

AN ABSTRACT OF THE THESIS OF

Stephen M. Schmidt for the degree of Master of Science in Mathematics

presented on May 30, 2001. Title: Spatial Ability and Mathematics.

Abstract approved: *Redacted for Privacy*

Barbara S. Edwards

Understanding mathematics and teaching mathematics involve numerous factors, one of which may be an individual's spatial ability.

This paper examines research conducted on the relationship between spatial abilities and mathematics, gender differences in the area of spatial ability, the types of experiences that may affect one's spatial ability, and issues surrounding the teaching of spatial skills.

Researchers have found that spatial ability does relate to mathematics and males tend to have greater spatial ability than females. Instruction has also been shown to be successful in helping individuals learn spatial skills.

This paper also reports the results of a study that examined the differences in spatial ability among 98 participants (males, females, faculty, and students in the sciences and non-sciences) at a Pacific Northwest university. Although not all the results were statistically significant, they tend to agree with earlier studies that found gender advantages in spatial abilities favoring males over females. They also

provide evidence of the existence of greater spatial abilities among participants who are engaged in scientific rather than non-scientific pursuits. The participants in this study also reported experiences that they believed influenced their success or failure in tasks requiring spatial ability. Such experiences were success in math and art classes, computer modeling, drafting, puzzles/games, Legos, construction, wood-working, and playing with blocks as a child. Participants also stated their belief that spatial ability related to success or lack of success in mathematics. Over half of the students felt that spatial ability would help in a math class. This study reveals that spatial ability does differ in individuals; that there exist experiences that individuals feel are important for developing spatial ability; and that spatial ability relates to mathematics. This information can be beneficial for both teachers and researchers.

©Copyright by Stephen M. Schmidt
May 30, 2001
All Rights Reserved

Spatial Ability and Mathematics

by

Stephen M. Schmidt

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented May 30, 2001
Commencement June 2002

Master of Science thesis of Stephen M. Schmidt presented on May 30, 2001

APPROVED:

Redacted for Privacy

Major Professor, representing Mathematics

Redacted for Privacy

Chair of Department of Mathematics

Redacted for Privacy

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for Privacy

/ Stephen M. Schmidt, Author

TABLE OF CONTENTS

	<u>Page</u>
CHAPTER I: INTRODUCTION	1
Introduction	1
Definitions of Spatial Tests	7
Statement of Problem	15
CHAPTER II: REVIEW OF LITERATURE	16
Introduction	16
Research on How Spatial Ability Applies to Mathematics	16
Research on Gender Differences in Spatial Ability	24
Research on How Prior Experiences May Effect Spatial Ability	27
Research on Instruction in Spatial Skills	31
Conclusion	34
CHAPTER III: RESEARCH DESIGN AND METHODS.....	36
Introduction	36
Subjects	36
Instruments	38
Instruction of Study	39
Data Collecting/Analysis	40
Summary	40
CHAPTER IV: RESULTS	42
Introduction	42

TABLE OF CONTENTS (Continued)

	<u>Page</u>
Group Comparisons	42
Analysis of Specific Problems on the Spatial IQ Test	50
Results From the Questionnaire	51
CHAPTER V: DISCUSSION	55
Discussion	55
Limitations of Study and Implications/Recommendations for Future Studies	60
Conclusion	61
BIBLIOGRAPHY	63
APPENDICES	66
APPENDIX A: CONSENT FORM	67
APPENDIX B: SPATIAL IQ TEST/QUESTIONNAIRE	68
APPENDIX C: COPYRIGHT PERMISSION	70

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
I.1: Spatial Visualization and Spatial Orientation Tree	2
I.2: Triangles in Spherical Space	4
I.3: Geometric Representation of Completing the Square	6
I.4: The Differential Aptitude Test: Space Relations (DAT:SR) Sample Problem	8
I.5: 3-Dimensional Cube Test (3DC) Sample Problem	9
I.6: The Form Board Test (FBT) Sample Problem	9
I.7: Hidden Figures Test (HFT) Sample Problem	10
I.8: Punched Holes Test (PHT) Sample Problem	11
I.9: Purdue Spatial Visualization Test: Rotations (PSVT:R) Sample Problem	11
I.10: Mental Rotations Test (MRT) Sample Problem	12
I.11: Mental Cutting Test (MCT) Sample Problem	13
I.12: Gestalt Completion Test Sample Problem	13
I.13: Middle Grades Mathematics Project Spatial Visualization Test (MGMPSVT) Sample Problems	14
II.1: Geometric Problem Solving/Strategies Test Sample Problem	18
II.2: Visually Presented Geometric Problem (Tartre, 1990a)	22
II.3: Geometric Problem in Study by Tartre (1990a)	23

LIST OF TABLES

<u>Table</u>	<u>Page</u>
IV.1: Significant t-test values when compared to the Faculty-Science Group	43
IV.2: Science vs. Non-Science and Male vs. Female Mean Scores of Students	44
IV.3: Science vs. Non-Science and Male vs. Female Mean Scores of Faculty	45
IV.4: Mean Scores of Faculty Versus Student in Sciences and Gender	46
IV.5: Mean Scores of Students: Science-Male vs. Science-Female vs. Non-Science-Male vs. Non-Science-Female	47
IV.6: Mean Scores of Faculty: Science-Male vs. Science-Female vs. Non-Science-Male vs. Non-Science-Female	47
IV.7: Mean Scores of Faculty Versus Student: Science-Male vs. Science-Female vs. Non-Science-Male vs. Non-Science- Female	48
IV.8: Mean Scores of Student Engineering Fields vs. Each Other	48
IV.9: Mean Scores of Faculty Fields of Study vs. Each Other	49

LIST OF APPENDICES

<u>Appendix</u>	<u>Page</u>
A: CONSENT FORM	66
B: SPATIAL IQ TEST/QUESTIONNAIRE	67
C: COPYRIGHT PERMISSION	69

SPATIAL ABILITY AND MATHEMATICS

CHAPTER I: INTRODUCTION

Introduction

The ability to understand and help others understand mathematics is an important issue in today's society and in the teaching profession. One factor that may play a role in learning mathematics is spatial abilities (Guay and McDaniel 1977.) The phrase, "A picture is worth a thousand words" has new meaning when applied to spatial ability. Spatial ability consists of at least two distinct areas: spatial visualization and spatial orientation where

Spatial visualization is an ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli....
Spatial orientation involves the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented, and the ability to determine spatial relations in which the body orientation is an essential part of the problem. (McGee, 1979, pgs. 3-4)

The difference between the two is essentially that spatial visualization involves mental manipulations whereas spatial orientation involves the ability to comprehend those changes but not necessarily create them mentally. Figure I.1 illustrates the components of spatial skills (Tartre,

1990b, pg. 30). We see in this figure that spatial visualization is broken down into rotations and transformations. This agrees with McGee's definition of spatial visualization. We also see spatial orientation is broken down into reorganized whole and part of field. Reorganized whole is the idea that we can see and understand multiple arrangements of a pattern. The part of field idea is concerned with the relationship of parts of images in relation to the whole image. Both parts of spatial orientation are associated with the ability to remain unconfused by the different representations of objects and is consistent with McGee's definition above.

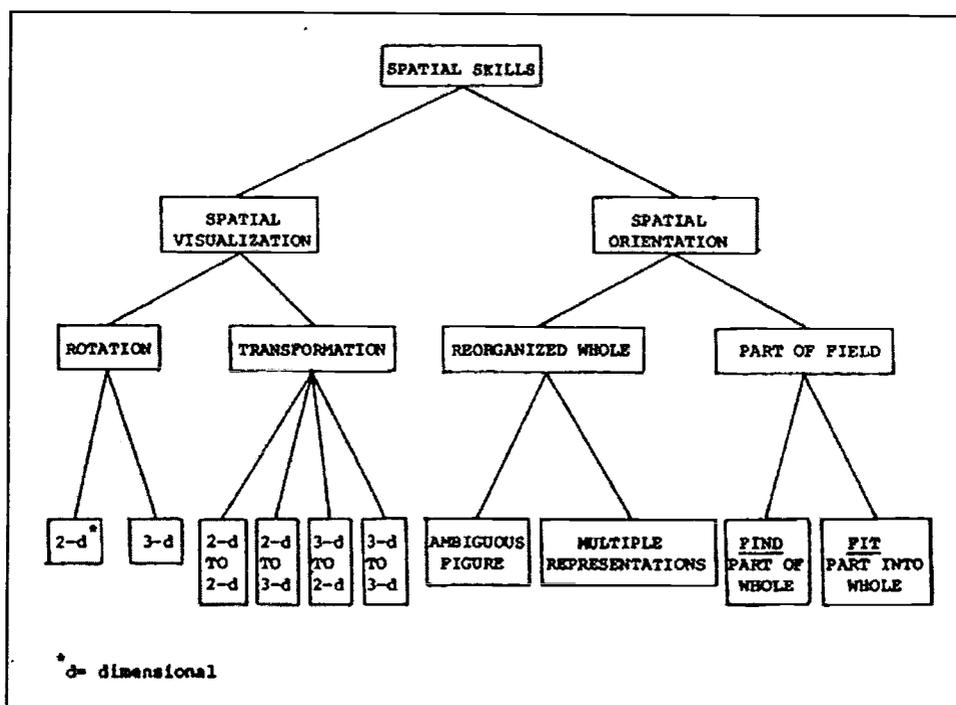


Figure I.1: Spatial Visualization and Spatial Orientation Tree

Throughout this paper we will use McGee's (1979) definition of spatial ability, visualization, and orientation.

The ability to visualize can be beneficial in many practical areas such as having a mental image of a street map, being able to visualize a scenic travel location, or even picturing the final product of an unfinished assignment. It can also be useful in the area of mathematics. "Much of the thinking required in higher mathematics is spatial in nature." (Seng & Chan, 2000, pg. 2) Further, "visualization as a factor of intelligence includes the mental manipulation of spatial configurations and has been associated with spatial abilities, creative thinking, and conceptual problem solving." (Roth, 1992, pg. 81)

Consider the possibility of visualizing triangles, straight lines, and other geometric images not only in Euclidean space but also in spherical or even hyperbolic space. In "Experiencing Geometry", a mathematics text by David W. Henderson (2001), geometric figures are considered on several surfaces. For example, a triangle is defined to be, "...a geometric figure formed of three points (*vertices*) joined by three straight line (geodesic) segments (*sides*) that divides the surface into two regions (the *interior* and *exterior*)." (Henderson, 2001, pg. 65) One quickly sees that on spherical surfaces this definition leads to triangles that are very different from those in Euclidean space. (Figure I.2.)

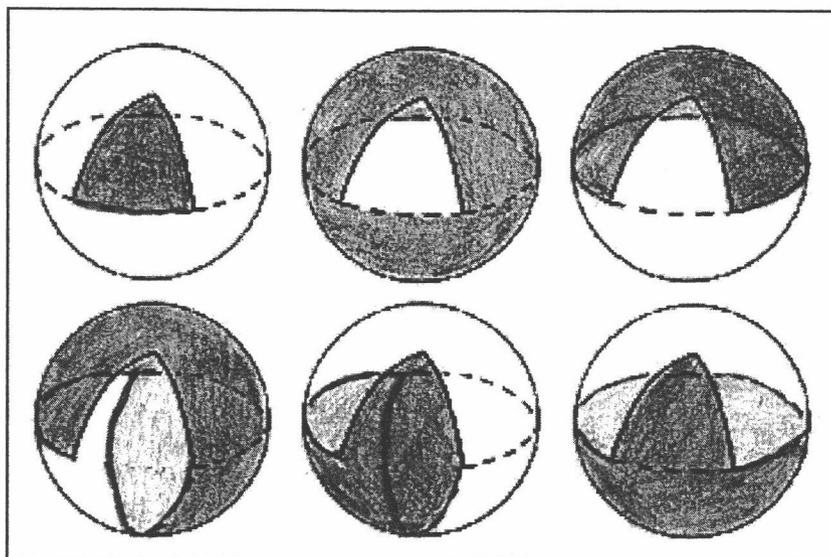


Figure I.2: Triangles in Spherical Space

In thinking about these triangles and their properties, spatial ability becomes a valuable asset. The ability to think and see in three-dimensions can help one develop a deeper understanding of concepts in spherical and hyperbolic space.

In some cases, it is essential that one is able visually to picture an image or rotation when talking about spherical space. “Albert Einstein used visualization and imagery to arrive at the theory of relativity and was able to ‘see’ the logic of the theory through the manipulation of analog images.” (Roth, 1992, pg. 82) In an excerpt from a lecture at the Prussian Academy of Sciences in 1921, Albert Einstein explained the concept of spherical space through the use of visual imagery. He said “...by using as a crutch the practice in thinking and visualization which Euclidean geometry gives us, we have acquired a mental picture of

spherical geometry. We may without difficulty impart more depth and vigour to these ideas by carrying out special imaginary constructions.” (French, 1979, pg. 297.)

In this instance, as in others, spatial visualization is the origin of many of our understandings and inventions. Consider the making of a computer-animated movie. The idea for the movie and what the characters will look like originated in someone’s mind. Those ideas are then transferred onto paper in the form of a visual drawing and possibly even some captions. Then, the actual computer graphics are created using a particular programming language such as Virtual Reality Modeling Language (VRML). When creating computer animation using VRML, you must be able to understand a three-dimensional grid. VRML uses translations of objects in the x, y, and z directions. It also allows someone to rotate an object a given number of degrees about a particular axis or combination of axes. This example relates many different fields: Spatial Visualization, Computer Graphics, Computer Animation, Mathematics, Video Production, Art, and others. The actual construction and concrete manufacturing of the computer animation came after the original idea and mental configuration. In the same sense, spatial visualization produces innovative ideas and thoughts in mathematics.

Almost a thousand years ago, a Persian geometer-poet, Omar Khayyam thought of quadratic equations using diagrams. An equation such as $x^2 + bx = c$ could be represented and solved pictorially. (Figure

I.3.) His idea was based upon the notion that any rectangle could be dissected to form a square. Assuming b is a dimension and c is an area, we can say that the rectangle of dimension x by $(x+b)$ has area c .

Therefore if we "complete the square" we see that the square $(x + b/2)^2$ has area $[c + (b/2)^2]$. Thus, one side of the square $(x + b/2)$ equals $\sqrt{c + (b/2)^2}$

and $x = -(b/2) \pm \sqrt{c + (b/2)^2}$.

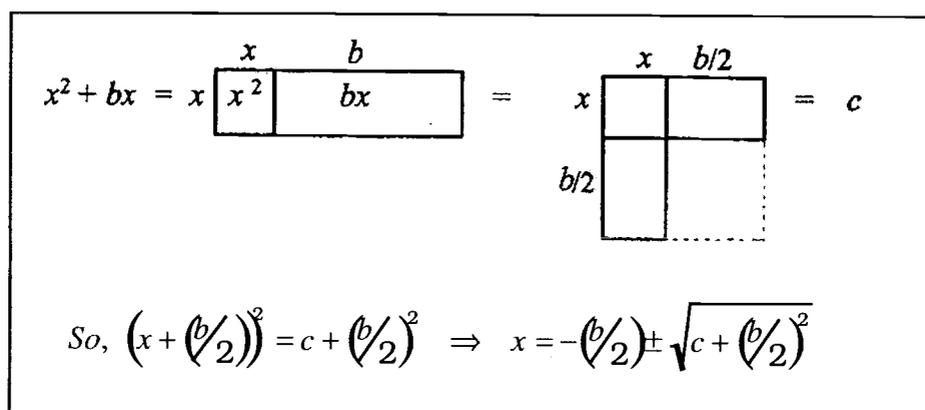


Figure I.3: Geometric Representation of Completing the Square

Although we may know how to solve a quadratic equation algebraically and understand the concept of completing the square, this geometric idea deepens our understanding of why it works. It gives us another way to look at an equation and find the solutions.

In considering the few examples of spatial visualization above, one may ask what the difference is between spatial visualization and visual images. Visual images alone are more a part of spatial orientation

whereas moving those visual images in an act of spatial visualization. Many people learn visually, but may not have high spatial visualization abilities. (Remember that spatial visualization requires the act of manipulating or creating an object and rotation, whereas spatial orientation requires the ability to see that the images have moved and understand the correlation between rotations.) Therefore, in learning visually, individuals must see the images and transformations but may not be able to create them on their own without experience. Spatial ability may be a learned skill. (Moses, 1980)

For example, a child may be given a cylindrical solid and a cube and asked to fit each object into either a square hole or a circular hole. When the child finally completes the task, has he learned spatial visualization or simply gotten lucky? A significant amount of research has addressed questions in the area of spatial visualization and spatial orientation in the last thirty years. In the next chapter, we will see what researchers have discovered about spatial skills. First we will discuss various tests that have been designed to evaluate spatial ability.

Definitions of Spatial Tests

A number of tests have been developed to determine an individual's spatial ability. Below is a list of the tests that are discussed throughout this paper:

- **The Differential Aptitude Test: Space Relations** (hereafter referred to as DAT:SR) by Bennett et al. (1972) assesses a person's ability to mentally-fold a two-dimensional pattern into a three-dimensional figure. This test consists of 60 problems and is considered to be a spatial visualization test. A sample problem from the DAT:SR is shown in Figure I.4.

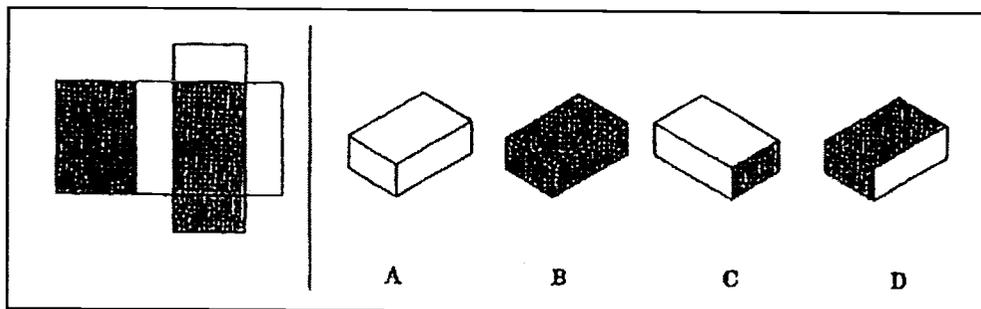


Figure I.4: The Differential Aptitude Test: Space Relations (DAT:SR) Sample Problem

- **3-Dimensional Cube Test** (hereafter referred to as 3DC) by Gittler (1998) assesses a person's ability to look at a cube that only has three sides showing and choose a related view of the cube after it has been rotated in space. This test is considered to be a spatial visualization test. The test has 18 questions of which 17 are scored. A sample problem from the 3DC is shown in Figure I.5 from Sorby (1990).

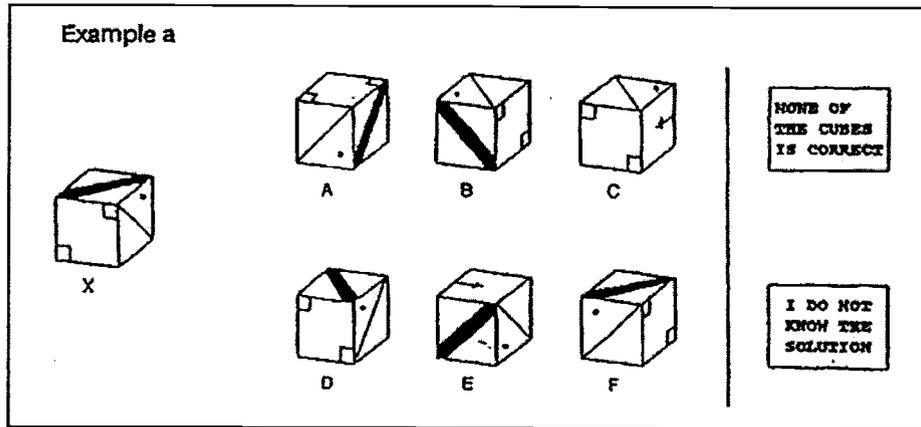


Figure I.5: 3-Dimensional Cube Test (3DC) Sample Problem

- The Form Board Test** (hereafter referred to as FBT)(*Kit of Reference Tests for Cognitive Factors*) assesses a person's ability to mentally-manipulate a pattern into other visual configurations. Of the five choices, you are to determine which would complete the outline form given. This test consists of 24 questions and is considered to be a spatial visualization test. A sample problem from the FBT is shown in Figure I.6 from Moses (1980)

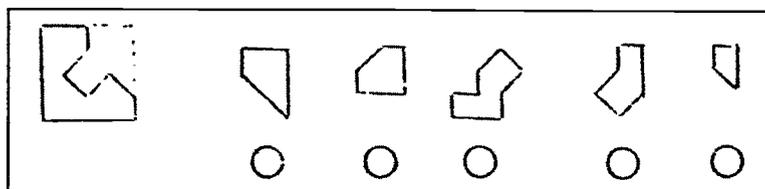


Figure I.6: The Form Board Test (FBT) Sample Problem.

- **Hidden Figures Test** (hereafter referred to as HFT)(*Kit of Reference Tests for Cognitive Factors*) assesses a person's ability to determine which of five images is embedded in another complex pattern. This test assesses spatial orientation and is of high difficulty level. The test consists of 16 questions. A sample problem from the HFT is shown in Figure I.7 from Moses (1980).

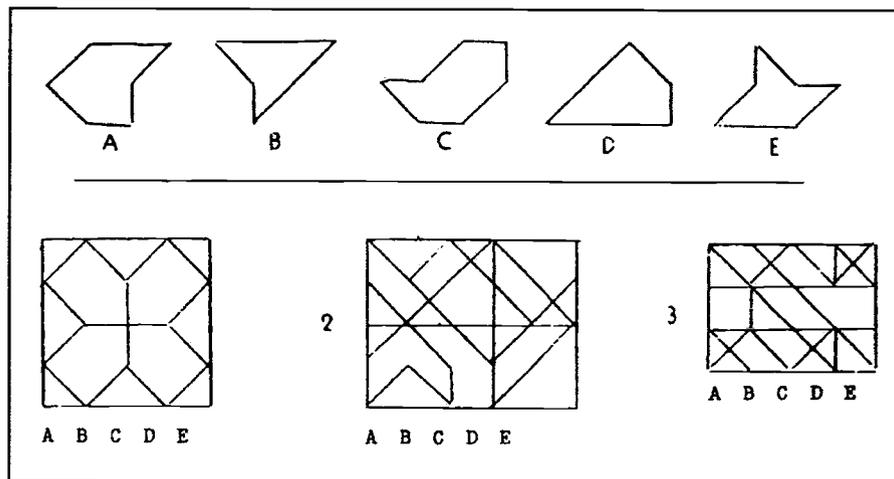


Figure I.7: Hidden Figures Test (HFT) Sample Problem

- **Punched Holes Test** (hereafter referred to as PHT)(*Kit of Reference Tests for Cognitive Factors*) assesses a person's ability to mentally-manipulate a pattern into another visual formation through folding the image. A folded image is shown with a hole punched in it and you are to determine which of five possibilities shows the paper correctly unfolded. This test has ten items and is considered to be a spatial visualization test. A sample problem is shown in Figure I.8 from Moses (1980).

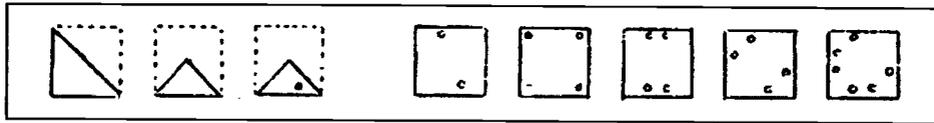


Figure I.8: Punched Holes Test (PHT) Sample Problem

- The Purdue Spatial Visualization Test: Rotations** (hereafter referred to as PSVT:R) was developed by Guay (1976) to assess a person's ability to visualize rotated solids. This test has 30 items and is scored as the percent correct. It is considered to be a spatial visualization test. A sample problem from the PSVT:R shown in Figure I.9.

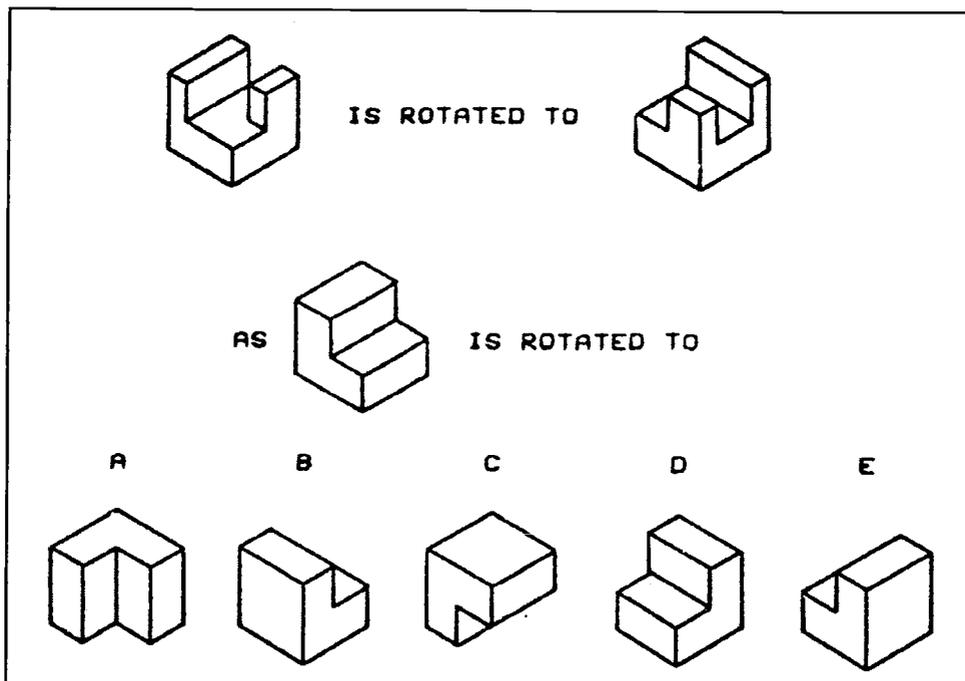


Figure I.9: Purdue Spatial Visualization Test: Rotations (PSVT:R) Sample Problem

- **The Mental Rotations Test** (hereafter referred to as MRT) was developed by Vandenberg and Kuse (1978) and consists of 20 items. Similar to the PSVT:R, this test assesses an individual's ability to mentally-rotate objects and choose correct representations of the objects after rotation. Each problem has two out of four correct possible rotations from the original figure. A sample problem from the MRT shown in Figure I.10.

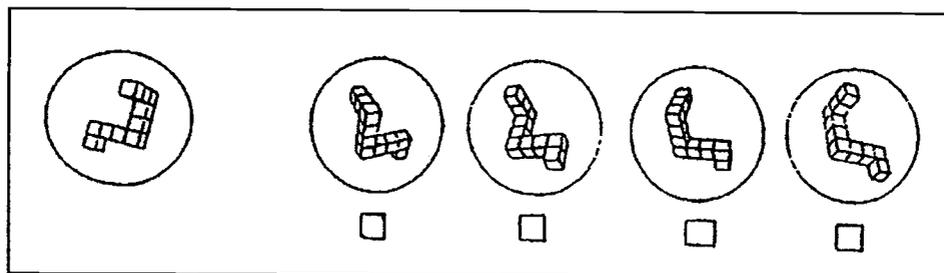


Figure I.10: Mental Rotations Test (MRT) Sample Problem

- **Mental Cutting Test** (hereafter referred to as MCT) was developed by the College Entrance Examination Board, USA (1939) and consists of 25 items. Each problem shows an original object that is to be cut with a plane. Participants must choose one correct cross section out of five choices. This is considered to be a spatial visualization problem. A sample problem from the MCT shown in Figure I.11 from Sorby (1999).

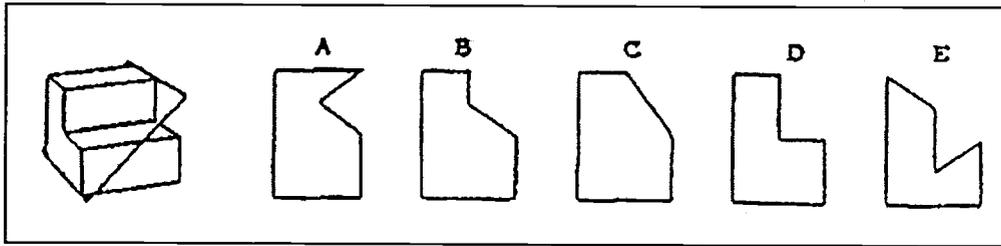


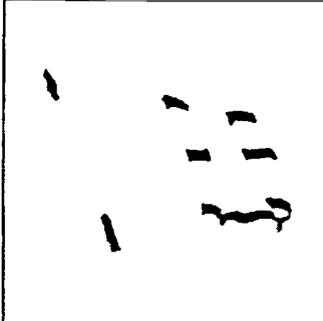
Figure I.11: Mental Cutting Test (MCT) Sample Problem

- Gestalt Completion Test** (*Kit of Reference Tests for Cognitive Factors*) is considered a spatial orientation test. This test assesses an individual's ability to mentally-see a whole, completed representation of an object given only part of the object. A sample problem from the Gestalt Completion Test is shown in Figure I.12 from Tartre (1990a).

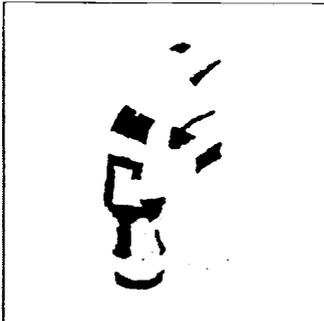
This is a test of your ability to see a whole picture even though it is not completely drawn. You are to use your imagination to fill in the missing parts.

Look at each incomplete picture and try to see what it is. On the line under each picture, write a word or two to describe it.

Try the sample pictures below:



1. _____



2. _____

(Picture 1 is a flag and picture 2 is a hammer head.)

From the *Manual for Kit of Factor-Referenced Cognitive Tests* (p. 27) by R. B. Ekstrom, J. W. French, & H. H. Harmon, 1976. Princeton, NJ: Educational Testing Service. Copyright © 1962, 1975 by Educational Testing Service. Reprinted by permission.

Figure I.12: Gestalt Completion Test Sample Problem

• **Middle Grades Mathematics Project Spatial Visualization Test** (hereafter referred to as MGMPST) The test consists of 32 problems with ten different types of items and is classified as a spatial visualization test. This test assesses an individual's ability to mentally picture an image from different points of view. For example, given the front view of an object, one may be asked to choose the side view of the object from five choices. Sample problems from the MGMPST are shown in Figure I.13.

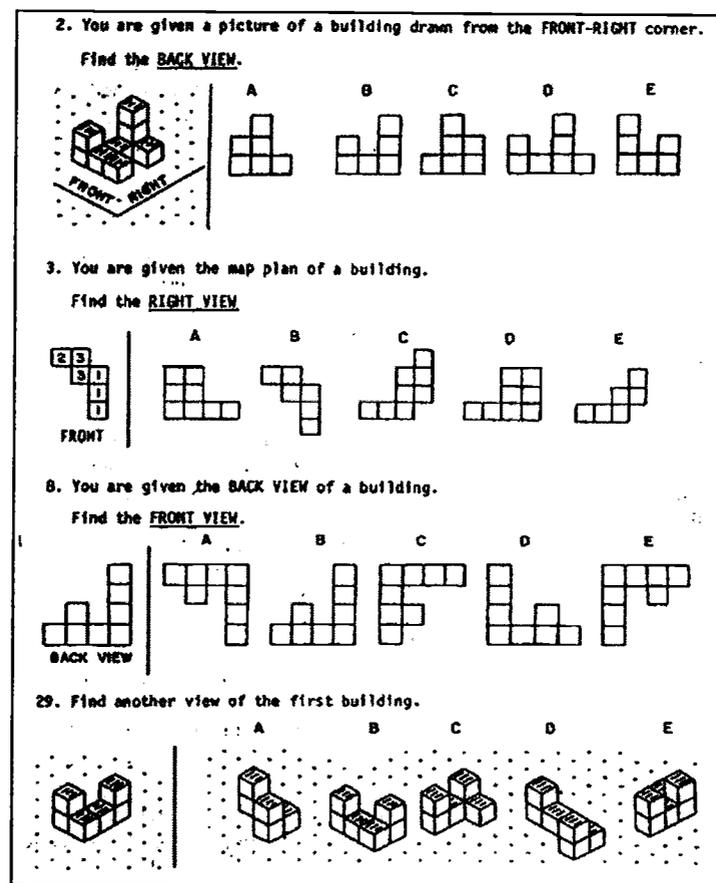


Figure I.13: Middle Grades Mathematics Project Spatial Visualization Test (MGMPST) Sample Problems

Statement of Problem

We have seen examples of how spatial abilities can lead to innovative ideas and enrich our understanding of mathematical concepts. This paper is concerned with exploring the opinions individuals have about the relationship of their spatial abilities to their past experiences and to mathematics in general. If we are to teach students spatial skills, knowing how students believe they learn spatial skills is important. Understanding the experiences of those with high spatial abilities could be very valuable in teaching and possibly improving individual's spatial skills. Discovering if certain categories of people have better spatial abilities than others is another goal of this research. The overall purpose of this study is to determine what type of people may have more developed spatial skills and what factors may be involved in achieving strong spatial skills.

CHAPTER II: REVIEW OF LITERATURE

Introduction

Researchers in the area of spatial visualization have been concerned with a variety of issues, among which are

- the relationship between spatial abilities and mathematics,
- gender differences in the area of spatial ability,
- the types of experiences that may effect one's spatial ability, and
- whether it is possible to teach spatial skills and who may benefit.

In the following studies we will find answers to these questions. These studies will also bring to light several other questions that I will address later in my research.

Research on How Spatial Ability Applies to Mathematics

Learning mathematics is a complex process; a rich understanding of many mathematical concepts involves spatial visualization. In calculus, some individuals prefer simply to learn how to compute a derivative of a function at a point algebraically or how to use the precise definition of a derivative. Others may prefer to see what the definition of a derivative is graphically and how they can visually compute the derivative of a function at a point. This graphical form of learning could be considered a type of spatial skill training. Spatial ability is not only

found in calculus, but is directly related to success in geometry, problem solving, and mathematics in general (Guay and McDaniel, 1977; Battista, 1982 & 1990; Moses, 1980; Fennema and Sherman, 1977; Fennema & Tartre, 1985; Tartre, 1990a.) Although one may benefit from spatial abilities, some researchers have found that those without high spatial ability can sometimes compensate when solving mathematical problems. (Fennema & Tartre, 1985; Tartre, 1990a.)

At the elementary level, Guay and McDaniel (1977) found a positive relationship between spatial abilities and mathematics. Their study consisted of four spatial ability tests, created by the experimenter, that were given to 90 children from the second to seventh grade. The reliability of these tests was computed using the Kuder-Richardson Formula 20 procedure and was found adequate for the study. Their results showed that on all four tests the mean score was significantly higher for the group of higher mathematics achievers than the lower mathematics achievers.

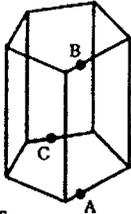
Battista (1990) found spatial visualization and logical reasoning to be significantly related to both geometric achievement and geometric problem solving for males and females. His study looked at 145 high school geometry students. They were given a spatial visualization test (a modified version of the PSVT:R), a logical reasoning test, knowledge of geometry test, and a geometric problem solving/strategies test (sample

problem from geometric problem solving/strategies test is shown in Figure II.1).

Problem

Consider the three-dimensional figure pictured below. What is the intersection of this figure and a plane that passes through points A, B, and C? Circle the letter of the best answer.

A. a triangle
B. a quadrilateral
C. a pentagon
D. none of the above



Strategy Choices
(Given on the page following the problem statement)

A. I figured that since the plane must pass through three points, the intersection would be a triangle. I did not draw on the figure, nor did I try to visualize how the plane intersected the figure.

B. I tried to logically deduce the answer based on a careful analysis of the given information. I did not draw on the figure, nor did I try to visualize how the plane intersected the figure.

C. I drew on the figure to help me visualize how the plane intersected it.

D. While looking at the figure, I tried to visualize how the plane intersected it.

E. NONE OF THE ABOVE choices accurately describes how I solved this problem. PLEASE DESCRIBE HOW YOU SOLVED THE PROBLEM BELOW.

Figure II.1: Geometric Problem Solving/Strategies Test Sample Problem

The correlation between spatial visualization and geometric problem solving as compared with the correlation between logical reasoning and geometric problem solving was very similar for students who scored at a medium or high level on the geometry achievement test. However, the correlation between spatial visualization and geometric problem solving was significantly higher than that of logical reasoning and geometric problem solving for students with low scores. Battista

(1990, Pg. 56) hypothesized that “this may be due to low-achieving geometry students taking a more visual than analytic approach to the subject.” This also suggests that both spatial ability and logical reasoning are important factors in doing well in geometry.

According to Moses (1980), spatial skills do play an important role in problem-solving performance. In her study with students ranging from fifth graders to university level, she said that those who were successful at problem solving were inclined to use visual solution processes. She used several spatial visualization tests to uncover these results. Although the tests she used were different from those tests given by the other researchers they still accurately measured spatial visualization ability among students. Battista et al. (1982) found that both cognitive development and spatial visualization are important factors in learning geometry.

Fennema and Sherman (1977) investigated gender-related differences in mathematics achievement of 1233 students in the ninth to twelfth grade. The researchers administered a variety of tests assessing math achievement, verbal ability, and spatial visualization (DAT:SR). They also focussed on variables associated with gender-related differences in mathematics achievement. One variable that proved to be a significant factor in mathematics achievement was spatial visualization.

However, in a later study, Fennema and Tartre (1985) found that students with low spatial visualization skills solved about the same amount of problems as those with high spatial visualization skills. This information may seem contradictory to what we have stated earlier, but perhaps this is because although spatial ability is related to success in mathematics, those without high spatial skills are able to use other abilities that enable them to succeed in mathematics. This study by Fennema and Tartre (1985) investigated spatial visualization skills of sixth grade students (using a portion of the DAT), mathematical achievement, and verbal skills (using a vocabulary test, cognitive abilities test, and verbal battery by Thorndike & Hagen, 1975). The subjects selected for the study were the students that had bi-polar scores on the DAT and verbal tests. The researchers categorized students into four groups: a high spatial/low verbal male, high spatial/low verbal female, low spatial/high verbal male, and low spatial/high verbal female. When the students reached the eighth grade they were re-tested with the same tests along with a random sample of students.

Fennema and Tartre found that the high spatial/low verbal students translated mathematical problems involving symbols into pictures better than the low spatial/high verbal group. They found that high spatial/low verbal students used mental movement more in solving problems than low spatial/high verbal students. The researchers also found that when using spatial visualization skills to solve mathematical

problems, the boys solved significantly more problems correctly than the girls.

From this study, the researchers concluded that despite the differences in spatial visualization skills, verbal skills, and the processes students use to solve problems, they do not differ in their ability to solve mathematical problems correctly. We have seen that Fennema believes that spatial visualization is related to mathematics achievement as stated in her study with Sherman (1977), but she also found that those without high spatial abilities can still perform well in mathematics by relying on other abilities.

With regards to spatial orientation, Tartre (1990a, pg. 227) found that, "...spatial orientation skill appears to be used in specific and identifiable ways in the solution of mathematics problems." In her study, tenth-grade students were given the Gestalt Completion Test (described earlier), and the students who scored in the top or bottom third of the distribution of scores were selected to be interviewed. Fifty-seven students were asked to do ten mathematical problems (geometric, non-geometric, visual, and non-visual) and to describe how they would solve them. The geometric non-visually presented problem described the relationships and distances among three towns and the students were to find the distance from one of the three towns to a fourth town. An example of a visually presented geometric problem is shown in Figure II.2.

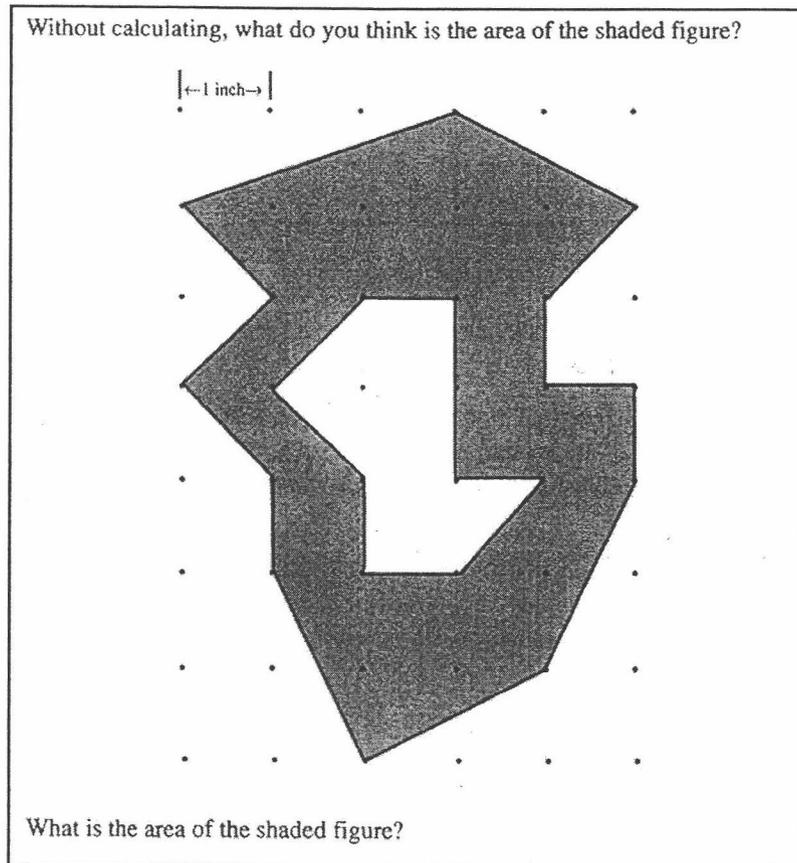


Figure II.2: Visually Presented Geometric Problem

In general, the students with higher spatial orientation were less likely to misunderstand what a problem was asking and were able to divide figures into different geometric shapes more easily than the students who had a lower level of spatial orientation. The students with higher orientation scores found the correct answer without a hint 41 percent of the time compared to only 10 percent for students with lower orientation scores. (A hint was only available in problem 6, Figure II.3).

Draw a square that has area equal to 2 square inches using four of the points below as vertices (corners).

←1 inch→

Explain how you know that the area of your figure is 2 square inches.
 (Hint given verbally if appropriate: You have used horizontal and vertical lines. Is there any other alternative?)

Figure II.3: Geometric Problem in Study by Tartre

However, once a hint was given, 56 percent of the high-spatial-orientation students and 47 percent of the low-spatial-orientation students found the solution. Tartre concluded that spatial orientation skills are used in solving mathematical problems, yet there was no significant difference in correct answers between spatial orientation groups. Students "...were able to make use of other skills, such as use of help given to them, to solve mathematical problems." (Tartre, 1990b, pg. 57)

We see that without hints, those who had higher spatial ability performed better than those with lower spatial ability. The use of a hint does not seem to be a skill but it is simply help on the problem. If the participants had been able to make use of other skills on their own, without help, then this would justify saying that there did not exist a significant difference in correctly answered problems.

As we have seen, researchers believe spatial visualization is an integral part of mathematics. Both Moses (1980) and Battista (1990) found that spatial visualization seems to have a significant correlation to geometric problems and general problem solving methods. The ability to visualize images and objects allowed students to better grasp ideas and concepts being presented. Fennema and Tartre (1985) found that students with high spatial ability were able to translate symbols into pictures more easily to aid them in solving mathematical problems. They also stated that although spatial ability relates to mathematics, those without high spatial abilities can still perform well in mathematics by relying on other abilities.

Research on Gender Differences in Spatial Ability

The relationship between gender and spatial abilities is a subject of several studies (Moses, 1982; Fennema & Tartre, 1985; Ben-Chaim et al., 1988; Sorby et al., 1999). Because it seems that spatial ability supports

success in mathematics, it would seem very plausible that if gender differences exist in spatial ability they may help explain the underrepresentation of women in mathematics.

Moses (1980) administered four spatial ability tests including the MRT, PHT, FBT, and HFT to participants from fifth-grade to post-secondary. The researcher found that at every grade level males seemed to perform better than females on each of the tests given. Moses also observed that the spatial visualization gap between males and females got noticeably wider from fifth-grade to the university level. Although he found the gap at the fifth-grade level to be insignificant, by the time an individual reached the university level that gap became significant.

Similarly, using the Middle Grades Mathematics Project Spatial Visualization Test, Ben-Chaim et al. (1988) found that there existed gender differences in fifth-grade to eighth-grade students. This test was administered at the beginning and end of an instructional period. His study found that as the students got older, the gap between spatial visualization scores increased, favoring the males. From the pre-test results, the mean score was 7.44 for the girls and 7.35 for the boys (Ben-Chaim et al., 1988). Although the girls start out slightly above the boys in fifth-grade the difference is not significant. By eighth-grade, the gap increases in favor of the boys with a mean score of 11.22 for the girls and 15.80 for the boys, according to pre-test results.

Fennema and Tartre (1985, pg. 205) found "the use of spatial visualization skills may indeed help explain the sex-related differences in mathematics, but one must never say, ..., that all girls are less able than all boys to use their spatial visualization skills appropriately in mathematics."

In looking at one more study of university level students, Sorby et al. (1999) found a significant difference in the test scores between males and females in three culturally different universities. The average test scores for males were at least ten percent higher than that of females. At a university in Germany, the average PSVT:R score for the men was 20 percent higher than that of the women. The researchers also found that women were more likely to fail (60 percent or less was considered failing) than men and at a university in Michigan where only four of the 79 students who received perfect (100%) scores were female.

Evidence has shown that there exist differences in spatial ability among males and females. We also saw that according to Moses (1980) the difference in spatial ability between males and females was almost identical while students were still in elementary school. Moses (1980) and Ben-Chaim et al. (1988) both suggested that males will eventually have higher spatial abilities than females. Determining what experiences may factor into the differences in spatial ability between males and females is of much interest and will be explored in the next section.

Research on How Prior Experiences May Effect Spatial Ability

Realizing that gender and time are possible factors in an individual's spatial ability suggests that other attributes and possible experiences could affect one's spatial ability. Cultural differences, childhood experiences, career paths, and a variety of unique backgrounds could play a role in one's spatial ability. For instance, if you grew up in a family of carpenters, you most likely would have grown up in the midst of blocks and wood pieces. Being around and playing with these three-dimensional wood pieces might have given you a better notion of rotations of solids or possible three-dimensional figures. These effects have only been studied a little, but the research is very intriguing.

Sorby et al. (1999) studied factors that may be significant in the development of visualization skills. They also examined gender differences and visualization ability of students enrolled in three different cross-cultural technical universities: Michigan Technological University (MTU) in the U.S., University of Kaiserslautern (UKL) in Germany, and Cracow University of Technology (CUT) in Poland. The PSVT:R was given to United States and Germany students, the MRT was given to Polish students, and the MCT was given to both the German and Polish students. Along with these tests, students were asked to answer questions regarding their age, handedness, childhood toy preferences,

previous instruction in geometry, occupational training, work experience, and participation in certain sports. (Sorby et al., 1999)

As stated earlier, Sorby et al. (1999) found differences of at least ten percent in the test scores between males and females at all three universities. The researchers also found that the differences in test scores between males and females were much higher in Germany than in the United States. Males were also more likely to have played with construction toys as children. In Germany males played significantly more video games than females, which was consistent with findings from a university in Brazil, Escola de Engenharia Maua (EEM) (Medina et al., 1998). In the United States and Brazil, males had previously taken design or drafting type classes more often than females. The reason we are comparing males to females in examining background experience is to find distinctions between the two sexes because males tend to score higher in the area of spatial visualization. The correlation between male dominated activities and higher spatial visualization scores could result in learning what activities may produce higher spatial abilities in people as well as how we can close the gap between males and females.

Deno (1995) also did a study of 396 engineering students enrolled in an Engineering Graphics and Problem Solving course. He used the MRT to test spatial abilities and a Spatial Experience Inventory (SEI) created by Deno. The SEI consisted of 480 spatial activities and 12 categories. The study looked more specifically at formal academic

subjects, non-academic activities, and sports. Each of these areas were broken down further into school levels (pre-school, elementary school, junior high school, and high school.) Deno found that non-academic activities seemed to have the strongest correlation to spatial visualization ability, but only for the men. Of these non-academic activities, the most significant relationship between activities and spatial ability occurred during the high school developmental period followed by the elementary developmental period. At the junior high and high school level, high correlation was found between their MRT scores and building activities such as: building race-car sets, building models, and repairing automobiles. For women, building train sets and navigating a car positively related to their performance on the MRT. The activities during the elementary period that were positively significant also consisted of building type toys such as Legos, log building sets, and art activities. For women, watching educational television and *Sesame Street* were positively significant factors.

Although the studies by Sorby et al. (1999), Medina et al. (1998), and Deno (1995) all involved university students specifically in the field of engineering, Guay (1978) had very similar results for a general population of university students. He also found that students with prior experience in areas that are thought to be spatially oriented did better on the spatial tests than students without these types of experiences.

McDaniel et al. (1978) also created a Spatial Experience Questionnaire which was given to 242 university students in an introductory psychology course. Spatial visualization was based on the ability to perform four tasks at the end of the questionnaire: constructing a mental map of a city, mentally manipulating a mathematical equation, visualizing the rotation of a cube, and determining the direction of one's parked car while inside an unfamiliar building. The researchers found that for males, making or repairing furniture, playing pool, reading a map or using a compass, and using machine tools were influential activities in determining spatial scores. For women, sketching house plans, using hand tools, skiing, putting together jigsaw puzzles, building models, weaving or macrame, and reading a map or using a compass were influential activities in differentiating between high and low spatial ability. This shows that there are activities that both males and females do that positively influence their spatial ability.

These studies have shown that past experiences can play a role in spatial ability. Males seem to generally do better in spatial visualization than females and males also seem to have played more with construction toys. Males in the engineering fields have also worked more with drafting than females. The studies also found that males tended to play more video games than females which positively influenced males spatial ability. All these areas that men participated in seem to have a connection to spatial visualization. It seems that construction toys, video

games, and drafting all have three-dimensional aspects to them that apparently helped in the male's spatial abilities.

Research on Instruction in Spatial Skills

We have seen that most researchers believe that spatial ability is an important factor to the success in mathematics. We have also seen that gender differences exist in spatial ability and that different experiences relate to one's spatial ability. Combining these ideas, we can consider the notion of teaching spatial ability. If we want to have better mathematics students, then increasing their spatial ability could help increase their mathematics achievement. Through instruction it may be possible to decrease the gender differences in spatial ability using those experiences that have been found to correlate to higher spatial ability. Interesting findings have been made in this area by numerous researchers. (Moses, 1980; Battista et al., 1982; Ben-Chaim et al., 1988)

Moses (1980) investigated, among other things, whether instruction in visual thinking tasks affects problem solving performance. Her research involved 170 students from eight separate classes: two fifth-grade classes, four ninth-grade classes, and two university classes. Students were given a set of pre-tests, followed by 12 weeks of instruction in spatial visualization, and then a set of post-tests which were the same as the set of pre-tests. The set of pre/post-tests consisted

of four spatial visualization tests (the MRT, PHT, FBT, and HFT), two reasoning tests, and a problem-solving test. Moses was the instructor for the 12-week period and she focused on three types of visual thinking: seeing, imagining, and drawing. She had students compare different three-dimensional objects such as cylinders, cones, and cubes. She also had the students rotate some of the objects as well as reconstruct objects with paper or clay. The students worked with two-dimensional figures, creating different types of polygons as well as finding hidden shapes and symmetrical qualities. Everything was a hands-on experience in the sense that all facets of instruction used objects that the students could hold and manipulate with their hands. Drawing these objects and configurations of objects was encouraged in each situation.

In analyzing the data, Moses found that instruction in visual thinking tasks positively affected spatial ability and reasoning ability. This suggests that spatial ability is a learned concept and not simply genetic as some have conjectured (Yen, 1975). However, instruction did not affect problem-solving performance or the use of visual solution processes.

Another study was done to determine whether pre-service elementary teachers could improve their spatial ability by taking an informal geometry course that emphasized spatial activities (Battista et al., 1982). At the beginning and end of a 15-week period, 82 students, pre-service elementary teachers, were given the PSVT:R. The students

also took the Longeot test of cognitive development at the end of the 15-week period. Students performed numerous spatial activities during the instruction. Some of these activities were very similar to those used by Moses (1980). Symmetries, manipulation of three-dimensional solids, and tessellations were just a few of the methods used to demonstrate geometric concepts.

Spatial visualization scores of pre-service elementary teachers significantly increased from the beginning of the semester to the end. (Battista et al., 1982) This research further asserts the prominence of both cognitive development and spatial visualization in the learning of geometry.

According to Moses (1980) the gap in spatial visualization scores between males and females increases from second grade to university level students. We can hypothesize that this is due to experiences they have encountered or possibly due to age and cognitive development. Is there a way to minimize this gap? Instruction in spatial ability is possible and is effective in increasing scores, but scores increase equally for both males and females. Ben-Chaim et al. (1988) recorded the pretest and posttest scores of fifth-grade to eighth-grade students. From the researchers' results, both males and females increased in spatial visualization, but the increases were equal, leaving the gap between their scores the same from pre-test to post-test. What was even more interesting is that the students, both male and female, retained their

spatial abilities when tested four weeks later and even a entire year later (Ben-Chaim et al., 1988). This is another indication that spatial abilities are traits that can be strengthened through instruction and training.

Both Moses (1980) and Battista et al. (1982) indicated that spatial visualization can be taught. They even suggested methods of instruction designed to increase spatial abilities in those who took the courses. Spatial ability was almost identical in elementary school but a gap was created by the time students reached the university level. (Moses, 1980) The gender differences in spatial abilities seem to begin around adolescence. This may be the time where spatial ability needs to be taught and possibly incorporated into a curriculum.

Conclusion

The phrase "seeing is believing" takes on more than one meaning with this topic. Spatial visualization seems to be involved in everything from playing with toys to solving mathematical problems. It is used at early ages and by those who have had significant amounts of schooling. How a person acquires spatial ability, what spatial ability influences, and who excels in spatial ability are still somewhat unclear. Studies have shown that spatial ability plays a role in success in mathematics, males have better spatial abilities than females, and instruction in spatial ability is possible. Researchers are still debating what types of

experiences and backgrounds effect one's spatial ability. Do one's major, gender, or math skills affect their spatial ability or is it the other way around?

There still remain unanswered questions and the purpose of this study is to answer some of them:

- 1.) In looking at one's background, who was better at spatial visualization? Science majors versus non-science majors? Males versus females? Faculty versus students?
- 2.) What experiences did the examinees feel were reasons for their perceived success or failure in spatial ability?
- 3.) In what ways did the examinees feel spatial ability related to their success or lack of success in mathematics?

CHAPTER III: RESEARCH DESIGN AND METHODS

Introduction

Researchers have been studying the ideas of spatial abilities for decades and there is still controversy over many of the issues relating to this area. This study addresses some of those issues and attempts to answer the following three questions:

- 1.) In looking at one's background, who is better at spatial visualization?
Science majors versus non-science majors? Males versus females?
Faculty versus students?
- 2.) What experiences did the examinees feel were reasons for their perceived success or failure in spatial ability?
- 3.) In what ways did the examinees feel spatial ability related to their success or lack of success in mathematics?

Subjects

We have cited research on the spatial abilities of elementary and high school age students (Seng & Chen, 2000; Moses, 1980; Guay & McDaniel, 1977), engineering students (Sorby et al., 1999; Devon et al., 1998; Medina et al., 1998), and geometry students (Battista, 1990; Battista et al., 1982). The purpose of this study is to look at a general population of university students and faculty, and to compare specific

subgroups within the population. Seventy-six students and 22 faculty from a Pacific-Northwest university participated in this study.

In selecting the students, five upper-level classes were approached and asked for volunteers to participate in the study. The five classes were in art, English, history, chemistry, and mathematics. Very few volunteers came from those classes so two more classes were approached, a sophomore-level psychology class and a sophomore-level mathematics class. The professors in both the psychology and mathematics classes offered their students some extra credit if they participated in the study. Consequently, these classes produced a majority of the student subjects.

The sample of students consisted of 28 females and 48 males where 41 were science majors and 35 non-science majors. The faculty members were from the art, English, history, chemistry, and mathematics departments on the same campus. Participation was completely voluntary for the faculty members in this study as well. The sample of faculty consisted of eight females and 14 males where 11 were in a scientific field and 11 in a non-science field. Those fields of study that were classified in the science groups were biology, mathematics, engineering, chemistry, architecture, computer science, biology, pre-medical, and pre-dental. The non-sciences consisted of individuals in the areas of anthropology, art, behavioral sciences, business, communications, exploratory studies, elementary education, food

sciences, human development and family studies, history, liberal arts, psychology, zoology, and undecided.

Instruments

As mentioned earlier, there are many instruments that test spatial ability, the PSVT:R, MRT, DAT:SR, 3DC, FBT, and HFT are only a few. In this study, spatial ability was measured by using a Spatial IQ test by Crampton (2000). This test was chosen, as opposed to the aforementioned tests, because of its integration of numerous aspects of spatial visualization and spatial orientation. It was important to the researcher to test all aspects of spatial ability. The MRT for example, may test one's ability to mentally rotate solids, but it fails to test the ability to fold two-dimensional objects in three-dimensional space. The 3DC may assess a person's ability to picture cubes and what they may look like on all sides, but fails to test how one may manipulate a solid or fold an image mentally. The spatial IQ test actually incorporates aspects of all six tests. (Appendix B)

The reliability of this test has not yet been determined. However, we found the figures to match those of other tests of this nature. Problems one and nine were very similar to problems on the DAT:SR. Problems two, three, and eight were all problems similar to that on the MRT and PSVT:R. Problems four and ten were similar to those on the

HFT and problem five was similar to the FBT but in three-dimensions. Problems six and seven were similar to those on the 3DC test.

After completing the Spatial IQ test, participants also completed a questionnaire. The questions ranged from basic information such as gender, major, and age to questions about past experiences that may have been perceived to contribute to their spatial ability. (Appendix B)

Instruction of study

All the students who volunteered for the study came to one of two scheduled periods to take the Spatial IQ test and answer the questionnaire. Students were allowed up to 50 minutes to take the test and finish the questionnaire, but all participants finished under the allotted amount of time. The faculty members were all given Spatial IQ tests in their campus mailboxes along with the questionnaire.

Instructions were attached to the test informing them of the time limit, where to return the test when completed, and other information that was verbally announced to the students during their testing time. The tests were sent to the faculty mailboxes due to time constraints that many faculty have.

Data Collecting/Analysis

Once the Spatial IQ tests and questionnaires were collected and returned, analysis of the data began. A qualitative analysis was done on the data to answer the intended questions of this study. The answers to every problem and question were recorded on spreadsheets. A binomial distribution was done on each of the problems to test whether they were valid or whether participants simply guessed randomly. Statistical comparisons were then made between the following subgroups: males, females, faculty, students, sciences, non-sciences, and combinations of these. A t-test was performed on each comparison to determine statistical significance. The open-ended questions were analyzed to categorize comments and note unique remarks. The information was finally organized in order to address each question of this study.

Summary

In testing both university students and university faculty, the study allowed for a strong analysis of spatial ability within a particular field of study. It also provided information addressing the influences of past experiences on the spatial abilities of the participants. It is important to note that all student and faculty participants in this study had a minimum of 18 years of experience, which is significantly more than the shorter time span of experience noted by elementary school

students. The qualitative analysis of this research furnishes us with a fascinating view of what role spatial visualization plays in the lives of mathematicians, scientists, and non-scientists.

CHAPTER IV: RESULTS

Introduction

In part, the results of this study corroborated results of earlier studies and addressed the following three questions:

- 1.) In looking at one's background, who is better at spatial visualization?
Science majors versus non-science majors? Males versus females?
Faculty versus students?
- 2.) What experiences did the examinees feel were reasons for their perceived success or failure in spatial ability?
- 3.) In what ways did the examinees feel spatial ability related to their success or lack of success in mathematics?

Group Comparisons

A t-test was performed on each of the following comparisons to determine statistical significance. Comparisons of males, females, science, non-science, faculty, students, and combinations of these were performed. The only comparisons that were found to be statistically significant or practically significant involved the faculty-science group.

(Table IV.1)

Significant t-test values (# of participants)	Mean	p-value
Faculty-Science (11)	6.91	
Student-Science (41)	5.73	p=0.057
Student-Non-Science (35)	5.57	p=0.037
Student-Male (48)	5.77	p=0.063
Student-Female (28)	5.63	p=0.029
Faculty-Non-Science (11)	5.18	p=0.019

Table IV.1: Significant t-test values when compared to the Faculty-Science Group

The faculty-science versus the faculty-non-science group had the greatest statistically significant results. Although the comparisons in Table IV.1 were the only comparisons found to be statistically significant, we did find many interesting trends in the data. These trends are what we will consider in this chapter. Further speculation as to why the other comparisons were not statistically significant will be discussed in the next chapter.

In this study, the mean score for all 76 students was 5.66. Science majors had a higher mean score on the Spatial IQ test than non-science majors as shown in Table IV.2. Although the mean score was very close, the percentage of science majors at or above the average (this was considered scoring a five or better) was six percent higher than that of the non-science majors. In the same type of comparison, males had a slightly higher mean score than females, but the percentage of males at or above the mean was 83.3 percent whereas there were only 67.9 percent of the females at or above the mean.

STUDENTS		Mean	At or Above Mean (scores of 5 or more)
Total	(76)	5.66	77.6%
Science	(41)	5.73	80.5%
Non-Science	(35)	5.57	74.3%
Male	(48)	5.77	83.3%
Female	(28)	5.63	67.9%

Table IV.2: Science vs. Non-Science and Male vs. Female Mean Scores of Students

Table IV.3 shows similar results for the faculty, however, the mean score for all 22 faculty members was 6.05. In the faculty group, those individuals in a scientific field had a mean of 6.91 compared to a mean of 5.18 for non-scientific faculty. Even more interesting is the difference in the percentage at or above the mean (this was considered to have a score of six or more for the faculty). There was an approximate 36 percent difference in the number of scientific faculty at or above the mean than the non-scientific faculty. This is also the comparison that had the greatest statistically significant difference as shown in Table IV.1. When comparing male faculty to female faculty, there was another noticeable difference. Males had a mean score of 6.29 as compared to females with a mean of 5.63. The male faculty also had approximately 21 percent more scores at or above the mean than female faculty.

FACULTY	Mean	At or Above Mean (scores of 6 or more)
Total (22)	6.05	63.6%
Science (11)	6.91	81.8%
Non-Science (11)	5.18	45.5%
Male (14)	6.29	71.4%
Female (8)	5.63	50.0%

Table IV.3: Science vs. Non-Science and Male vs. Female Mean Scores of Faculty

In comparing the faculty to the students, the faculty had a higher mean than the students, 6.05 to 5.66 respectively (Table IV.4). The male faculty in the sciences also had a higher mean score than students with science majors, 6.91 to 5.73 respectively. However, the reverse happened for non-science individuals. The non-science faculty had a lower mean than the non-science students. Comparing male faculty to male students shows that the faculty had a mean of 6.29 and the students a mean of 5.77. However, the female faculty and the female students had the same mean of 5.63. As we saw in Table IV.1, the science-faculty had statistically significant differences when compared to non-science students and female students. The science-faculty also had t-test values that were very close to being statistically significant when compared to the science students and male students.

	Total (# of examinees)	Science	Non-Science	Males	Females
Faculty	6.05 (22)	6.91 (11)	5.18 (11)	6.29 (14)	5.63 (8)
Students	5.66 (76)	5.73 (41)	5.57 (35)	5.77 (48)	5.63 (28)

Table IV.4: Mean Scores of Faculty Versus Student in Sciences and Gender

The comparison of Science-Male (SM), Science-Female (SF), Non-Science-Male (NSM), and Non-Science-Female (NSF) was also considered for the 76 students, shown in Table IV.5. The mean score for SM compared to SF was almost identical. Those at or above the mean for SM was about 11 percent higher than the SF. For NSM, their mean score was 5.86 compared to NSF of 5.38. A considerable difference of about 19 percent, favoring the NSM, was found in the percentage of scores at or above the mean. An interesting comparison here is that NSM actually had a slightly higher mean score than SM. They also had a higher percentage of scores at or above the mean, by about three percent. The NSF had slightly lower mean scores than the SF with the percentage of scores at or above the mean favoring the SF by about five percent.

Further results were found for the 22 faculty, shown in Table IV.6. Just as with the student's scores, the faculty's SM mean score was fairly close to the SF mean score. An interesting observation is that out of the four NSF, only one scored at or above the mean whereas out of the four

SF, three scored at or above the mean. The SM also had a much higher mean score than the NSM and NSF.

Student Science/Gender	Mean	At or Above Mean (scores of 5 or more)
Total (76)	5.66	79.0%
Science-Male (34)	5.74	82.4%
Science-Female (7)	5.71	71.4%
Non-Science-Male (14)	5.86	85.7%
Non-Science-Female (21)	5.38	66.7%

Table IV.5: Mean Scores of Students: Science-Male vs. Science-Female vs. Non-Science-Male vs. Non-Science-Female

Faculty Science/Gender	Mean	At or Above Mean (scores of 6 or more)
Total (22)	6.05	63.6%
Science-Male (7)	7.00	85.7%
Science-Female (4)	6.75	75.0%
Non-Science-Male (7)	5.57	71.4%
Non-Science-Female (4)	4.50	25.0%

Table IV.6: Mean Scores of Faculty: Science-Male vs. Science-Female vs. Non-Science-Male vs. Non-Science-Female

Comparisons between faculty and students in the areas of Science-Male (SM), Science-Female (SF), Non-Science-Male (NSM), and Non-Science-Female (NSF) were also found (shown in Table IV.7). The faculty's mean scores were higher than students' mean scores for both males and females in the sciences. However, the opposite was true for

the non-sciences. Both males and female faculty had lower mean scores than the students in the non-sciences.

Sciences/ Gender	Total (# of examinees)	Science Male	Science Female	Non-Science Male	Non-Science Female
Faculty	6.05 (22)	7.00 (7)	6.75 (4)	5.57 (7)	4.50 (4)
Students	5.66 (76)	5.74 (34)	5.71 (7)	5.86 (14)	5.38 (21)

Table IV.7: Mean Scores of Faculty Versus Student: Science-Male vs. Science-Female vs. Non-Science-Male vs. Non-Science-Female

An analysis was also made on the different fields of engineering students and how they compared to one another (Table IV.8). Overall, they were fairly close, however, computer engineers did have a much higher mean than the other areas of engineering: 90.9 percent of the computer engineering students scored at or above average. Those engineer majors in the "other" category were electrical, general, and unspecified fields of engineering. The reason the electrical engineering was combined with the "other engineers" category is because only one electrical engineer participated in the study.

Student Engineer Major	Mean	At or Above Mean (scores of 5 or more)
Total (32)	5.66	79.0%
Civil Engineers (6)	5.33	83.3%
Computer Engineers (11)	6.18	90.9%
Mechanical Engineers (6)	5.67	66.7%
Other Engineers (9)	5.33	75.0%

Table IV.8: Mean Scores of Student Engineering Fields vs. Each Other

When comparing results for faculty by fields of study, the results are similar results to the science versus non-science comparisons. The chemistry faculty had the highest mean score of seven and the history faculty had the lowest mean score of four. Math and "other" fields had a mean score of 6.5 or better while English was at 5.29. Those in the "other" category consisted of art, bio-mechanics, and other because only one individual from each of those fields participated in the study. These results are shown in Table IV.9.

Faculty Fields of Study	Mean	At or Above Mean (scores of 6 or more)
Total (22)	6.05	63.6%
Chemistry (6)	7.00	83.3%
English (7)	5.29	57.1%
History (2)	4.00	0.0%
Math (4)	6.50	75.0%
Other (3)	6.67	33.3%

Table IV.9: Mean Scores of Faculty Fields of Study vs. Each Other

Another interesting result not shown in the above tables is that only one student received a nine out of ten and that student was in the sciences and was a male. On the other end, the only student to receive a score of one out of ten was a student not in the sciences and was a female. Similar results were found in the faculty as well. Two faculty members scored a nine out of ten and those two faculty members were

males in the sciences. The lowest score for the faculty was a three out of ten scored by a female not involved in a scientific field of study.

Overall, males tended to score higher on the Spatial IQ test than females both at the university level as well as the faculty level, with the exception of female-science-faculty over male-science-students. It was also found that both students and faculty in the sciences scored higher on the test than those not in the sciences. Male and female faculty members in the sciences scored better than students on the Spatial IQ test. However, students in the non-sciences scored better than the faculty in the non-sciences.

Analysis of Specific Problems on the Spatial IQ Test

Taking a closer look at each individual problem, some interesting results were found. Over half of the 76 students correctly answered problems one through three and five through eight. Eighty-two percent answered problem one correctly, 89 percent answered problem five correctly, and 79 percent correctly answered problems six. However, only 25 percent answered number four correctly, only 29 percent answered problem nine correctly, and only 30 percent answered number ten correctly.

Similar results were found with the faculty's scores. More than half of the 22 faculty members correctly answered all problems except

numbers four and ten. Problem number five was answered correctly by 100 percent of the faculty members. Number four was answered correctly by only two of the 22 faculty (nine percent) and number ten was answered correctly by only five of the 22 faculty (23 percent). Both faculty and students apparently found problems four and ten to be difficult. This is interesting, considering that these two problems are both similar to problems on the Hidden Figures Test and the only two spatial orientation problems on this test. (According to Ekstrom et al. (1976), the HFT is classified as a spatial orientation test as opposed to a spatial visualization test.)

The mean score for those students who did get number four or number ten correct was 6.16 and 6.65, respectively. The mean score for those who got both correct, only four of the 76 students, was 7.5. Remember that the mean score for all 76 students was 5.66. The mean score of the two faculty members (both in the non-sciences, one male and one female) that got number four correct was only 5.0 whereas the mean score of the five faculty members that answered number ten correctly was 7.6. None of the faculty answered both correctly.

Results From the Questionnaire

This questionnaire enables us learn what individuals feel is related to their success or lack of success in spatial ability and mathematics. It

helps us determine what experiences may benefit an individual in the area of spatial skills. The questionnaire was also designed to give the researcher information about whether individuals felt that they could be taught spatial ability or not.

Question #1: If you felt you did poorly, what do you think the reason for that was? If you felt you did well, what past experiences/classes may have contributed to your ability to do well on this test?

Generally, students who felt they did well on the test attributed their success to: math classes (6), geometry classes (5), art classes (3), computer modeling (3), drafting (2), and puzzles/games (2). Other unique answers were Legos, oragami, construction, wood-working, and playing with blocks as child. Faculty members also mentioned puzzles/games (3), geometry (2), as well as oragami (1) and construction (1). Students who felt they did poorly listed reasons such as: not understanding the patterns (9), being bad at math (2), and not having enough patience (1). There were also many students who simply stated that they were not visual and felt that this was the reason they did poorly on the test. Faculty members also mentioned inability to project patterns (3) and impatience (1).

Question #2: What do you think would have or would help you to do better on a test of this nature?

Over 20 percent of the students felt that practice in this area would help with spatial visualization. Over 20 percent also felt that the use of objects and being able to touch and manipulate the figures would help them to succeed better in spatial visualization. Other answers listed were drawing, art courses, geometry, and more explanation or instruction on each problem. One student said that, "I think that more practice and a better understanding of shapes and their movement would have helped."

Question #3: When attacking a math problem what is the first thing you usually do?

Over 25 percent of the examinees stated a type of visual approach as a starting point to solving a mathematical problem. Such approaches were to write everything down, draw a picture, visualize the problem, or graph the problem. Over 30 percent of the examinees said that they started by thinking about the process in their heads and trying to figure out what the problem was asking and what tools to use in solving the problem. One faculty member stated, "I try to visualize even if it's seeing numbers or shapes in my head."

Question #4: Do you think being able to see 3-D spatial images would help you in a math class? Why?

Over half of the students felt that spatial ability would help in a math class. Less than ten of the 76 students felt that spatial ability did not play a role in math and about 15 percent said that it depended on the class. Here are some quotes from the students' answers to this question:

- “Yes, if you can visualize what you are calculating then it makes it easier to understand the concept.”
- “Yes, it would make more sense to me. Often I just memorize numbers, but if I saw images in 3D I could get the concept better”
- “Yes, it provides a greater understanding of geometry and problem solving.”
- “It definitely helps in MTH 252 (*Integral Calculus*) but it would also help with problem solving ability and logic which would help with math.”

One professor stated, “In some math classes, would give a more ‘complete’ perspective.”

CHAPTER V: DISCUSSION

Discussion

We have defined spatial ability as consisting of two factors: spatial visualization and spatial orientation (McGee, 1979). Spatial visualization requires the act of manipulating or creating an object and rotating it, whereas spatial orientation requires the ability to see that the images have moved and to understand the correlation between rotations. In this study we saw significant differences in the examinees' ability to perform spatial visualization and spatial orientation skills. If we exclude student performance on problem nine, at least 50 percent of the students and faculty answered problems associated with spatial visualization correctly. The examinees performed very poorly on the two spatial orientation problems on the test, problems four and ten. According to the binomial distribution done on these problems, both were found to be valid problems. Those who answered one of the two questions correctly tended to score better on the test, with the exception of the two faculty members that got number four correct; their mean score was five. This may lead us to believe that spatial orientation is a higher ability than spatial visualization. Since spatial orientation deals with understanding the connection between two images, these results may simply tell us that spatial orientation requires more logical thinking than does spatial

visualization. In either case, further research is needed to answer this question.

In comparing the different groups, very few groups have statistically significant differences. This may be due to many factors such as the level of education of the participant, the fact that participants were volunteers, sample size, or the number of questions on the test. The participants in this study are all better educated than a group drawn randomly from the general population because they are part of the university system. The participants were also volunteers, creating the possibility that those who felt they had poor spatial abilities decided not to volunteer and the tested population was then skewed. The other factor could have been the sample size. Although 76 students is a decent sample size, 22 faculty may not have been sufficient to create statistical significance. The last factor could have been that more than ten problems might have been needed to determine one's spatial ability and create statistically significant differences. In any case, we will focus on the trends shown in the data.

In this study, the mean score for males, both faculty and students, was higher than that of female participants. This is consistent with findings by many other researchers (Moses, 1982; Fennema & Tarte, 1985; Ben-Chaim et al., 1988; Sorby et al., 1999). However, in one comparison, science faculty females scored higher than all students including student-science males. This implies one of two things: either

experiences and exposure to the sciences creates higher spatial ability; or females with high spatial abilities chose a scientific field. It is also possible that both factors are significant in this result.

This study also found that female faculty and female students had an identical mean score on the spatial IQ test. They both had a mean of 5.63 whereas male faculty members' mean score was higher than male students. Yet, results did show that in the sciences, female faculty had higher mean scores than female and male science students. In the non-sciences, the reverse was true, female faculty had lower mean scores than females and males in the non-sciences. Similar results held true for male faculty. Male science faculty had higher mean scores than anyone, and in the non-sciences, male faculty had lower scores than male students. This suggests similar implications as above: the use of spatial skills may increase as one engages in a scientific field and may decrease as one engages in a non-scientific field; or individuals gravitate to a scientific field because of their high spatial abilities or a non-scientific field because of their low spatial abilities. The fact that the only statistically significant results came from the comparisons involving faculty in the sciences reinforces these two implications.

We can only speculate that spatial abilities increase while one is engaged in a scientific field because our faculty participants are not the same people we tested as university students. (In other words, this study was not developed to follow the university students into their later

professions. Time and the limitation of this study do not permit us to test the student participants again to find whether their spatial ability would increase or decrease over time or how the change in their abilities would correlate to the field they might choose as a career. However, this is something that future researchers might want to consider testing.) In considering the idea of an individual decreasing in spatial ability, we must remember the study by Ben-Chaim et al. (1988). The researchers in this study found that both males and females retained their spatial ability over time. However, the students were children, fifth graders and eighth graders, and they were followed for only one year. By the time these eighth graders grew to the age of the faculty in this study we might find that, without the constant use of and exposure to spatial skills, retention might decrease over time. Another explanation for students in the non-sciences having higher scores than the faculty in the non-sciences could be that the students are still exposed to the use of spatial skills through other required courses, with the exception of female-non-science students which were not higher than male-non-science faculty. This implies that work in scientific fields may indeed be a factor to higher spatial ability.

Some fields of study seem to require more spatial ability than others. Comparing student engineer majors, computer engineers seemed to have much higher spatial ability than the other engineer majors. Norman (1994) found that the key difference to a person's ability to work

with computers is their spatial skill level. In comparing faculty fields of the current study, chemistry had a higher mean and percentage of people at or above average than the other fields of study. This suggests that well developed spatial skills may be essential for understanding basic chemistry and structural chemistry.

This study also analyzed student reports of the experiences they felt may have contributed to their spatial ability. The only student who received a nine out of ten on the test said that he felt the reason he did well on the test was due to the fact that he had, "...taken a number of hands on style geometry classes." The only student that received a one out of ten on the test said that, "I think I did poorly because I have always done terrible in geometry and anything involving shapes or predicting outcomes. I am not good at visualizing objects." This information gives us a basis for creating more specific questions enabling us to better test for the correlation between experiences and spatial ability. The information might also enable us to answer the question, "What affects an individual's spatial ability?" If we find what affects spatial ability, it may in turn help us understand what experiences may improve student understanding in mathematics.

The present study shows some very interesting responses from the students regarding the correlation between mathematics and spatial visualization. The student who received a nine out of ten said that being able to see 3-D spatial images, "...provides a greater understanding of

geometry and problem solving.” The other student participants in this study stated that they felt spatial visualization would help them succeed in mathematics and believed practice would increase their spatial skills. Teaching spatial skills might be helpful. Over 30 students stated that they used a type of visual approach when asked, “When attacking a math problem what is the first thing you usually do?” If visual approaches are viable starting points when solving mathematics problems, then improving spatial ability would help students become better problem solvers. Over 30 students made statements emphasizing the re-reading of the problem, trying to figure out what it is asking, and trying to think of solution strategies. Spatial ability is a tool that can give students a basis to start from and an aide in solving mathematical problems.

Limitations of Study and Implications/Recommendations for Future Studies

Data collected for this study did not directly address the effects of instruction on spatial ability or the effects of spatial ability on success in mathematics. Although, in the questionnaire, participants did state their beliefs about what affected their spatial ability and whether they thought spatial ability was related to success in mathematics. The information gathered in this study could be very valuable to future researchers as well as instructors. In future studies, it would be interesting to see if students’ spatial abilities increase because of experiences in topology or

geometry courses. For instance, one could give a spatial test at the beginning and end of a geometry sequence and determine whether work in geometry affects one's spatial abilities. Similar studies have been done (Battista et al., 1982) but never with university students. It would also be of interest to track students over a longer time interval, possibly a decade, and to see if spatial abilities are retained and what factors influence growth or retention of these abilities.

Further research into the differences between spatial visualization and spatial orientation would be very fascinating. Understanding influential factors in an individual's spatial ability could give us a better idea of how students develop spatial ability. This information could be used to create instructional material for the purpose of enhancing students' spatial abilities. Realizing that spatial ability differs in students and that spatial ability relates to mathematics achievement is a great benefit to the instructor.

Conclusion

We have seen that spatial ability can play a role in understanding and succeeding in mathematics. Researchers found that spatial ability does relate to mathematics and males tend to have greater spatial ability than females. Instruction has also been shown to be successful in helping individuals learn spatial skills.

Although not all the results in the current study were statistically significant they tend to agree with earlier studies that found gender advantages in spatial abilities favoring males over females. They also provide evidence of the existence of greater spatial abilities among participants who are engaged in scientific rather than non-scientific pursuits. The participants in this study also reported experiences, such as math and art classes, computer modeling, and construction, that they believed influenced success or failure in tasks requiring spatial ability. Over half of the students felt that spatial ability would help them in mathematics and believed spatial ability related to their success or lack of success in mathematics. This reveals that spatial ability does differ in individuals; that there exist experiences that individuals feel are important for developing spatial ability; and that spatial ability relates to mathematics. This information can be beneficial to both teachers and researchers.

BIBLIOGRAPHY

- Battista, M. T. 1990. Spatial Visualization and Gender Differences in High School Geometry. *Journal for Research in Mathematics Education*, Vol. 21, No. 1, 47-60.
- Battista, M. T., Wheatley, G. H., and Talsma, G. 1982. The Importance of Spatial Visualization and Cognitive Development for Geometry Learning in Preservice Elementary Teachers. *Journal for Research in Mathematics Education*, Vol. 13, No. 5, 332-340.
- Ben-Chaim, D., Lappan, G., and Houang, R. T. 1988. The Effect of Instruction on Spatial Visualization Skills of Middle School Boys and Girls. *American Educational Research Journal*. Spring, Vol. 25, No. 1, 51-71.
- Bennett, G. K., Seashore, H. G., and Wesman, A. G. 1972. *Differential Aptitude Tests: Form S*. New York, New York: The Psychological Corporation.
- Crampton, A., Jerabek, I. (2000). Spatial IQ Test. Body-Mind QueenDom, http://www.queendom.com/tests/iq/spatial_iq.html
- Deno, J. A. 1995. The Relationship of Previous Experiences to Spatial Visualization Ability. *Engineering Design Graphics Journal*. Autumn, Vol. 59, No. 3, 5-17.
- Fennema, E., and Sherman, J. 1977. Sex-Related Differences in Mathematics Achievement, Spatial Visualization and Affective Factors. *American Educational Research Journal*. Winter, Vol. 14, No. 1, 51-71.
- Fennema, E., and Tartre, L. A. 1985. The Use of Spatial Visualization in Mathematics by Girls and Boys. *Journal for Research in Mathematics Education*, Vol. 16, No. 3, 184-206.
- French, A. P. 1979. *Einstein: A Centenary Volume*. Cambridge, Massachusetts: Harvard University Press, 297.
- French, J. W., Ekstrom, R. B., Price, L. A. 1963. *Manual for Kit of Reference Tests for Cognitive Factors*. Princeton, New Jersey: Educational Testing Service.

- Guay, R. 1976. Purdue Spatial Visualization Test. West Lafayette, IN. Purdue Research Foundation.
- Guay, R. B. 1978. Factors Affecting Spatial Test Performance: Sex, Handedness, Birth Order, and Experience. *Paper Presented at the 1978 Annual Meeting of the American Educational Research Association*. 62nd, Toronto, Ontario, Canada, March 27-31.
- Guay, R. B., and McDaniel, E. D. 1977. The Relationship Between Mathematics Achievement and Spatial Abilities Among Elementary School Children. *Journal for Research in Mathematics Education*, 8, 211-215.
- Henderson, D. W. 2001. *Experiencing Geometry: In Euclidean, Spherical, and Hyperbolic Spaces*. Upper Saddle River, New Jersey: Prentice-Hall, Inc.
- McDaniel, E., Guay, R., Ball, I., and Kolloff, M. 1978. A Spatial Experience Questionnaire and Some Preliminary Findings. A paper presented at the Annual Meeting of the American Psychological Association. Toronto, August, 1978.
- McGee, M. G. 1979. *Human Spatial Abilities*. New York, New York: Praeger Publishers.
- Medina, A. C., Gerson, H. B. P., and Sorby, S. A. 1998. Identifying Gender Differences in the 3-D Visualization Skills of Engineering Students in Brazil and the United States. *Proceedings of the International Congerence for Engineering Education*. Rio de Janeiro, Brazil.
- Moses, B. E. 1980. The Relationship Between Visual Thinking Tasks and Problem-Solving Performance. *Department of Mathematics & Statistics*. Bowling Green State University, Technical Report No. 80-08, April.
- Norman, K. L. 1994. Spatial Visualization—A Gateway to Computer Based Technology. *Journal of Special Educational Technology*. Vol. 12, No. 3, 195-206.
- Roth, S. K. 1993. Visualization in Science and the Arts. *Art, Science, & Visual Literacy: Selected Readings from the Annual Conference of the International Visual Literacy Association*. 24th, Pittsburgh, PA, September 30-October 4, 1992

- Seng, S., Chan, B. 2000. Spatial Ability and Mathematics Performance: Gender Differences in an Elementary School. (ERIC document #438937)
- Sorby, S. A. 1999. Developing 3-D Spatial Visualization Skills. *Engineering Design Graphics Journal*. Vol. 63, No. 2, 21-32.
- Sorby, S. A., Leopold, C., and Gorska, R. 1999. Cross-Cultural Comparisons of Gender Differences in the Spatial Skills of Engineering Students. *Journal of Women and Minorities in Science and Engineering*. Vol. 5, 279-291.
- Tartre, L. A. 1990a. Spatial Orientation Skill and Mathematical Problem Solving. *Journal for Research in Mathematics Education*. Vol. 21, No. 3, 216-229.
- Tartre, L. A. 1990b. Spatial Skills, Gender, and Mathematics: In Fenneam, E., and Leder, G. C., 1990. *Mathematics and Gender*. 27-59.
- Vandenberg, S. G., and Kuse, A. R. 1978. Mental Rotations, A Group Test of Three-Dimensional Spatial Visualization. *Perceptual and Motor Skills*. 47, 599-604.
- Yen, W. M. 1975 Sex-Linked Major-gene Influences on Selected Types of Spatial Performance. *Behavior Genetics*. Vol. 5, No. 3, 281-298.

APPENDICES

APPENDIX A: CONSENT FORM

Informed Consent Form

**Research done by: Stephen Schmidt
Oregon State University Mathematics Department
3-D Spatial Visualization**

This research project is on 3-D Spatial Visualization. In giving this Spatial IQ test to both professors and students, I will be able to study the results to determine which people are more spatial than others. With that information, I can then take my study a step further to find out why some people do well and why others do poorly. I will learn if it was prior experiences or classes that helped spur their ability, how to possibly teach spatial ability better to others, and if it is helpful in learning mathematics better.

I, _____, understand that as a participant in this study, the following things will happen:

- I will be asked to show up to a particular classroom to take a test.
- This test will take approximately 45 minutes.
- There are no risks or discomfort involved except those associated with test taking.
- I have the chance to win a free pizza.
- My name will not appear anywhere on the test and therefore I will be kept anonymous.

I affirm that my participation in this study is completely voluntary. I understand that I may either refuse to participate or withdraw from the study at any time without penalty. I understand that any questions I have about the research study or specific procedures should be directed to Barbara Edwards or Stephen Schmidt, Oregon State University, Mathematics Department, 368 Kidder Hall, Corvallis OR 97331, (541) 737-5179. If I have questions about my rights as a research subject or if I have sustained a project-related injury, I should contact the IRB Coordinator, OSU Research Office, (541) 737-3437.

My signature below indicates that I have read and I understand the procedures described above and give my informed and voluntary consent to participate in this study. I understand that I will receive a signed copy of this consent form.

Signature of subject (or subject's legally authorized representative)

Name of Subject

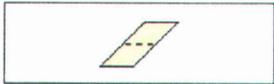
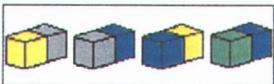
Date Signed _____

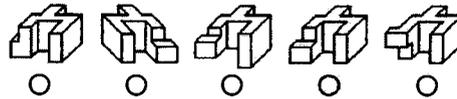
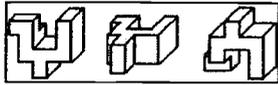
Subject's Present Address

Subject's Telephone Number

APPENDIX B: SPATIAL IQ TEST/QUESTIONNAIRE

The following IQ test is designed to test your visual and perceptual abilities, as well as your abstract reasoning. Examine the image sequence. Select the answer option which should come next. Go to the next page and complete the questions.

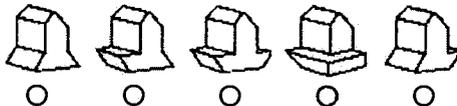
	    	I don't know
	    	I don't know
	    	I don't know
	    	I don't know
	    	I don't know
	    	I don't know
	    	I don't know



I don't know



I don't know



I don't know

Amount of time you spent on the test? _____

Department/Major? _____

Age? _____ Male or Female? _____

In the math classes you have previously taken, did you prefer algebra or geometry? _____

Have you ever taken a test of this sort before? _____

Do you feel you did well or poorly? _____

If you felt you did poorly, what do you think the reason for that was? If you felt you did well, what past experiences/classes may have contributed to your ability to do well on this test?

What do you think would have or would help you to do better on a test of this nature?

When attacking a math problem what is the first thing you usually do?

Do you think being able to see 3-D spatial images would help you in a math class? Why?

APPENDIX C: COPYRIGHT PERMISSION



Stephen Schmidt
Oregon State University
Corvallis, Oregon
sschmidt7@hotmail.com

Re: Permission to use psychological tests

Dear Stephen Schmidt,

By this letter, I authorize you to use any of the scales made available on the web site *QueenDom.Com*, of which QueenDom.com is the author.

This permission authorizes the use of the scales for research or teaching purposes. The questionnaires may be administered either on-line or as paper/pencil questionnaire, so you can print out the questionnaires and make up to 500 copies. The questions and rating scales may be published as teaching material. Since the scoring keys are proprietary information that we do not reveal, the questionnaires must be scored on-line using the forms available on my website. The scales should be referenced similarly to the example below, specifying that it is an electronic publication.

I would also appreciate if you could send me a copy of the final report or a complete reference of the materials in which my scales are used.

Sincerely Yours,

Laurel Tidman
Queendom.com

References can be found at:
<http://www.queendom.com/tests/psychometrics/references.html>

Thursday, May 17, 2001

Page 1

[Image][Image]MSN HomeHotmail[Image] Web Search[Image]Shopping[Image] Money[Image]People & Chat[Image] (Sign out of Passport : [Image])
 [go to MSN] [Image]
 Hotmail" sschmidt7@hotmail.com
 Inbox Compose Address Book Folders Options Messenger Calendar Help
 Folder: Inbox

From: laura@queendom.com Save Address - Block Sender
 To: sschmidt7@hotmail.com Save Address
 Subject: Re: contact
 Date: Mon, 7 May 2001 16:45:01 -0400
 Reply Reply All Forward Delete Previous Next Close

Hi Stephen,

I don't think there's going to be a problem with your proposal. Basically, if you know the answers then there's nothing to stop you from using them. We will take you up on the offer of not publishing them, however. Good luck with your research.

Regards,

Laura.

On 7 May 2001, at 15:42, contact@queendom.com wrote:

> Below is a feedback from "contact" form.

>

>

> name:
 > Stephen Schmidt
 > email:
 > sschmidt7@hotmail.com
 > subject:
 > Feedback about a test
 > message:

> Hello. I have recently recieved permission to use your Spatial IQ Test as part of my research Thesis at Oregon State University in the Mathematics Department. As part of my research, I was hoping to do look at each question and report how many people got the answers correct or incorrect for each problem. I know you do not distribute scoring systems, however, when I took the test myself, I recieved a 100% on it and therefore know all the correct answers. I was wondering if it would be okay or if I could get permission to use my results to score the tests. I promise that I will not publish the answers anywhere and I will be the only person to know the answers. I can even sign and fax you something saying that I will not make the answers public domain. I am hoping that this will work, otherwise I will have to input 98 test scores into your website to get results and even then I will not have results for each question. You will be recieving a copy of my Thesis which will describe how your test was used for research purposes. Please let me know as soon as possible if I can do this. Thank you.

>

> Sincerely,
 > Stephen Schmidt

Reply Reply All Forward Delete Previous Next Close

Inbox Compose Address Book Folders Options Messenger Calendar Help

Get notified when you have new Hotmail or when your friends are online, send instant messages, listen to music and more. Try the new browsing software from Microsoft that makes it easy to get more from the Web. Get your FREE download of MSN Explorer at <http://explorer.msn.com>

<p>(go to MSN)</p> <p>Other Links: [Image] Buy Music Download Music Buy Books Free Games Pharmacy More...</p>	<p>Special Features: [Image] eShop: great stores, great deals Are your friends online? The Web's best personal finance site Keep your car running longer Send Money Online More...</p>
--	--

© 2001 Microsoft Corporation. All rights reserved. TERMS OF USE TRUSTe Approved Privacy Statement