td>25.1</td>
<td>1</td>
<td>25.1</td>
<td>1.8</td>
<td>.1896</td>
</tr>
<tr>
<td>Error</td>
<td>520.6</td>
<td>37</td>
<td>14.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1603.1</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7

Correlation Matrix

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>Gender</th>
<th>Computer</th>
<th>Drafting</th>
<th>Grade</th>
<th>GPA</th>
<th>Instruction level</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 40</td>
<td>n = 40</td>
<td>n = 40</td>
<td>n = 40</td>
<td>n = 40</td>
<td>n = 40</td>
<td>n = 20</td>
<td>n = 40</td>
<td>n = 40</td>
</tr>
<tr>
<td>Group</td>
<td>-0.00</td>
<td>.16</td>
<td>.28</td>
<td>-0.06</td>
<td>.02</td>
<td>0.00</td>
<td>-0.10</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>-0.14</td>
<td>.07</td>
<td>0.09</td>
<td>-0.05</td>
<td>-0.17</td>
<td>-0.15</td>
<td>-0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer</td>
<td>-0.11</td>
<td>-0.00</td>
<td>.06</td>
<td>-0.32</td>
<td>.06</td>
<td>.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drafting</td>
<td>0.04</td>
<td>-0.00</td>
<td>.47*</td>
<td>.05</td>
<td>.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>-0.04</td>
<td>.04</td>
<td>.37*</td>
<td>.33*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td>.26</td>
<td>-0.18</td>
<td>-0.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Instruction level</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.23</td>
<td>.10</td>
<td></td>
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<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.81*</td>
<td></td>
</tr>
</tbody>
</table>

*p > .05
Correlation Matrix

The researcher wanted to determine if any correlation existed between the six demographic variables in the study. The cutoff point for significance in the correlation matrix was .05. This value was determined before the onset of the study. Anything under the value of .05 was determined to be significant. Anything over the value of .05 was determined to be not significant. Correlation coefficient analysis was used to determine correlation and the results were set into a correlation matrix (see Table 7). Correlations are ranged on a scale from positive 1 to negative 1, with positive one being a strong positive correlation and negative one being a strong negative correlation. A positive correlation means that the variables analyzed were correlated (related) to each other and negative correlation suggests that the variables are not related to each other. The correlation of drafting (number of semesters of drafting) to instruction level (number of completed exercises) was found to be significant (.47). The two significant correlations existed between grade level and pretest (.37) and grade level and posttest (.33). A significant correlation also existed between the pretest and the posttest (.81).

Summary

There were both similarities and dissimilarities between the Control Group and the Experimental Group. As pointed out at the beginning of this chapter, demographic data were analyzed to determine the extent of the differences between the two groups.
In terms of similarities, the two groups were similar in the number of semesters of computer courses, gender, grade level, and GPA. As for their dissimilarities, the groups differed in the number of semesters of drafting courses (although not statistically significant).

The Control Group's posttest mean increased 2.75 to a mean of 52.55, and the skewness of the distribution went to -.11 from -.80. The posttest scores for the Experimental Group had a mean of 53.15 (up 4.9 from the pretest) and a skew to the negative of -1.15, showing the improvement expected in the hypothesis. Using ANCOVA, the combined groups were viewed for variables which might affect the combined pretest scores. No significant differences were found in any of the variables.

The results of the ANCOVA revealed that group membership did not predict additional variance in posttest spatial visualization scores. Thus the Experimental Group did not improve more than the Control Group in spatial visualization ability.
CHAPTER 5

Summary, Conclusions, and Recommendations

Summary

This study reviewed spatial visualization skills and its importance in many occupational and school subjects. The literature reviewed showed that without proper spatial visualization training a person's vocational pursuits can be hindered.

In particular, the focus was on improving gifted adolescents' spatial visualization ability through the use of computer-aided design (CAD). CAD is a natural medium to teach spatial visualization skills. In CAD, students must be able to visualize objects on the computer screen and "mentally rotate" those objects. This study assessed whether training in CAD had any effect on the spatial visualization ability of selected gifted students. The instrument chosen to measure this effectiveness was the Revised Minnesota Paper Form Board (RMPFB) test.

Two groups were participants in a three week Governor's School program for the Gifted in Technology. The Experimental Group, consisted of 20 students who were enrolled in the CAD class offered by the Governor's School. The Control Group consisted of 20 students not enrolled in the CAD class. Both groups were given a pretest and a posttest using the RMPFB test, with the results compared following the end of the three week program.
The results of the study showed that both groups were influenced by the RMPFB test. Both groups had higher posttest scores than pretest scores. However, the Experimental Group did not improve significantly more in spatial visualization ability than did the Control Group.

It was expected that the Control Group would have shown no change in spatial visualization ability because they had no exposure to any spatial visualization training other than the RMPFB test. However, this group showed a growth in spatial visualization ability similar to that of the Experimental Group. Since the Control Group showed improvement comparable to that of the Experimental Group this would suggest that exposure to the RMPFB test itself provided a training experience from which the Control Group profited. If this conclusion is sound, one inference that may be drawn is that a three week long training class in CAD may be insufficient and that a longer training period would be necessary.

Of the six demographic variables (gender, grade level, number of exercises completed, GPA, semesters of computer courses, and semesters of drafting courses) none were found to have any statistical significance on spatial visualization ability. The demographic variable gender showed that males increased by 4.15 points from the pretest to the posttest while the females increased by only 3.08 points. This is in contrast to the research by Sherman (1977), Benbow and Stanley (1980), and Meehan (1984) The finding is, however supported by Fennama and Tartare (1985) and Weiner (1986). The demographic variable gender would most likely yield a significant effect if the number of males and females were considerably larger. The review of literature on the effect of gender on spatial visualization ability is significant in terms of
studies conducted. In the studies conducted by Sherman (1977), Benbow and Stanley (1980), and Meehan (1984) it is suggested that spatial visualization ability skills in females might influence their achievement in math and science. While others have refuted claims that spatial visualization contributes to differences in mathematics performance (Armstrong, 1981; Fennema & Sherman, 1977; Fennema & Tartre, 1985; Weiner, 1986). All of those studies used larger numbers of subjects therefore no inferences can be made from this study about gender since the population consisted of only 40 subjects (12 females). The demographic variable grade level did not have any statistical significance with spatial visualization ability. Yates (1988) states that as people mature they develop spatial visualization ability. If a more heterogeneous population were selected, a more diverse variation in grade level as it related to spatial visualization could likely be found. Looking at the demographic variable of the number of exercises completed before the posttest, it was found that the more semesters of drafting experience a subject had the greater the number of training exercises completed. Sixty percent of the Experimental Group had no high school drafting experience, however the subjects still completed 85% of the exercises during the treatment period.

The demographic variable of grade point average (GPA) did not have statistical significance with spatial visualization. The researcher believes that since the study’s population was composed of highly gifted high school students, GPA would have very little effect of spatial visualization ability. Since the subjects were gifted and one of the selection criteria for acceptance into the Governor’s School program was GPA, it is understandable that a majority of the subjects would have GPA’s of 3.5 or higher. Conversely, if a more
heterogeneous population was selected the researcher believes that GPA could be more correlated with spatial visualization. Jones (1990) states that the gifted student that use computers develop higher level thinking skills and work smarter. This refutes the findings of the study since no correlation existed between the number of computer courses a student had and spatial visualization ability and drafting experience. The study found that there was no significant correlation between spatial visualization ability and drafting experience. This is in contrast to the findings by Yates (1968), Brinkmann (1966), and Blade (1949). However, these findings were supported by Faubion, Cleveland, and Harrell (1942), Mendicino (1958), and Myers, (1958).

Conclusions

While generalizations from the findings of this study must be tempered by the inherent limitations of the study, the following conclusions could be inferred:

1. The results obtained in this study suggest that the CAD instruction did not improve the spatial visualization ability of the gifted students.

2. Students spatial visualization ability was not related to gender, grade level, number of exercises completed, GPA, semesters of computer courses, and semesters of drafting courses.

3. Learning occurred as a result from taking of the pretest and subsequent taking of the posttest.
Recommendations

Continued investigation into this area is both warranted and needed. On the basis of the findings of this study and the review of the relevant literature, the following suggestions for further research concerning the effect of spatial visualization instruction using CAD are offered, if further research is to be replicated:

1. The treatment should be extended beyond the three week period. The rationale of the researcher was that the intensity of the training would have invalidated any chances of the test subjects remembering test items or strategies. Because of the closeness of the pre- and posttests, caution is urged in using these data as collected unless similar studies produce results which appear to support this study’s findings that exposure to the RMPFB test is, in itself, sufficient experience to trigger improvement in latent spatial visualization ability.

2. A more homogeneous mix between gifted and non-gifted students should be used in subsequent studies. This mix was not possible given that the program was for selected gifted students. A study designed for average high school students would, most likely, produce a higher significance between the experimental and control groups.

3. A study to determine the correlation between spatial visualization and problem solving skills is warranted. Since spatial visualization skills have been associated with certain problem solving skills, this study could be conducted and the students tested for enhanced problem solving skills. The study could be done in a similar problem solving environment, such as in a geometry class.
4. A "time series" experiment (Campbell and Stanley, 1963, p. 37) re-examining the spatial visualization abilities of each experimental student is suggested. This type of design could determine if the initial exposure and training of this study created a lasting awareness and desire in the treated students to further develop and utilize their spatial visualization ability.

5. Spatial visualization is a multidimensional ability and therefore should be measured by more than one instrument. The RMPFB measures the subjects' ability mentally rotate the images on a flat two-dimensional surface. By developing an instrument to measure a subjects' ability to dynamically rotate an image on a computer screen, one might be better able to determine a subjects' three-dimensional spatial ability.

6. According to the RMPFB test manual, this test should be administered to a wider range of subjects to obtain a higher reliability coefficient. As according to Likert & Quasha (1970) a sample with a wide range of ability will generally yield a higher reliability coefficient than a sample with limited range.

7. This study looked at the demographic variable computer experience as a group of experiences. Subsequent studies should break down computer experience into specific experiences. If a student has one or more semesters of computer word processing courses will he or she have more developed spatial visualization ability than a student who has one or more semesters of computer graphics courses?

3. A treatment of a different type could reveal different results than the treatment used in this study. A treatment consisting of subject manipulation of three-dimensional images on the computer screen or hands-on manipulation of an object while testing for spatial ability before and after the treatment.
9. Since the pretest and posttest were two dimensional in nature, that is paper and pencil, a system of computer-based three dimensional measurement should be evaluated.

Discussion

The McCarthy (1980) states that people can be right brained, left brained or integrated (equally facile with both hemispheres). Further research should be conducted in determining the learning needs of gifted adolescents in each teacher's classroom. By meeting the learning needs of the individual gifted student, that is attending to their right/left brain needs, teachers will keep them interested and challenged in their subjects. The range of applications of learning style and personality type information is wide and meaningful. Sharing the information on learning styles and personality types with the gifted adolescent is critical during their quest for self-understanding (Bireley & Genshaft, 1991). This indicates that teachers should be more attentive to teaching to the right brain needs of gifted adolescents.

Computer use in the school setting has been steadily increasing over the past two decades. Many gifted students have access to computers in their classrooms, and many have computers in their homes. Business, industry, and educational leaders as well as the general population believe our most able students must be computer literate for our nation to be competitive in the next generation. Only recently, with the gulf between promises and achievements widening, have voices of concern been raised. The disparity between theory and practice is attributed to many causes, ranging from a lack of educational
focus to a shortage of funding. Even those individuals who are reporting these
problems have found evidence that students are working “smarter”. Whether
they are learning and using information, understanding key concepts and
relationships better, or developing higher level thinking skills. Gifted students
are benefiting from increased use of computers because their special needs are
being met through informed use of technology.
REFERENCES


Harrington, R. C. (1982). Caution: Standardized testing may be hazardous to the education program of the intellectually gifted children, Education, 103, 112-117.


Johnson, P. A. An investigation of differences in selected curriculum and student characteristics in regular and gifted English classes in Area I Fairfax County Public Schools, Fairfax County, Virginia. (Doctoral Dissertation, Virginia Polytechnic Institute and State University, 1987). Dissertation Abstracts International, 48(03), 1901A.


Lolla, R. S. The effect of selected instruction in tactual-visual perception on ninth-grade male and female visual imagery, mechanical reasoning, and spatial relations abilities, (Doctoral Dissertation, Purdue University, 1973). Dissertation Abstracts International, 34/09, 5673A.


Myers, C. T. (1951). The effect of training or practice, or both, on scores on CEEB spatial relations test, form VACI. *ETS Research Bulletin*, March 16.


1. Description of Course

In this three-week course, the students will explore in detail the use of microcomputers in computer-aided design (CAD). Emphasis will be placed on the use of hardware and software for automating the design process. Concepts and skills learned in this course will be used to document research and development activities in other courses.

II. Course Objectives for CAD using CADKEY 3.5

1. To become familiar with the CADKEY 3.5 screen.
2. To understand the functions of the History Line, the Prompt Line, the Status Window, and the Cursor Tracking Window.
3. To learn how to use the Immediate Mode Commands to delete, scale, redraw, and save drawings.
4. To learn how to Save and Retrieve drawing using the Files menu.
5. To learn how to use the Polar and Delta options of the Position Menu.
6. To learn how create Circles, Arcs, Fillets, and Chamfers.
7. To learn how to use the L-Limits (line limits) toggles.
8. To learn how to use the various options of the Delete Menu.
9. To learn how to make changes in the drawing using the Edit Menu.
10. To learn how to control the Attributes of entities.
11. To learn how to use different Levels in a drawing.
12. To learn how to use the Grid and Snap commands.
13. To learn how to combine several drawings using Pattern Files.
14. To learn how to obtain a copy of a drawing using a Plotter.
15. To learn how to move, rotate, scale, mirror, and make copies of selected entities using the X-Form Menu.
16. To learn how to create drawing of objects that have symmetry and/or repetitive features.
17. To acquire an understanding of many of the three-dimensional capabilities.
18. To learn how to create a 3D wireframe drawing by extruding a 2D drawing in a direction perpendicular to the screen.
19. To learn how to create a multi-view drawing.
20. To understand the effects of the 2D/3D construction switch and the depth setting; to be able to use the system controls in the creation of 3D drawings.
21. To learn how to use the 3D capabilities of CADKEY to create assembly drawings.
22. To develop skills further by working on more complicated wireframe models.

III. Learning Strategies

1. Student lead discussions.
2. Instructor lead discussions.
3. Extensive hands on learning through the use of prepared exercises.
4. Demonstrations by the instructor.
5. Demonstrations by the students.
6. Out of class assignments (readings, homework).
7. Quizzes to assess learning extent.

IV. Content Outline (following pages)

V. Methods of Evaluation

All classroom activities and exercises will be assessed to determine the students progress. This assessment will be used to determine the students mastery of the course objectives.

VI. References


<table>
<thead>
<tr>
<th>Week</th>
<th>Objectives</th>
<th>Time</th>
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<tbody>
<tr>
<td>Week 1</td>
<td></td>
<td></td>
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<tr>
<td>Monday</td>
<td>1. Pretest - RMPFB</td>
<td>25 min</td>
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<td></td>
<td>2. Introduction to Class, Computers</td>
<td>20 min</td>
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<tr>
<td></td>
<td>3. Introduction to CADKEY - (System Layout, Entity types, Immediate mode commands, Saving files)</td>
<td>45 min</td>
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<td></td>
<td>4. Work on Exercise 1</td>
<td>25 min</td>
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<tr>
<td>Tuesday</td>
<td>1. Review Previous Lesson</td>
<td>10 min</td>
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<td></td>
<td>2. Creating a Blank Part File</td>
<td>15 min</td>
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<tr>
<td></td>
<td>3. Creating Lines, Arcs, Circles, Points</td>
<td>20 min</td>
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<tr>
<td></td>
<td>4. Universal Position Menu</td>
<td>15 min</td>
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<tr>
<td></td>
<td>5. Exercise 2 &amp; 3</td>
<td>60 min</td>
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<tr>
<td>Wednesday</td>
<td>1. Angular Representation</td>
<td>15 min</td>
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<tr>
<td></td>
<td>2. Universal Selection Menu</td>
<td>15 min</td>
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<tr>
<td></td>
<td>3. Fillets &amp; Chamfers</td>
<td>10 min</td>
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<td></td>
<td>4. Coordinate System (View)</td>
<td>20 min</td>
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<td></td>
<td>5. Exercise 4,5</td>
<td>60 min</td>
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<tr>
<td>Thursday</td>
<td>1. Trim &amp; Extend</td>
<td>20 min</td>
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<td></td>
<td>2. Views (Rotate Views)</td>
<td>15 min</td>
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<td></td>
<td>3. Exercise 4,5 (Continued)</td>
<td>90 min</td>
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<tr>
<td>Friday</td>
<td>1. Levels</td>
<td>20 min</td>
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<td></td>
<td>2. 2D vs. 3D</td>
<td>20 min</td>
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<td>3. Exercise 6,7</td>
<td>75 min</td>
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<tr>
<td>Week 2</td>
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<tr>
<td>Monday</td>
<td>1. X-Form</td>
<td>45 min</td>
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<td></td>
<td>2. Part and Pattern Files</td>
<td>15 min</td>
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<tr>
<td></td>
<td>3. Exercise 6,7</td>
<td>60 min</td>
</tr>
<tr>
<td>Tuesday</td>
<td>1. Plotting a Drawing</td>
<td>20 min</td>
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<td></td>
<td>2. Construction Planes</td>
<td>20 min</td>
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<td></td>
<td>3. Exercise 8,9</td>
<td>80 min</td>
</tr>
<tr>
<td>Wednesday</td>
<td>1. Macro's</td>
<td>30 min</td>
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<td></td>
<td>2. Work on Exercises 8-11</td>
<td>90 min</td>
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<tr>
<td>Thursday</td>
<td>1. Calculator Function</td>
<td>20 min</td>
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<tr>
<td></td>
<td>2. Work on Exercises 9-12</td>
<td>110 min</td>
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<tr>
<td>Friday</td>
<td>1. Working from a 3D Drawing</td>
<td>30 min</td>
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<tr>
<td></td>
<td>2. 3D Exercises (Toolpost, Finger Guide)</td>
<td>90 min</td>
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<tr>
<td>Day</td>
<td>Activities</td>
<td>Time</td>
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<tr>
<td>Monday</td>
<td>1. Detailing</td>
<td>30 min. 90 min.</td>
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<tr>
<td></td>
<td>2. Work on Exercises</td>
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<tr>
<td>Tuesday</td>
<td>1. Demo on CNC with Mike D.</td>
<td>120 min.</td>
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<tr>
<td>Wednesday</td>
<td>1. Work on Exercises</td>
<td>120 min.</td>
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<tr>
<td>Thursday</td>
<td>1. Posttest - RPMFB</td>
<td>25 min.</td>
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<tr>
<td>Friday</td>
<td>1. Work on Exercises</td>
<td>60 min. 50 min.</td>
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<tr>
<td></td>
<td>2. Wrap up class &amp; Evaluations</td>
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</tbody>
</table>
APPENDIX 2

Virginia Governor’s School Selection Process
Criteria for Nominating Students

Nominees

1. Must be qualified and genuinely interested in attending the Governor's School. It is looking for the student who enjoys creating solutions to technical problems.

2. Must be enrolled during the school year in a public or private high school in Virginia or eligible to attend public school in Virginia tuition-free.

3. Should be sophomores and juniors, but may be mature freshmen during the current school year.

4. Must be residents of the Commonwealth of Virginia.

5. Must be selected by a local school nomination committee.

6. Must not be a former participant in a state-wide Residential Governor's School.

7. Must be willing to work on and complete a research project during the school year and report findings at a regional site and other appropriate state, national, or international event.

Nominees in technology must be designated by technology teachers, administrators of gifted programs, or other professionals who know their capabilities. Standardized test scores should remain reasonably high because these students will take other classes and seminars.
Steps in the Nomination Process

High schools are encouraged, but not required, to submit a student nomination at the local level for this new Governor's School of Technology. The administrators of gifted programs will expect a nomination from each high school in the division unless they are notified by the principal or guidance department that such a nomination will not be forthcoming.

1. Each high school, regardless of enrollment, will nominate one student from either the ninth, tenth, or eleventh grade as a division's candidate for the Governor's School of Technology.

2. Names of nominees and any additional information required are forwarded to the division administrator of gifted education. The local committee may not need a completed application; if that is true in a division, only nominees to the state would be required to have a complete application.

3. Under the direction of the division administrator of gifted programs, a school division committee is formed to select candidates to submit to the Virginia Department of Education which will select 50 statewide participants.

4. The committee should consist of the gifted program administrator and representatives of some of the following groups: local directors of vocational education, persons with expertise/experience in technology, science and/or mathematics, and interested representatives of business and industry. The members of the school division committee should represent as many of the schools as possible.

5. The schools division committee will consider the pool of local nominees and select one nominee for every 5,000 students or portion thereof.
enrolled in grades 9, 10, and 11 from the division. Depending on the local membership in grades 9, 10, and 11, the local gifted coordinator will submit at least one complete student application from each division.

5. Private schools which have nominees should submit applications directly to the Virginia Department of Education. The number of private school participants in the Governor's School of Technology will be based on membership in grades 9 - 11 of the private schools submitting applications.
VITA

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Virginia Tech
Technology Education Department
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EDUCATION

1992 Doctor of Education in Vocational Education with a concentration in Technology Education, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

1989 Master of Science in Industrial Arts, Central Connecticut State University, New Britain, Connecticut

1979 Bachelor of Science in Industrial Arts, State University of New York College at Oswego, Oswego, New York

WORK EXPERIENCE

1991 - Present ADJUNCT FACULTY - New River Community College, Dublin, Virginia. Instruct classes in Introduction to Microcomputers, desktop publishing. Designed and developed curriculum materials for use in a microcomputer laboratory. Responsible for some computer lab maintenance, including updating hardware and software.

1990 - Present GRADUATE PROJECT ASSISTANT - Virginia Governor's School for Technology, Virginia Tech. Assist Director of Virginia Governor's School for Technology. Assist the Director in organizing and administration of students and personnel involved with the Governor's School. Other duties include development and instruction of a three week intensive computer-aided design curriculum. Responsible for follow up evaluation of students after their completion of Phase I.

1987 - 1989 TRAINING AND DEVELOPMENT SPECIALIST - CADKEY INC., Manchester, Connecticut. Developed a nationwide network of 65 approved training centers, certified to offer instruction on CADKEY software products. Other responsibilities include conducting formal and informal training, seminars and workshops. Knowledge of principles of in-service training, adult learning techniques, business and organizational dynamics, and staff development. Knowledge of educational methods and techniques. Experienced with the full range of training materials, resources and research techniques. Ability to analyze and identify training needs; determine objectives of training programs; to develop, organize and conduct training
programs in accordance with prescribed objectives both long and short term. Considerable ability to develop curriculum and prepare training materials in written, computer-based or audiovisual formats. Ability to prepare and present clear and comprehensive written and oral reports.

1986 - 1987
INDUSTRIAL ARTS INSTRUCTOR - South Windsor High School, South Windsor, Connecticut. Taught Graphic Arts and Aviation/Aerospace Education. Designed and developed a new Aerospace curriculum. Assisted in streamlining the Graphic Arts curriculum. Advisor to National Honor Society and R/C Model Airplane and Car Club.

1984 - 1986
TERRITORY MANAGER - Larsen of Connecticut, East Hartford, Connecticut. Train outside salespersons in the graphic arts equipment field; proposal writing; bid quotation; payroll administration; purchasing and cost efficiency. Knowledge of printing equipment, negotiate vendor contracts, purchase printing equipment, inventory control. Responsible for forecasting sales and setting accurate goals.

1981 - 1984
RETAIL STORE MANAGER AND TRAINING DEVELOPMENT SPECIALIST - Radio Shack, Retail store manager; 52% overall sales gain for last fiscal year worked. Supervised 15 full and part time employees. Created a district wide sales and management training program. This included video tape and slide productions and presentations. Conducted training classes for managers and manager-trainees. Supervise and train new managers on purchasing, inventory control, sales, management techniques and customer service.

1980 - 1981
ASSISTANT PRODUCTION MANAGER IN CHARGE OF PRODUCTION PLANNING - K & R Printers, Ellington, Connecticut. Prepare job orders; assign work; coordinate with other departments; keep work on schedule. Purchase paper, inks and supplies, negotiate and contract with outside vendor orders.

1979 - 1980
INDUSTRIAL ARTS INSTRUCTOR - East Windsor High School, East Windsor, Connecticut. Developed photography and graphic arts curriculum for grades 9 - 12. Responsible for purchasing supplies and equipment. Advisor to the yearbook staff and the freshman class, and an assistant soccer coach.

1979 - 1979
INDUSTRIAL ARTS INSTRUCTOR - Indian Lake Central School, Indian Lake, New York. Taught general Industrial Arts courses for grades 6 - 12. Specialized courses included photography, graphic arts and alternate energy forms.

SPECIAL COMPETENCIES

Computers  Ten years of experience with IBM PC, UNIX, and Macintosh computers. This experience encompasses setup, administration, maintenance, and networking computers in business, educational, and personal settings. Extensive experience in many software packages for both DOS-based and Macintosh computers including CADKEY, AutoCAD, MasterCAM, SmartCAM, Microsoft Windows, Word, and Excel, Aldus PageMaker, Persuasion, and FreeHand, Novell NetWare and TOPS networking software, communication software such as PROCOMM PLUS, Ashton-Tate dBase IV and MultiMate, and many others. Excellent working knowledge of PC/MS-DOS and Macintosh System 7 operating systems. Excellent analytical and
debugging skills. Experienced with peripherals including laser printers, plotters, scanners, and modems.

Training

Ability to determine training needs, priorities, and performance objectives. Knowledge of training methodologies including teaching, instructional systems, testing and evaluating programs, and curriculum development. Ability to design, develop, and administer training courses and programs, analyze needs and effectiveness, and create and edit training literature. Knowledge of staff development objectives, principles and practices of training, and instructional design. Excellent interpersonal and oral presentation skills.

AWARDS and HONORS

President's Club, CADKEY Inc., 1989
Student Exhibitor, VPI&SU, Juried Student Photography Exhibit, 1992

MEMBERSHIPS IN PROFESSIONAL ASSOCIATIONS

Council on Technology Teacher Education
Epsilon Pi Tau
International Technology Education Association
Phi Delta Kappa
National Association of Industrial and Technical Teacher Educators
International Graphic Arts Education Association
Southeastern Technology Education Conference

PRESENTATIONS

"Virginia Governor's School for the Gifted in Technology" given at the ITEA Conference, Salt Lake City, March, 1991.

COMMUNITY SERVICE ACTIVITIES

National Eagle Scout Association - Life member
Merit Badge Counselor, Blue Ridge Chapter, Boy Scouts of America

LEISURE ACTIVITIES

Photography and computers
Licensed private pilot

SPouse'S WORK

Computer programmer, programmer/analyst, local area network specialist
SPECIAL RESEARCH INTERESTS
Gifted and talented
Computer-Aided Design

DISSERTATION
Mack, Warren E., "The Effect of Training in Computer-Aided Design on the Spatial Visualization Ability in Selected Gifted Adolescents" Virginia Polytechnic Institute and State University, 1992

REFERENCES

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