1985

Spatial Visualization, Attitudes Toward Mathematics, And Mathematics Achievement Among Chinese-American, Hispanic-American, And Caucasian Seventh And Eighth Grade Students

Wenfu Shieh
University of the Pacific

Spatial Visualization, Attitudes Toward Mathematics, and Mathematics Achievement Among Chinese-American, Hispanic-American, and Caucasian Seventh and Eighth Grade Students

A Dissertation

Presented to

the Faculty of the Graduate School

University of the Pacific

In Partial Fulfillment

of the Requirement for the Degree

Doctor of Education

by

Wenfu Shieh

August, 1985

Spatial Visualization, Attitudes Toward Mathematics, and Mathematics Achievement Among Chinese-American, Hispanic-American, and Caucasian Seventh and Eighth Grade Students

Abstract of the Dissertation

Many studies have shown that spatial visualization and attitudes toward mathematics are positively and significantly correlated to achievement in mathematics. This study attempted to find out whether these relationships remain consistent across various ethnic groups. This study also attempted to ascertain if spatial visualization ability and attitudes toward mathematics vary among ethnic groups, and if these possible variabilities correspond to the different degrees of mathematical achievement.

One hundred five 7th and 8th grade Caucasian, Chinese-American, and Hispanic-American students were selected from three of the five middle schools in the Stockton Unified School District to participate in this study. The DAT Space Relations Test, the Fennema-Sherman mathematics Attitude Scales, and the Comprehensive Tests of Basic Skills were administered to the students in the Spring of 1985 to assess spatial visualization ability, attitudes toward mathematics, and achievement in mathematics, respectively.

The results indicated that Chinese-American students achieved significantly higher than Caucasian and Hispanic students in mathematics. The results of this study suggested that when English proficiency and family-income levels are controlled, Hispanic students (males and females combined) did not achieve at a significantly lower level than did Caucasian students as suggested in previous studies. Also when all three ethnic groups were combined, males achieved significantly higher than did females in mathematics.

The data of the spatial visualization variable in this study indicated that Chinese-American males scored at a significantly higher level than did Chinese-American females. There was no significant sex difference in Caucasian and Hispanic groups.

Students of both gender and all ethnic groups showed strongly positive attitudes toward mathematics. There were very few significant sex differences or ethnic differences in attitudes toward mathematics.

There was a substantial correlation between spatial visualization and mathematics achievement. When all three ethnic groups were combined, females had a significantly higher correlation between mathematics achievement and spatial visualization than did males. Spatial visualization, ethnicity, and confidence of learning mathematics were significant predictors of mathematics achievement for the student population of this study.

ACKNOWLEDGMENTS

I would like to express my appreciation to Dr. Bobby R. Hopkins for serving as the chairman of my dissertation committee and his valuable suggestions. I would also like to thank Dr. David Baral for his encouragement and helpful advices in my review of literature. I am very grateful to each member of the committee: Dr. David P. Baral, Dr. Marjorie C. Bruce, Dr. Deann Christianson, and Dr. Stephen E. Trotter for their time in reviewing each chapter and their valuable comments which greatly enhanced the writing of my dissertation.

I very much appreciate the support of Dr. Roger Reimer, the Director of Research and Pupil-Service, Stockton Unified School District, and the assistance of the principals, Mr. Robert Cossey, Ms. Sarah Turner, Ms. Jean Wadley, and the school counselors, Mr. Ronald Duncan and Mr. Sal Lopez.

I would also like to thank Mrs. Mary Arbury and Dr. Paul Hillar for their kindness in consulting and supporting my efforts in this research. Most importantly, I am truly appreciative of my wife, Yehching, for her great patience and indulgence during the time spent on my doctoral study.

TABLE OF CONTENT

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF FIGURES

Chapter 1

INTRODUCTION

The degree of achievement in mathematics can be a function of many elements, which are classified in the cognitive and affective domains. Spatial visualization ability, a cognitive variable, may serve as a fundamental aptitude for math achievement. Attitudes toward mathematics, as affective variables, may affect one's willingness to learn more about mathematics, to persist in mathematical study, and to choose mathematics or mathematics-related areas as future career goals.

Many studies have indicated that minority students in the United States, with the exception of Asian-American students (of whom Chinese-Americans are the majority), often achieve well below average in mathematics (Anick, Carpenter, and Smith, 1981; Backman, 1972; Matthews, Carpenter, Lindquist, and Silver, 1984; Tsang, 1976). In contrast with other minority students, Chinese-American students have generally been considered high achievers in mathematics despite the fact that children of these ethnic groups are often enrolled in the same schools (Tsang, 1972, 1984).

Differences in spatial visualization ability and attitudes toward mathematics may conceivably partially account for the gap in mathematical achievement between these groups and the divergence of their achievement scores. This study examined the correlations among spatial visualization, attitudes toward mathematics, and mathematical achievement. The patterns of spatial visualization ability, attitudes toward mathematics, and mathematical achievement among ethnic groups were compared to investigate possible ethnic or gender distinctions among these variables. Data such as these may provide bases for improving both academic achievement in mathematics and mathematics instruction.

Brief Literature Background

Spatial ability has been regarded as an element of mathematical ability by many researchers. Fennema (1974) stated that the relationship between spatial visualization ability and mathematics is logically evident. In a study of 9th-12th grade students, Fennema and Sherman (1977, p. 66) concluded that "spatial visualization was importantly related to mathematical achievement as much as it related to verbal ability."

Garrard (1981) found that spatial visualization ability, as measured by the Differential Aptitude Test (DAT), was highly related to mathematical problem-solving performances. Students with high spatial visualization abilities often learn more than students with low spatial visualization abilities in mathematical instruction where spatial or visual presentations are common.

Certain student characteristics are expected to interact explored by studies involving aptitude-treatment interactions. DuRapau and Carry (1981) found that different instruction approaches (treatments) would produce better transfer of geometrical concepts for students with different visualization abilities.

There are areas in which females and males differ in mathematics achievement. Thirteen-year-old female students often perform better in computation and spatial visualization than males but their problem-solving skills are comparable. In overall comparisons, both genders at this stage start their middle school mathematics studies with approximately equal mathematical abilities. However, by the end of high school, males generally achieve higher in mathematics (Armstrong, 1981; Fennema and Sherman, 1978).

Research results are inconsistent in terms of the relationship of spatial ability to sex differences in mathematical achievement. McGee (1979) found that among high school seniors, sex differences in mathematics were related to sex differences in spatial visualization abilities. However, no relationships between gender and spatial visualization abilities were found for high school seniors in two national surveys on achievement in mathematics (Armstrong, 1981).

Gibson (1953) demonstrated that practice, feedback, and reward can improve perceptual judgment. Reportedly spatial visualization abilities tend to be modifiable and can be shaped by the cultural and social environment. Studies indicate that socio-cultural factors are highly related to the development of spatial visualization abilities and mathematical achievement (Vernon, 1965; Sherman, 1967; Fennema, 1977). Lesser et al (1972) found that ethnicity, socio-economic status, and sex showed substantial relationships to spatial and mathematical abilities. For reasons of socio-cultural involvement, Aiken (1973) suggested that the effects of ethnic group membership needed to be considered in studies of mathematical ability. However, very few studies have compared mental abilities, including spatial ability, across ethnic groups other than for Blacks and Caucasians.

Attitudes toward mathematics is reported to be another important factor contributing to mathematical achievement. Students may start to form their attitudes toward mathematics early in elementary school, but the junior high school years, during which abstract mathematics is introduced, appear to be the crucial period (Aiken, 1970). Studies show that attitudes toward mathematics become increasingly less favorable as students progress in school (Aiken, 1970; Neale, 1969).

It appears that attitudes toward mathematics can be affected by many external factors. Poffenberge and Norton (1959) found that parents could affect their children's attitudes toward mathematics in three ways: expectations of their children's success in mathematics, their own attitudes, and encouragement to take advanced math courses. It seems likely that not all parents, and particularly parents of minority students, have the educational background and knowledge to facilitate their children's decisions with regard to future education plans (Matthews, 1984).

Teachers' attitudes and effectiveness may also be important in the development of students' attitudes and performance in mathematics (Aiken 1970; Brassll, Petry, & Brooks, 1980). Certain teacher behaviors such as commenting on returned papers may also affect students' attitudes (Aiken, 1970).

Socioeconomic status may also affect children's attitudes toward mathematics (Spickerman, 1965). Several studies, however, found that social class has a limited relationship to student attitudes toward mathematics (Aiken, 1970; Haladyna, Shaughnessy, & Shaughnessy, 1983).

The formation of mathematical attitudes may differ according to gender. Males tend to outpace females in both attitudes and performance in mathematics at the junior high level and beyond (Aiken, 1970, 1976). Female high school students show more and deeper declines in attitudes toward mathematics (Sherman, 1980). The stereotyping of mathematics as a male domain and parental and socio-cultural expectations may contrubute to the less favorable attitudes toward mathematics among fe·ale high school students.

Attitudes toward mathematics may be influenced by cultural environment or racial stereotypes. Some minority students may not be as likely to perceive the utility of mathematics in their future schooling or careers as majority students do. They may also perceive mathematics as a White domain (Matthews, 1984). Very few studies have been conducted to explore attitudes toward mathematics across ethnic groups. It appears that comparative research on mathematical attitudes is needed to determine whether differences of attitudes exist among ethnic groups, or whether these possible differences relate to the divergence of actual achievement.

Hispanic students and Black students have been found to achieve at lower levels in mathematics than majority students in many surveys and studies (Anick, Carpenter, and Smith, 1981; Carpenter, Lindquist, and Silver, 1984). One study reports that Hispanic students start to lag behind White students in mathematical performance at the age of nine and the gap increases as students grow older (Matthews, 1984). Many Mexican-American junior high students opt to take only the minimum requirement in mathematics (MacCorquodale, 1980).

Few studies have been conducted with Chinese-American students addressing their mathematics learning, patterns of course participation, and performance. Chinese-American, however, are perceived as high achievers in mathematics (Stodolsky & Lesser, 1967; Tsang, 1976, 1984).

Statement of the Problem

Mathematics is a fundamental basis for many fields of study. Students who choose business, science, or engineering as careers must possess extensive mathematical backgrounds. Some minority group students in the United States achieve lower in mathematics than the majority students at every academic level. Such a deficiency may demonstrate a possible lag in cognitive development and/or less concern with academic success among minority groups.

Many research studies have demonstrated that a positive correlation exists between mathematics achievement and spatial visualization (Fennema, 1974; Muscio, 1962; Fennema & Sherman, 1977; Garrard, 1981). Attitudes toward mathematics have also been shown to relate strongly to mathematics achievement and performance. Although students of some minority groups are generally reported to be poor achievers in this subject, there is substantial variability among the students of various ethnic groups in terms of mathematical performance in school. Some research has been conducted to discover the factors underlying mathematical learning and performance, however, several questions in regard to mathematics achievement among ethnic minority students remain to be clarified:

1. Are there differences in mathematics achievement among Caucasian, Chinese-American, and Hispanic seventh and eighth-grade students when family income-level and English proficiency are controlled?
2. Does spatial visualization ability differ among the students of these three ethnic groups? Do the differences of spatial visualization ability correspond to the differences of mathematical achievement?
3. Do attitudes toward mathematics differ among these three ethnic groups? Is attitude related to mathematics achievement for these three ethnic groups?

Research Hypotheses

Based on a review of the available e pirical findings, the following research hypotheses were investigated:

1. Among seventh and eighth-grade students there are sex differences and ethnic differences in mean scores among the three ethnic groups, Caucasian, Chinese-American, and Hispanic-American, with respect to:

   a) math achievement as measured by Comprehensive Tests of Basic Skills (CTBS) Form U Total Math. Chinese-American students score the highest. Caucasian students score higher than Hispanic-American students. There is no sex difference within each ethnic group.

   b) spatial visualization ability as measured by Differential Aptitude Tests (DAT) Form S Space Relations. There is no difference among ethnic groups. There are sex differences within each ethnic group with males outperforming females.

   c) attitudes toward mathematics as measured by Fennema-Sherman Mathematics Attitudes Scales (FSMAS). There is no difference between Caucasian and Chinese-American students. Both groups have more positive attitudes than Hispanic-American students. Males have more positive attitudes than females within each ethnic group.

2. There are correlations between CTBS total mathematics scores and

a) DAT spatial visualization scores of male students within each ethnic group. The Pearson correlation coefficients (r) are positive and significant.

b) DAT spatial visualization scores of female students within each ethnic group. The Pearson correlation coefficients are positive and significant.

c) scores of the FSMAS attitude scales of male students within each ethnic group. The Pearson correlation coefficients are positive and significant.

d) scores of the FSMAS attitude scales of female students within each ethnic group. The Pearson correlation coefficients are positive and significant for all of the eight attitude scales.

3. The correlations between spatial visualization ability and the total mathematics scores differ among these three ethnic groups. The correlation coefficient of Caucasian group is higher than those of Chinese-American and Hispanic-American groups. There is no difference between Chinese and Hispanic groups.

4. The correlations between the scores of each attitude scale and the total mathematics scores do not differ among these three ethnic groups.

5. The variables Spatial Visualization and Mathematics Attitudes jointly correlate with Mathematics Achievement to a significantly higher degree than when correlated individually.

Sampling and Testing Procedures

Three of the five middle schools in the Stockton Unified School District (SUSD) participated in this study. In order to be included in the sample, all subjects met four requirements: 1) fully proficient in English, 2) not receiving free or partially free lunches, 3) not enrolled in special education programs, and 4) have completed at least four years of education in the United States. Thirty-five qualified ethnic Chinese students were identified. The same numbers of Caucasian an' Hispanic subjects were then randomly selected from the lists of qualified students (see table 2, chapter 3).

Eleven testing periods including three make-up testing periods for absentees were conducted in the last two weeks of March, 1985. The Space Relations test of DAT and the FSMAS were administered to approximately equal numbers of subjects from each ethnic group in each testing period. As a district policy, all students in SUSD were required to take the CTBS, which was administered in the last week of April and the first week of May, 1985 . The Total Math scores were obtained from the Research Department of SUSD. The statistical analyses were processed by the Statstical Package for Social Science (SPSS) on the Burroughs 6700 computer at the University of the Pacific.

Limitations

Factors which may limit the generalizability of this study include:

1. The experimentally accessible population was limited to Stockton Unified School District. The extent to which students in this district are representative of their respective population is unknown.
2. The motivational level of the students to perform well on achievement test and to give candid answers to the affective measures is unknown. An inadequate level of cooperation by students could obscure the actual relationships under study.

Definitions of Terms

Chinese-American Student: A student whose parents are of Chinese-origin.

Hispanic-American Student: A student whose parents are of Mexican, Puerto Rican, Cuban, Central or South American, or other Spanish culture of origin --- regardless of race.

Caucasian Student: The student whose parents are of mainstream White Americans, excluding those of Hispanic origin.

Spatial Visualization Ability: The ability to visualize a constructed object from a picture of a pattern and the ability to imagine how an object would appear if rotated in various ways. This ability is measured by the Space

Relations test of the Differential Aptitude Tests (Bennett, Seashore, & Wesman, 1974).

Attitudes toward Mathematics: Self-reported attitudes toward mathematics as measured by the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). The eight scales adopted in this study are: attitude towards success in mathematics, mathematics as a male domain, confidence in learning mathematics, effectance motivation in mathematics, usefulness of mathematics, mother scale, father scale, and teacher scale.

Mathematics Achievement: Achievement in mathematics computation, concepts and applications as measured by the Comprehensive Tests of Basic Skills Total Math score (CTBS, 1982).

Significance of the Study

Differences in the cognitive and affective domains of learning processes may contribute to differences in mathematics achievement. Ethnic minority students, who are reared in various socio-cultural environments, may have developed these cognitive and affective dimensions in different ways. High variability in mathematics achievement has been found to exist among ethnic groups in the United States.

Many studies have shown that spatial visualization and attitudes toward mathematics are positively and significantly correlated to achievement in mathematics. This study attempted to find out whether these relationships remain consistent across various ethnic groups. This study also attempted to ascertain if spatial visualization ability and attitudes toward mathematics vary among ethnic groups, and if these possible variabilities correspond to the different degrees of mathematical achievement. The findings of this study were expected to make a significant contribution to the understanding of mathematics achievement and attitudes in relation to ethnicity.

Summary

Ethnic minority students, in general, achieve lower than the Caucasian students in mathematics. However, Chinese-American students have performed very well in this subject. Since mathematics is a fundamental basis for many fields of study, it appears that there is a need to study the patterns of achievement in mathematics and the related factors across ethnic groups to understand more completely factors which affect mathematics learning.

Many studies have shown a positive correlation between mathematics achievement and spatial visualization ability. Also, students with higher positive attitudes toward mathematics tend to achieve at higher levels in mathematics. It was one of the purposes of this study to examine the correlations among spatial visualization, attitudes toward mathematics, and achievement in mathematics across three ethnic groups.

One-hundred-five 7th and 8th-grade Caucasian, Chinese-American, and Hispanic American students were randomly selected from three of the five middle schools in the Stockton Unified School District to participate in this study. The DAT Space Relations test, the Fennema-Sherman Mathematics Attitude Scales, and the Comprehensive Tests of Basic Skills were administered to the students to assess spatial visualization ability, attitudes toward mathematics, and achievement in mathematics, respectively. Statistical analyses were processed by the Statistical Package for Social Science (SPSS) on the Burroughs 6700 computer at the University of the Pacific (Nie, et al., 1975; Hull & Nie, 1981).

Chapter 2

REVIEW OF THE LITERATURE

Mathematical achievement has historically been and remains today a major concern in primary and secondary education. Researchers have examined many factors which are relevant to perfor ance in mathematics, among which are spatial visualization ability, attitudes toward mathematics, sex, and ethnicity. Those variables are the focus of this investigation.

This chapter reviews the reported differences in spatial visualization ability and attitudes toward mathematics which may partially account for the divergence of mathematical achievement scores among ethnic groups. Studies regarding correlations between spatial visualization and attitudes toward mathematics, and mathematical achievement are also examined. Findings pertaining to the association of gender and environmental factors, i.e., socio-economic status and socio-cultural media, are compiled as they relate to the development of spatial visualization ability, mathematics attitudes, and mathematical performance.

Spatial Visualization

A factor analytic study conducted by Gilford and Lancy in the Aviation Psychology Program during World War II revealed the first clear evidence for the existence of spatial abilities (cited in McGee, 1979). Two spatial factors were identified as spatial visualization and spatial relations. Spatial visualization is a factor which involves visual manipulative ability. People may possess this ability to perceive the relative changes of objects and to recognize the new position or appearance after they are moved, turned, twisted, rotated, folded or unfolded. Spatial relation is described as an ability to discriminate the direction of motion such as up and down, left and right, and in and out (Fruchter, 1954; McGee, 1979).

McGee (1979) extensively reviewed the research reports on human spatial abilities and concluded that there was strong and consistent evidence to support the existence of two distinct spatial abilities: visualization and orientation. Spatial visualization represents the ability "to mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object" (McGee, p.893). It is the ability to comprehend movement in three-dimensional space.

Spatial orientation, similar to spatial relation proposed by Gilford and Lancy, involves "the co prehension of the arrangement of elements within a visual stimulus pattern and the aptitude to remain unconfused by the changing orientation in which a spatial configuration may be presented" (McGee, p.893). However, positive correlations between tests of spatial visualization and orientation have been found in many studies. Thus the distinction between visualization and orientation factors is not clear.

The Relationship Between Spatial Visualization and Mathematics Achievement

Spatial ability has been regarded, to some extent, as an element of mathematical ability by many researchers. The relationship between spatial ability and mathematics is logically evident, particularly in the area of spatial visualization (Fennema, 1974).

McGee (1979) described Hamley's definition of mathematical ability which was suggested in 1935 as "a compound of general intelligence, visual imagery, and ability to perceive number and space configurations and to retain such configurations as mental pattern" (McGee, p.897). Kabanova-Meller reported that Russian mathematicians regard mathematics and spatial abilities as inseparable (Fennema, 1974). Krutetskii analyzed the responses of Russian school children to mathematical problems. He isolated spatial concepts as one of the seven basic co ponents of mathematical ability (cited in Aiken, 1973).

In her review of studies on the relationship between mathematics and spatial ability, Fennema (1974) found that geometry is one area of mathematics closely related to spatial visualization. Although geometry is only one faucet in the vast mathematical field, many mathematicians believe that geometrical ideas are involved in all of mathematical thought. However, some researchers do not agree that the spatial factor has any significant correlation with mathematics performance (Fennema, 1974).

Researchers have been attemping to explore the issue of the role that spatial ability plays in mathematical performance mainly by using two methods: one is to examine the direct evidence of correlations between spatial ability and mathematical achievement; the other is an indirect method, the aptitude-treatment interaction (ATI) study, which attempts to predict the outcome of certain instructional treatments in mathematics depending upon student's spatial ability.

Coleman (1956) attempted to predict mathematical achievement of college students from the test scores of spatial relationships, which involve ability to visualize objects in space. He concluded that ability to perceive spatial relationships helped in a limited area in mathematical learning. However, Martin (1966) pointed out that mathematics could be used as a valid index of spatial visualization abilities of prospective teachers.

Wrigley (1958) explored the factorial nature of ability in elementary mathematics. He found that performance in geometry was connected with spatial ability. Muscio (1962) found a significant correlation (.52) between mathematical ability of six-grade students and their scores on a test of spatial relationships. Several other studies also indicated that geometrical studies could improve spatial perception. Gibson (1953) demonstrated that perception could be taught, and that practice, feedback, and reward were keys for improving perceptual judgment. Brinkmann (1966) pointed out that the ordinary school curriculum was ineffective in developing spatial visualization. He used two matched groups of eighth grade pupils, one as a control group. The experimental group, which had received three weeks of programmed instructions in selected geometry concepts and materials for tactual-kinesthetic visual feedback, showed a significant increase of spatial ability. Moses (1978) conducted a similar study with 145 fifth graders. He administered five spatial tests (Punched Holes Test, Card Rotation Test, Form Board Test, Figure Rotations Test, and Cube Comparisons Test) and a problem-solving test before and after nine weeks of instruction on geometric perceptual techniques. His findings, among others, were: 1) spatial ability correlated significantly with problem-solving performance ($p < .01$); 2) the instruction had a strong positive effect on spatial ability ($p < .01$).

Fennema and Sherman (1977, p.66) studied 589 female and 644 male 9th-12th grade students, and concluded that "spatial visualization was importantly related to mathematical achievement as much as it related to verbal ability." Sherman(1979) had similar findings in a longitudinal study which predicted the mathematical performance of high school girls and boys. Four hundred thirteen ninth grade students were tested in 1975, and tested again in 1978 when they were 12th graders. Sherman found that spatial visualization was the only variable, other than mathematical achievement in ninth-grade which significantly predicted mathematical problem-solving scores for girls over a 3-year period (10th, 11th, and 12th grades). For both sexes, the correlation between spatial visualization and achievement in mathematics (.48) was as high as the correlation of verbal skills with mathematical achievement. Sherman also conducted a second study in 1980, which supported the findings of her 1979 study.

The relationship of spatial visualization with mathematics achievement continues to be a research topic in 1980s. Garrard (1981) tested 120 eighth grade students with Differential Aptitude Test (DAT), and found that spatial visualization ability was highly related to mathematical problem-solving performance. Bergeson (1982) also found the same results. Battista (1981) concluded that students with high spatial visualization abilities have an advantage over students with low spatial visualization abilities, and therefore will learn more during mathematical instruction where both spatial or visual presentations are commonly used.

Fennema (1974, p.10) believes that spatial abilities are clearly linked to Piaget's cognitive developmental theory. She stated that,

> since the only way to add simple mathematical ideas to one's cognitive structure at early developmental levels is by interaction with concrete or pictorial materials which represent those ideas, and since those representations depend heavily on spatial attributes, if for some reason one is hampered in perception of those spatial attributes then one is hampered in learning those early mathematical ideas. Without knowledge of these ideas, it is impossible to learn advanced mathematics. Therefore, spatial ability or the abilities to learn spatially appears to be of utmost importance at early stages of learning.

Some researchers adopted the aptitude-treatment interaction (ATI) approach to explore the relationship between spatial visualization and mathematical achievement. Cronbach (1957) was the first researcher who examined the existence of aptitude-treatment interactions. He stressed that psychologists should deal with treatments and persons simultaneously. Persons who possess certain characteristics are expected to have strong interactions with certain treatment variables. For this reason, Cronbach argued that we should measure the aptitude which predicts who will learn better from one curriculum than from another. The ultimate goal is to place students with particular aptitude patterns in a group, and give the specially designed instructions (treatments), which fit the needs of the group.

Also, Eastman and Salhab (1978, p.152) stated that the purpose of ATI studies was to answer two related questions: "can we adapt instruction to patterns of individual differences among students? If so, for which students is a particular method of instruction most effective?" In most ATI studies, we expect to show that a correlation of spatial visualization and mathematical achievement exists when positive interactions are found.

Nelson (1969) designed three different approaches (treatments) -- verbal, visual, and numerical and eclectic--- for units on function concepts to be taught to twelve eighth grade math classes. The visual approach was found superior to the other two approaches. The group taught by the visual approach had the highest mean scores on all achievement tests, significantly higher than the other groups.

Eastman and Carry (1975) randomly assigned eighty tenth-grade geometry students to two groups: an analytic treatment group and a graphical treatment group. The DAT Battery (form A) and the Reference Test for Cognitive Abilities were used to measure spatial visualization and general reasoning ability, respectively. An achievement test of quadratic inequalities was administered after two class periods of instruction. The results showed that the measure of spatial visualization significantly predicted the outcomes of both the graphical and the analytical treatments.

A similar ATI study on absolute value equations was conducted by Eastman and Salhab (1978) with college students. Two treatments were adopted: an algebraic treatment via verbal-symbolic-numeric instruction, and a geometric treatment through verbal-figural-numeric instruction. The data confirmed that an aptitude-treatment interaction did exist.

In another ATI study, Sternberg and Well (1980) hypothesized that the subjects' pattern of verbal and spatial abilities would determine their efficiency in solving linear syllogisms. They divided 144 college students into three treatment groups: untrained, visualization, and algorithmic. The dependent variable was solution latency, which was measured in "seconds", for each of the two- and three-term series problem types. The data indicated that the solution latencies were significantly correlated with spatial ability scores of the DAT Spatial Relation Test, but were not correlated with verbal ability.

DuRapau and Carry (1981) claimed that ATI research provides better understanding of the relationships between aptitudes and achievement. They randomly assigned 132 secondary school students enrolled in geometry classes to two treatment groups: one received five days' transformational instruction; the other received nontransformational instruction during the same period. The Purdue Spatial Visualization: Rotation Test (PSVR) and The Paper Folding Test were administered to measure Gestalt visualization, and analytic processing of spatial tasks respectively. A significant ATI was found, that is, treatments would produce better transfer of geometry concepts for students with different PSVR scores. Analysis of the data also showed a significant ATI with the Paper Folding test scores.

Battista (1981) found no significant ATI with spatial visualization ability and different treatments in algebraic structures. He attributed his results to the short duration of the experimental treatment and a lack of prerequisite knowledge of algebraic structure among his subjects. In the next year, Battista, Wheatley, and Talsma (1982) conducted a correlational study of spatial visualization and cognitive development for geometry learning. Spatial ability and cognitive development accounted for a third of the variance in grade scores.

Sex Differences in Spatial Visualization in Relation to Mathematics Achievement

Two national surveys on achievement in mathematics have provided valuable information on the development of mathematical abilities in male and female students. The first survey, Women in Mathematics Project, was conducted in 1978 by the Education Commission of the States (ECS). National data were collected on achievement and participation in mathematics for a sample of 1452 13-year-olds and 1788 high school seniors. The second survey was conducted by the National Assessment of Educational Progress (NAEP) during the 1977-1978 school year. The mathematics abilities of 75,000 9-year-olds, 13-year-olds, and 17-year-olds were assessed (Armstrong,1981).

Armstrong (1981) has analyzed the data from those two surveys. His analysis revealed that 13-year-old females performed better than males in computation and spatial visualization, but the problem-solving skills of both genders were nearly equal. In overall comparisons, females and males at this stage started their high school mathematics with equal mathematical abilities. However, by the end of high school, males became superior in mathematics, even when differences in participation in mathematics classes were controlled. Females also lost their edge in spatial visualization.

No sex differences in spatial visualization abilities were found among high school seniors in those two surveys. Thus no sex differences in spatial visualization existed, in spite of the observed differences in mathematical achievement. This finding contradicted McGee's (1979) argument that sex differences in mathematics were a secondary consequence of sex differences in spatial visualization and orientation abilities. It also contradicted the findings of a review by Maccoby and Jacklin (1974) which concluded that males were significantly superior in spatial visualization from puberty to adulthood. The research results were inconsistent in terms of the influence of spatial ability on sex differences in mathematical achievement.

Fennema and Sherman (1978) studied sex-related differences in mathematical achievement and spatial visualization among eighth-grade and eleventh-grade students. The data indicated that there were no sex differences in mathematical achievement in grade eight, whereas males in grade eleven performed better than females. However, males and females in both grades did not show a difference in spatial visualization. Fennema & Behr (1980) reported in his study of 1320 sixth to eighth grade students that there were no universal sex-related differences in mathematical learning and that there were no evidences of sex-related differences in spatial visualization. Opposite findings were reported by Garrard (1981) in his study of 120 eighth graders. Garrard concluded that there were significant sex-related differences in spatial visualization. Males also outperformed females on the test of mathematical problem solving.

Sherman (1980) found that male students increased slightly more than females from eighth grade to eleventh grade in spatial skills, but the difference was not statistically significant. Interestingly, spatial visualization tended to be a better predictor of mathematical achievement for females than for males. Shermann hypothesized that since spatial visualization ability was less likely to be problematic for males than females, it would differentiate more among females than it would among males in predicting mathematical performance.

Since the majority of studies have reported a greater proportion of spatializing males than females, some researchers have suggested a recessive, X-linked model to explain these sex differences in spatial test performance.

The recessive, X-linked inheritance means that a trait carried in a single gene on the X chromosome is X-linked, and would appear more often in male offsprings than in females. The common finding that only one fourth of all female scores are above the median for males on the tests of spatial ability is consistent with such a hypotheses.

Stafford (1961) studied spatial visualization ability of 104 fathers and mothers and their 58 teen-age sons and 70 daughters. Males were significantly superior to females, for parents as well as children. He stated that the aptitude of spatial visualization is a genetic trait which is transmitted by a sex-linked recessive gene carried by the X-chromosome. Moses (1978), however, disagreed that spatial ability is innate. He insisted that spatial ability is modifiable by instruction.

McGee (1979, p.901) reviewed research of the genetic influences on spatial abilities. He concluded that "spatial abilities are equally as, or more, heritable than verbal ability and much less correlated with traditional measures of environmental quality such as level of education and SES."

Cultural and Environmental Influences on the Development of Spatial Visualization and Mathematics Achievement

Spatial visualization, although it might be a hereditary trait, tends to be modifiable. The cultural and social environment can shape one's spatial ability. In societies where females are dominant, for instance, a lack of masculine models for children to identify with may favor verbal development at the expense of spatial ability (Vernon, 1965).

Sherman (1967) pointed out that differential practice may widen the sex gap in spatial visualization ability. Very few girls are found in mechanical drawing, shop, or analytical geometry classes in high school. Sources of differential practice could also extend to out of school activities, such as tinkering with the car, model building, sports, driving, direction finding, and map reading, which seem very likely to be involved in the development of spatial skills.

The effects of inadequate practice on spatial ability might also have an impact on girls' mathematical learning (Sherman, 1967). Fennema (1977) confirmed Sherman's viewpoint, and also provided evidence that socio-cultural factors were highly related to the sex-differences in mathematical achievement and spatial visualization.

Because of the obvious involvement of cultural and social factors, Aiken (1973) recommended that the effects of ethnic group membership needed to be considered in studies of mathematical ability. However, relatively few studies have compared mental abilities, including spatial ability, across ethnic groups. Most studies confined their comparison to black and whites. Backman (1972) studied patterns of mental abilities---spatial, verbal, English language, mathematics, perceptual speed and accuracy, and memory--- among twelfth-grade Jewish, non-Jewish white, Negro, and Oriental Americans. He found that ethnicity as well as sex had a substantial effect on these patterns. Socioeconomic status was also found to have a statistically significant effect on the patterns of mental abilities. The data indicated that Jewish subjects were relatively superior in verbal and mathematic skills. Non-Jewish white subjects did fairly well in all measures. Oriental-American subjects performed distinctively better in mathematics.

The influential study by Lesser, Fifer, and Clark (1965) compared mental abilities among Chinese-American, Jewish, black, and Puerto Rican first-grade children in New York City. The main purpose of this study was to investigate the differences between social classes and cultural groups in patterns of intellectual expression. Four abilities--- verbal, reasoning, number, and space--- were asssessed by means of a revised version of the Hunter College Aptitude Scales for Gifted Children. The data indicated that there were remarkable ethnic differences in overall levels of mental ability. SES showed a significant influence on the level of performance within each ethnic group.

Stodolsky and Lesser (1967) conducted a similar study in Boston by administering the same tests to blacks and Chinese-American children. The main findings were consistent with the results found in New York. Data analyzed in both studies suggested that Chinese-American subjects did best in spatial, number, and reasoning tests, but did poorly in the verbal test. Puerto Rican students performed poorly compared to Chinese-American and Jewish subjects. Black subjects did well in the verbal test but were poor in the other three tests.

Another study by Leifer compared 4-year-old children in New York city from Chinese, Italian, Black, and Puerto Rican backgrounds on four tests: mosaics, body parts, copying of geometric figures, and verbal fluency (cited in Loehlin, Lindzxey, and Spuhler, 1975). Chinese-American children outperformed the other three groups on the first two tests, but did poorly on the verbal-fluency measure. Puerto Rican children performed relatively well on the verbal test.

Werner, Simonian, and Smith (1968) compared 10-year-old Japanese-American, Hawaiian, Filipino, Portuguese, and Anglo-Saxon Caucasian children in Hawaii using the Primary Mental Abilities Test, which measures verbal, reasoning, spatial, perceptual, and numerical abilities. Caucasian subjects performed best on most measures with one exception, in the numerical test they scored second-highest. Oriental subjects performed relatively high on spatial and reasoning tests.

Many researchers agree that the cultural environment has a significant impact on intellectual achievement. Some even argue that there is a biological basis for the development of mental abilities. Dasen (1972) suggested that four factors could be considered as determinants of development: 1) a biological factor, 2) interaction with the physical environment, 3) interaction with the social environment, and 4) socio-cultural factors such as language and education. Guttman and Guttman's (1963) study of 13000 eighth-grade students in Israel for different ethnic backgrounds supported the genetic viewpoint. Majoribanks (1972) assessed cultural and family environmental influences on the level and patterns of mental abilities among 11-year-old boys from five ethnic groups in Canada. He found more cultural impact in the higher-performing groups than in the lower-performin roups.

Greenfield and Bruner (1969, p.633) stated that "there is no psychological phenomenon without a biologically given organism nor one that takes place outside an environment." Value orientation, language, and schooling are some of the factors which influence cognitive growth. Some cultural environment "push" intellectual growth earlier than others (Greenfield and Bruner, 1969). Vernon (1965) also concluded that the possibility of genetic differences in aptitudes among ethnic groups could not be ruled out, although it tended to be small compared to environmentally produced differences.

Summary

Spatial visualization ability has been shown to be positively correlated with mathematics learning and mathematical achievement. Aptitude-treatment interaction studies also suggest that specially designed instructional programs may be effective with the students who have particular aptitude patterns.

The majority of studies report superior spatial abilities in the male population rather than the female population. These difference between sexes may be caused by socio-cultural factors, although some researchers attribute them to genetic traits.

Differences in spatial abilities also were found among ethnic groups. Spatial visualization abilities, a definite component involved in mathematics achievement, exist to transcend nationality, culture, or ethnic background (Stafford, 1972). The research which was reviewed in this paper has suggested that spatial abilities may distinguish different ethnic groups in terms of their mathematical performance.

Attitudes Toward Mathematics And Mathematics Achievement

Mathematics has been considered a difficult subject by most students. Attitudes toward mathematics can be defined as a general disposition toward the school subject of mathematics. A student with a favorable attitude toward mathematics maximizes the possibility that he will persevere in his efforts in mathematical study, and will elect to take more courses in mathematics (Neale, 1969; Aiken, 1972; Echols, 1981; Haladyna, Shaughnessy, & Shaughnessy, 1983). The relationship between attitudes toward mathematics and mathematical achievement can be the consequence of a reciprocal influence in that attitudes affect achievement, and achievement in turn affects attitudes (Aiken, 1970). Many researchers have found that there exists a low but significant and positive correlation between attitudes and achievement in mathematics in spite of early research (Spickerman, 1970; Neale, 1969) which found no significant relationship between these two variables. The reviews by Aiken (1970, 1976) demonstrated that this positive correlation is true at the elementary, secondary, college undergraduate and post graduate levels. Although the relationship between attitudes toward mathematics and mathematical achievement are typically not high in elementary school, achievement was greater at the high school level when the students' attitudes had remained favorable or had become favorable since elementary school.

Students may start to form their attitudes toward mathematics as early as third grade. However, since arithmetic is stressed more during the fourth through sixth grades, these years are believed to be more influential in the formation of attitudes toward mathematics (Aiken, 1970). During these three grades, arithmetic was ranked in the middle of a list of the most to the least preferred subjects (Herman et al., 1969).

Aiken (1970) pointed out that the junior high school years were the crucial period in the determination of attitudes toward mathematics. Collaham (1971) also reported that grades 6 and 7 were critical in the development of mathematical attitudes. Approximately fifty percent of the sixth and seventh-graders experienced a change in their attitudes toward mathematics during these grades.

Anttonen (cited in Neale, 1969) conducted a longitudinal study, and concluded that attitudes toward mathematics become increasingly less favorable as children progress through the school. Mean attitude scores declined one standard deviation during six years (fifth or sixth grade to eleventh or twelth grade).

Junior-high is the period during which abstract mathematics are introduced. According to Piaget's cognitive theory, the junior-high students who have not progressed from the concrete operational stage to the formal operational stage may encounter difficulty in dealing with abstract mathematics, such as algebra. It is not surprising that more negative attitudes toward mathematics develop as students ascend the academic ladder (Aiken, 1970).

Personality, anxiety, and intellectual factors may play major roles in the formation of attitudes. Some social and cultural factors are also crucial. Many researchers have devoted themselves to the study of environmental influences in the determination of attitudes toward mathematics. Studies of the influence of parents, teachers, socioeconomic status, sex, and cultural factors are reviewed below.

Parental Influences on Attitudes Toward Mathematics

Parental attitudes toward mathematics are important in setting the climate for the development of their children's attitudes. Poffenberge and Norton (1959) conducted a study of 390 college freshmen. They found that parents could affect their children's attitudes toward mathematics in three ways. First, the father's or mother's expectations are important. The child will make less effort in mathematics if not expected to do well by his parents. Second, the parent's own attitudes, particularly the father's attitudes, are also important. Finally, parental encouragement to take mathematics courses in high school play a role. Burbank's (1970) research on 411 seventh-grade students supported the suggestion that parents's attitudes toward mathematics were significantly correlated with their children's attitudes toward mathematics. However, no parental influence on their children's attitudes toward mathematics was found in an earlier study (see Aiken, 1961).

A review by Aiken (1972) concluded that mothers had more influence on the attitudes of both sons and daughters toward mathematics because children spend more time with their mother. However, the father's expectation of success had more influence than the mother's expectation on the son's attitudes toward mathematics. Echols (1981) found that attitudes of both fathers and mothers were significantly ~~correlated with their children's attitudes toward~~ mathematics.

Research using parental interviews and questionnaires to determine the extent of the influences of parental attitudes and values on the attitudes of their seventh-grade children toward mathematics has been conducted by several researchers. The results suggests that: 1) for both sexes children's attitudes are positively correlated with the amount of mathematics education desired by their parents, 2) the importance which parents place on grades and parents' demands for higher grades is positively correlated with boys' attitudes but negatively correlated with girl's attitudes, 3) for both boys and girls, positive attitudes are associated with the parental view that competition is good and necessary in the modern world (cited in Aiken, 1970).

Teacher Influences on Attitudes Toward Mathematics

A teacher with positive attitudes toward mathematics may be able to change the negative attitudes of the students who come to his classroom (Poffenbergh and Norton, 1959). Some particular teacher behaviors, such as failing to announce examinations or writing comments on returned papers, may also affect students attitudes (Aiken, 1976).

A review by Aiken (1970) concluded that the teacher's attitudes and effectiveness were important in the determination of students' attitudes and performance in mathematics. Brassell et al (1980) also stated that teacher's attitudes toward mathematics determined pupils' attitudes toward mathematics. Poor mathematics performers need a teacher's considerate attention and also need positive experiences with mathematics, which may in turn improve their attitudes toward this subject. Jackson (1974) found that the culturally and educationally disadvantaged students experienced a significantly positive change in attitudes toward mathematics when they were taught by teachers who were sensitive to their problems.

Aiken (1972) stated that improvement of teachers' attitudes toward mathematics could promote the formation of more positive attitudes by their students. In another review Aiken (1976) found that prospective teachers' attitudes toward mathematics could be improved by taking specific courses in this subject.

Haladyna, Shaughnessy and Shaughnessy (1983) conducted a study of over 2000 students in grades 4, 7, and 9. They found strong associations between teacher quality measures and the students' attitude toward mathematics. The general findings at grade 4 were that attitudes toward mathematics were not significantly affected by any variables. However, fourth graders' attitude toward mathematics was more influenced by teacher quality than other factors. Teacher quality significantly influenced the determination of students' attitudes toward mathematics at grade 7 and 9 levels.

Influences of Socioeconomic Status on Attitudes Toward Mathematics

There is little research on the effects of SES on attitudes toward mathematics. Spickerman (1965) found no statistically significant relationship between these two variables, but pupils from families of higher SES tended to have more favorable attitudes than those from families of low SES. Also, high mathematical achievers tended to come from higher SES families. Haladyna, Shaughnessy, and Shaughnessy (1983) also concluded that social class has a limited relationship on children's attitudes toward mathematics. Also, Aiken (1970) found that SES has more influence on verbal subjects than on mathematics.

Relationship of Gender to Attitudes Toward Mathematics

At the elementary level, girls and boys do not differ in their liking for arithmetic. Beginning at the Secondary-school level, however, males are found to have a significantly more positive attitudes toward mathematics than females (Aiken, 1970). The fact that boys outpace girls in both attitudes and achievement in mathematics at the junior high level and beyond is frequently found in research (Aiken, 1976).

Sherman (1980) conducted a longitudinal study on the change of attitudes toward mathematics in girls and boys in grades 8-11. Females showed less improvement and greater declines in attitudes toward mathematics when they were tested on measures of confidence in learning mathematics, their teachers' attitudes toward them as learners of mathematics, the usefulness of mathematics, and effective motivation in mathematics. She found that the stereotyping of mathematics as a male domain was an important causal variable influencing later mathematical performance. This attitude negatively affected females' mathematical learning. Besides, studies had shown that the female adolescents' deeper interest in human relationships and their greater social interests might interfere with an interest in mathematics and with concentrated effort in this subject (Nevin, 1973; Fox, 1974). Also, differing socio-cultural expectations and the effect of same-sex role modeling might contribute to sex differences in attitudes toward mathematics.

Influences of Cultural and Social Factors on Attitudes Toward Mathematics

Attitudes which reflect the individual's experience with environment are learned. Some attitudes, therefore, can be shaped within the cultural group. Values, child-rearing beliefs and practices, sex roles, population density, parental behaviors, and ethnic minority stereotypes may partially influence individual attitudes (Davidson and Thomson, 1980). Race-related differences in attitudes toward mathematics have been found in some studies. Minority students in the United States are less likely than majority students to perceive the utility of mathematics in their future schooling or careers. Furthermore, minority students may hold a racial stereotype, in which mathematics is perceived as a white domain (cited in Matthews, 1984.)

One study showed that although performing poorly in mathematics, black students have been found to rate mathematics as the most important subject, to like mathematics, and to indicate a greater desire than their peers to take more mathematics. But they actually took fewer advanced mathematical courses than white students (Anick, Carpenter, and Smith, 1981). Matthews (1981) also found race-related differences in the enrollment patterns of high school students.

In general, parents of minority students had received less education than the majority students' parents. One study has shown that many minority parents did not have the knowledge to help their children, either with homework or with decisions about future education plans (cited in Matthews, 1984.)

It is a common belief that a lack of concern about academic work by Hispanic parents may in turn negatively influence their children's attitudes toward schooling, resulting in low achievement. However, a study, which was conducted in San Francisco, showed that Hispanic high school students believed that their parents considered it important to learn mathematics and English (Fernandez, Espinosa, and

Dornbusch, 1975). In addition, they did not see their parents as being unconcerned about their school performance. Nevertheless, their mathematics achievement was considerably lower than Whites and Asian-American students. Hispanic students' performance in mathematics and other school subjects did not fit the image of students who cared deeply about schooling, although the poorly designed questionnaire, which was used in that study may have invalidated the measurement of Hispanic students' and their parents' attitudes toward mathematics.

Stereotypes of the mathematics ability of various ethnic groups may have an impact on the formation of attitudes toward mathematics among ethnic minority students. Davidson and Thomson (1980, p.43) stated that "the larger the difference between the social type of groups A and B, on characteristic X, the more likely it is that X will appear in the stereotypes of the two groups". However, very few studies have been conducted to test this hypothesis. It appears that comparative research on attitudes toward schooling, or toward a specific subject such as mathematics, is needed to determine whether differences of attitudes do in fact exist, or whether these differences contribute to the variance of actual achievement.

In summary, attitudes toward mathematics have a moderate but positive relationship with mathematical achievement. Males begin to have more positive attitudes than females at the secondary-school level. Attitudes toward mathematics can be learned, and also can be shaped by many environmental factors. Attitudes toward mathematics can be improved by higher family expectations, considerate and encouraging teachers, and awareness of mathematics as an essential elements in many prestigious careers. In order to improve mathematical achievement, ethnic minority students may need to facilitate positive attitudes toward this subject through many channels.

Mathematics Achievement and Ethnicity

There is far more research on Hispanic students than on Chinese-American students regarding their performance in mathematics. In general, the mathematical performance of Chinese-American students is superior to that of Hispanic students at every school level. Chinese-American students perform equally well or, in many instances, better than White students.

The 1978 National Assessment of Educational Progress was conducted with a national sample of over 70,000 9-, 13- and 17-year-olds. A wide range of basic mathematics exercises were administered to these students during the 1977-1978 school year. Anick, Carpenter, and Smith (1981) analyzed the assessment data of Blacks and Hispanics. They consisted of 14 percent and 5 percent of the total sample, respectively. The results showed that both groups of students performed significantly below the national average at each age assessed.

Slight improvement in performance was found in the 1982 National Assessment of Educational Progress in Mathematics.

However, Hispanic and Black students continued to perform significantly below the national average (Matthews, Carpenter, Lindquist, and Silver, 1984).

A study comparing the mathematical achievement of 709 white, black, Asian-American and Spanish-surname students found that Blacks and Chicanos were lower than Whites and Asian-Americans in mathematical achievement before entrance into high school, and that their relatively low achievement continued through high school (Fernandez, Espinosa, and Dornbusch, 1975). It was also found in the same study that Chicanos performed better than Blacks, and therefore, these two groups should not be treated together as a homogeneous group.

Very little empirical evidence could be found to support the hypothesis that achievement differences exist at a younger age. It is also not clear at what age Hispanic students start to lag behind white students in mathematical achievement. A study by John et al. stated that significant differences were often found between minority and majority populations after age 9, and that the gap increased as students grew older (cited in Matthews, 1984). Although it was reported that nine-year-old Hispanic and black students made a modest improvement in the national assessments between 1972 and 1978, they still scored significantly below the national average (Anick, Carpenter, and Smith, 1981).

An examination of patterns of course participation may help to explain why minority students achieve increasingly poorer as they grow older. Poor achievement might discourage them from taking more mathematics courses than the minimum requirement. Lack of advanced training in mathematics could result in even poorer achievement in the future.

Although the data gathered from the 1977-78 National Assessment of Educational Progress does not conclusively demonstrate a causal relationship between mathematics courses taken and achievement, the difference between the blacks and the national averages is considerably narrowed when course background is held constant (Anick, Carpenter, and Smith, 1981). Hispanic enrollment in mathematics probably follows the pattern for black students, although National Assessment did not summarize course background data for this group of students (Valverde, 1984). Another study showed that many Mexican-American junior high students do not continue to take more advanced mathematics after they have completed the minimum requirement (MacCorquodale, 1980).

The factor of language problems may hamper Hispanic students' acquisition of mathematical concepts. Valverde (1984) stated that approximately half of the 4.2 million Hispanic students in American schools are of limited proficiency in English. However, there are few teachers able to communicate with these students, let alone to teach them the concepts of mathematics in their native language. It is reasonable to assume that the lack of English proficiency could hamper the learning of mathematical concepts and skills.

Another potentential factor related to poor mathematical achievement may be the cognitive style of Hispanics.

Research has revealed that children from certain cultural groups may be more field dependent than those from other groups (Ramirez and Castaneda, 1974). Mexican-American students are reported to be more field dependent than are White children (Ramirez & Castaneda, 1973; Ramirez & Price-Williams, 1974; Knight, Kagan & Nelson, 1978; Roberge & Flexer, 1983). A review by Wong (1982) demonstrated that field-dependent-independent measures are significantly correlated with mathematical achievement. Roberge & Flexer (1983) indicated that field-independent students score significantly higher than field-dependent students in mathematical concepts, problem-solving tests, and total mathematics achievement tests.

Different pedagogical considerations may be required to fit the pupil's cognitive style. In this country, however, "mathematics education has been organized to favor the field-independent rather than the field-dependent child; that is, open-ended discovery rather than definite outcomes, individualization of instruction rather than group learning, and competitive more than cooperative activities" (Valverde, 1984, p.127). This pedagogy may have partially contributed to the poor achievement of field-dependent pupils.

Few studies have investigated the mathematics learning and performance of Chinese-American students. In some studies, Chinese-American students were included in the group of Oriental or Asian-American students. In an early large scale study, a group consisting mainly of Chinese and Japanese, labeled Oriental, which represented 1% of the sample, scored slightly lower (0.1 s.d.) than the White students in mathematics (Mayeske, Okada, Beaton, Cohen, & Wisler, 1973).

Backman (1972) reanalyzed the mathematics achievement data, which was collected on 400,000 students in grades 9 through 12 in 1960, and found that Orientals achieved at the same level as Jewish Whites and higher than non-Jewish Whites. A study, which was cited earlier in this review, compared Chinese, Jewish, Black, and Puerto Rican first-grade students' mental ability, and found that Chinese and Jewish students performed at the same level, and that both performed significantly better than the other two groups (Stodolsky & Lesser, 1967).

Tsang (1977) tested 323 seventh- and eighth-grade Chinese students in California, and compared the results with scores obtained by the National Longitudinal Study of Mathematical Ability (NASMA). He found that the mean score for Chinese students in his study was 14.69, compared to the national average of 11.28 in the NASMA.

Hsai reviewed data from Scholastic Aptitude Test (SAT) and Graduate Record Examination (GRE). She found that Oriental high school seniors scored an average of 517 on the mathematics part of the SAT in 1971-1972, compared to the mean score of 505 for White students. She also found that Asian-American had a higher average quantitative score in the GRE (566) than White Americans (525), who scored higher than the total mean of all American candidates (512) (cited in Tsang, 1984).

The 1982 Census showed that over 70 percent of Asian Americans live in metropolitan areas. A large number of Asian-American students are enrolled in urban school districts where the overall achievement level is low. Asian-American students, however, achieved significantly higher than Blacks and Hispanics in the same school districts (Tsang, 1984).

Several factors may contribute to the high mathematical achievement of Asian-American students. One major factor is that Asian-Americans tend to invest heavily in education to offset discrimination and obtain upward mobility. Asian parents as well as the school counselors also tend to advise Asian-American students to choose science and mathematics-related careers that do not depend heavily on English proficiency. Opportunities of securing higher socioeconomic status in scientific and technical fields may have encouraged them to pursue the study of mathematics. In addition, many Asian immigrants are well-trained engineers and scientists in their mother lands, many come as students and decide to stay in this country. Their offspring are likely to be influenced to pursue a mathematics-based career by their parents. These extrinsic factors may contribute to their relatively high mathematical achievement (Tsang, 1984).

In summary, Hispanic students perform below the national average. This may partially be due to their preferred cognitive style and to a language barrier. They have a tendency not to take advanced mathematical courses, which may hinder them from future learning and achievement.

Chinese-American students generally achieve quite well in mathematics. This remains true even when samples are drawn from the same school districts. There is no research evidence to prove that Chinese-American students have higher innate mathematics aptitude. Some social, cultural and other extrinsic factors have been found to be related to the mathematical performance of Hispanic and Chinese-American Students.

Summary of the Review of the Literature

Many studies have shown that spatial visualization and attitudes toward mathematics are positively correlated with mathematical achievement. Spatial visualization is considered to be one of the components of mathematical abilities, and therefore is inseparable from mathematics. Positive attitudes toward mathematics will facilitate perseverance in one's efforts at mathematical study and may result in higher achievement.

Both spatial visualization and attitudes toward mathematics are shaped by many extrinsic factors. Cultural and social factors may exert influences on the formation of spatial visualization ability as well as attitudes toward mathematics. Ethnic differences have been found in these two variables, but no empirical study has been conducted to identify the factors which may contribute to the differences among ethnic groups. Parents' educational background, expectation of their children's academic success, and their own attitudes toward mathematics influence their children's attitudes toward mathematics and their mathematical performance. Teachers' quality and attitudes have similar effects on students' attitudes toward mathematics and mathematical achievement.

No study designed to find a relationship between spatial visualization and socio-economic status (SES) has been reported. No relationship between SES and attitudes toward mathematics has been found, although pupils from high SES families tend to have more favorable attitudes than those from low SES families.

Sex is a major factor in the determination of spatial visualization ability as well as attitudes toward mathematics. Sex-role stereotypes decrease the female's opportunity of engaging in activities, in which people use and practice spatial visualization abilities. Females are found performing better in spatial visualization in elementary school, but males become superior in spatial visualization from puberty to adulthood. The belief in mathematics as male-domain may hamper conceivably the formation of positive attitudes toward mathematics among female students. There are no sex differences at the elementary school level, but males begin to show significantly more positive attitudes toward mathematics at the secondary school level, as well as higher achievement in mathematics.

Significant differences are found in mathematical achievement between minority students and majority students.

However, performance is not homogeneous among various minority groups. Hispanic students, while achieving significantly lower than the majority White students, are slightly better than Black students as far as mathematical achievement is concerned. Chinese-American students achieve higher than average in mathematics, which remains true even when the samples are drawn from the traditional low achieving urban school districts.

Cultural and environmental factors have been found influential in the formation of spatial visualization ability and attitudes toward mathematics, which in turn affect mathematical performance in schools. However, very few studies have been conducted to assess these two variables among students of various ethnic background in relation to their mathematical achievement. Studies in this area will facilitate understanding of ethnic minority students' cognitive and affective background, and hopefully might suggest the implementation of specially designed curriculum and pedagogy in order to fit their particular cognitive and affective styles.

Chapter 3

METHODS AND PROCEDURES

This study was designed to investigate relationships among the three variables of spatial visualization ability, attitudes toward mathematics, and mathematics achievement for Caucasian, Chinese-American, and Hispanic-American seventh and eighth grade students. Three measurement instruments, the Differential Aptitude Space Relations Test (DAT) Form S, the Fennema-Sherman Mathematics Attitude Scales (FSMAS), and the Comprehensive Test of Basic Skills (CTBS) Form U were used to assess these three variables for the selected students.

The main purposes of this study were to investigate potential ethnic differences with respect to these three variables, and to examine the relationships of achievement in mathematics to spatial visualization ability and attitudes toward mathematics within and among ethnic groups. This study also assessed the multiple correlation between achievement scores of CTBS Total Math and scores of the DAT Space Relations test and the eight scales of FSMAS.

Sampling

The accessible population consists of seventh and eighth-grade Caucasian, Chinese-American, and Hispanic-American students in the Stockton Unified School

District who are not from low-income families. The subjects have received formal education in the United States for four or more years, thus ensuring some commonality of education background. The sample consists of twenty female and fifteen male students from each of the three ethnic groups.

Stockton Unified School District, which serves approximately 26,000 students, is one of the largest districts in the state of California. The district operates five children centers, 27 elementary schools, four middle schools, three regular high schools, five alternative high schools, and several other types of schools and centers.

Seventh and eighth-grade students attend four middle schools (school B, C, D, E) and a fifth school which serves students from kindergarten to eighth grade (school A). Since the school district is under a court ordered desegregation plan, many students are bussed to schools outside their neighborhood. Among the total of 3939 middle school students, there are 28 percent Caucasian, 34.9 percent Hispanic, 15.3 percent Black, 15.6 percent Asian, 5.5 percent Filipino, and 0.7 percent American-Indian Students.

Since the parental occupation and familiy income are confidential, it was not possible to determine the parents' socio-economic status or to select the subjects from families of specific income levels. Therefore, a decision was made to use the "eligibility for free lunch progra as a criterion for selection. The students who are receiving or are qualified to receive free or partially free lunch were considered to come from low-income families. Those students were excluded from this study.

To enhance the homogeneity of education background, the subjects were required to be either native English-speaking students or bilingual students who were classified as fluent-English-proficient (FEP) students by the school district. In addition, students who were enrolled in special education classes were not included in the sample.

In summary, in order to be included in the sample, all subjects met four requirements: 1) fully proficient in English, 2) not receiving free or partially free lunches, 3) not enrolled in special education programs, and 4) have completed at least four years of education in the United States.

The research proposal was submitted and approved by the Research Department of the Stockton Unified School District (SUSD) in the February of 1985. Administrative support was sought from the principals of all five middle schools of the district. However, the principal of school E was reluctant to participate in this study and there were no qualified ethnic Chinese students in school D. Therefore, the sample was drawn from the other three schools, labelled A, B, C.

Qualified ethnic Chinese students were first identified with the assistance of the school-site administrators and the school counselors. After selection of the Chinese sample, equal numbers of qualified male and female students in seventh and eithth-grades were then randomly selected for the Hispanic and Caucasian groups. The computer printouts of the ethnic census, the English proficiency report, and the lunch program report were used in the identification of the qualified students. The special education teachers in each school were also consulted for the identification of special education students so that they could be eliminated from the list of potential subjects for the study. Table 1 and Table 2 describe the distributions of the subjects by school site, ethnicity, grade level, and sex.

The decision to select students at the middle school level as the target population was made based on the following considerations: 1) Attitudes are less stable in the elementary school than are in secondary school (Aiken, 1972); 2) Grade six and seven are critical grades in the development of mathematics attitudes (Callahan,1971); and 3) Males start to outperform females in mathematical achievement at the middle school level (Shermann, 1980).

Table 1

Number and Ethnicity of the Subjects From Each School

School	Caucasian-American	Hispanic-American	Chinese-American	Total
A	5	5	5	15
B	8	7	5	20
C	22	23	25	70
D	0	0	0	0
E	0	0	0	0
Total	35	35	35	105

Table 2

Distribution of the Subjects by Ethnicity, Grade Level, and Sex

	Caucasian-American		Hispanic-American		Chinese-American		
Sex	7th	8th	7th	8th	7th	8th	Total
Male	9	6	9	6	9	6	45
Female	9	11	9	11	9	11	60
Total	18	17	18	17	18	17	105

Instrumentation

The variables under study were spatial visualization ability, attitudes toward mathematics, and achievement in mathematics. Spatial visualization ability is the ability to manipulate relationships between objects or components of objects in three-dimensional space. This ability was expected to show a strong correlation with the CTBS mathematics achievement scores. Differences in this ability among ethnic groups were also expected. The Space Relations (SR), a subtest of a widely used educational and occupational aptitude test, the Differential Aptitude Test (DAT), was selected to measure this ability.

A second variable under study, mathematics attitudes, is a general disposition toward the subject of mathematics. Attitudes toward mathematics can potentially be shaped by many factors and some influential figures such as parents and teachers. The Fennema-Sherman Mathematics Attitude Scales (FSMAS), which is reported to be a reliable and valid test instrument, was used to assess this variable.

A third variable, mathematics achievement, is a general assessment of arithmetic skills, mathematics concepts, and mathematics applications. A standardized test, Comprehensive Tests of Basic Skills (CTBS) Form U, was adopted by the Stockton Unified School Distrcit (SUSD) to test all the students at the end of each school year. The "total math" scores of CTBS were used as a measurement of achievement in mathematics.

Spatial Visualization Ability

Spatial visualization ability involves visual and mental manipulative abilities to perceive the relative changes of objects and recognize their new position or appearance after they are moved, turned, twisted, rotated, folded or unfolded (Fruchter, 1954; McGee, 1979). It is the ability to comprehend movement in three-dimensional space.

Spatial visualization ability is "an ability needed in such fields as drafting, dress designing, architecture, art, die-making, and decorating, or, whereever there is need to visualize objects in three dimensions" (Bennett et al, 1974, p.9). Recent research findings have also shown that spatial visualization ability is an element of mathematical ability, and is closely related to mathematics achievement (Fennema, 1974; Battista, 1981; McGee, 1979).

Although males are generally perceived as better performers in spatial ability, some researchers have found no sex-related differences in this ability (Armstrong, 1981; Fennema-Sherman, 1978). Some research findings demonstrated that spatial visualization ability can be influenced by the cultural and environmental factors (Aiken, 1973; Backman, 1972). However, very few studies have been conducted to investigate the differences of spatial ability across ethnic groups.

The variable of spatial visualization ability was measured by DAT-SR. This test was designed to evaluate the ability to manipulate things mentally and to create a structure in one's mind from a plan (Bennett et al, 1974). The exact time allowed for this test is twenty-five minutes.

This Space Relations test has been described as an unspeeded test. Hence, the "split-half" procedure is used to estimate the reliability of this test. The reliability coefficient for eighth-grade females and males are .89 and .90 respectively.

The validity of Space Relations Test is supported by its predictability of mathematics grades or mathematics achievement scores. The test manual as well as many research studies indicate that the test results are significantly related to students' mathematics achievement (Bennett, et al., 1974; Fennema & Sherman, 1977; Sherman, 1979).

Attitudes Toward Mathematics

Mathematics attitudes are the mental disposition with regard to the subject of mathematics. The decision to elect more courses in mathematics or the efforts to persevere in mathematical studies may be affected by attitudes toward mathematics.

Many studies have demonstrated that attitudes toward mathematics are highly correlated to achievement in mathematics (Aiken, 1970, 1976; Haladyna, Shaughnessy, & Shaughnessy, 1983). Therefore, the study of these attitudes as well as the factors related to these attitudes may enhance our understanding of mathematics achievement.

Studies also show that ethnic minority students in general achieve lower in mathematics as compared to the majority White students. The study of attitudes toward mathematics across ethnic groups may enhance our understanding of mathematics achievement for ethnic minority students.

FSMAS was designed to assess the students' attitudes toward mathematics, and to measure some relevant factors with regard to these attitudes. This instrument consists of nine scales. The Anxiety Scale was not used in this study since it correlates .89 with the Confidence Scale and thus seems redundant. The remaining eight scales were adopted for this study. The function of each scale follows (Fennema, & Sherman, 1976, p. 2-5):

1. Attitudes toward Success in Mathematics Scale
   This scale was developed "to assess the motive to avoid success in mathematics", and "to measure the degree to which students anticipate positive or negative consequences as a result of success in mathematics."
2. Mathematics as a Male Domain Scale
   This Scale is intended "to measure the degree to which students see mathematics as a male, neutral, or female domain."
3. Mother Scale and
4. Father Scale
   These two scales were designed "to measure students'

perception of their mother's/father's interest, encouragement, and confidence in the student's ability" in mathematics.

5. Teacher Scale

   This scale was designed "to measure students' perceptions of their teachers' attitudes toward them as learners of mathematics."

6. Confidence in Learning Mathematics Scale

   This scale is intended "to measure confidence in one's ability to learn and to perform well on mathematical tasks."

7. Effectance Motivation Scale in Mathematics

   This scale is intended "to measure effectance as applied to mathematics. The dimension ranges from lack of involvement in mathematics to active enjoyment and seeking of challenge."

8. Mathematics Usefulness Scale

   This scale was designed "to measure students' beliefs about the usefulness of mathematics currently and in relationship to their future education, vocation, or other activities."

Each scale consists of six positively stated and six negatively stated items. There are five response alternatives: strongly agree, agree, undecided, disagree and strongly disagree. Each response is given a score from 1 to 5. In each scale, except the Male Domain Scale, the weight of 4 and 5 are given to the responses which are hypothesized to represent positive attitudes toward mathematics. The

Mathematics as a Male Domain Scale is weighted differently so that the student scores higher if he or she has less sex stereotyping in mathmatics. The total score of each scale is the cumulative score of 12 items in the scale. The higher the score, the more positive the attitudes the student possess.

To establish content validity, each of the two authors independently wrote items representing the dimension of each scale. The resulting 173 items, 18 to 22 per scale, which were agreed by both authors were randomly distributed into one instrument and were administered to 367 hgih school students. Selection of items in the final versions of the scales were based on the following criteria: 1) high correlation of the item with the total score for each sex; 2) higher standard deviations of item scores for each sex; 3) consistency of the result scores of the item with the theoretical construct of a scale; 4) the ability to differentiate mathematics and non-mathematics students.

The FSMAS have been widely used in educational research since it was developed in 1976. Many studies have demonstrated that the test scores are positively correlated to achievement in mathematics (Fennema & Sherman, 1977, 1978, 1980; Sherman, 1980).

Reliability of each sacle is determined by split-half method. Reliability coefficients range from .86 to .93. The content validity is adequately presented by the authors of this instrument. The total testing time is about twenty-five minutes.

Mathematics Achievement

Mathematics achievement is a mastery of the skills and concepts comprising mathematics. In this study the operational measurement of achievement was the Total Math scores on a standardized test, CTBS Form U. The mathematics portion of CTBS is consists of two tests: mathematics computation, and mathematics concepts/applications. Each test score and the composite score (total mathematics) are given. Since CTBS is regularly administered to the students, the results were obtained from the Research Department in Stockton Unified School District.

To establish the content validity, state and district curriculum guides, textbook series, instructional programs, and norm-referenced and criterion-referenced assessment instruments were reviewed. From the analyses of those educational materials, the content for CTBS Form U was defined. A staff of professional item writers developed two to three times as many items as would be needed. Readability for each item was determined by using widely-used formulas. The teachers who administered the Tryout Edition were also asked to review the items and provide comments. All test items were reviewed by educators to eliminate possible ethnic, racial, age, and gender bias. The final selection of test items were based on the following considerations: 1) to minimize standard error of measurement; 2) to maximize fit; and 3) to minimize ethnic, racial, age, and gender bias (CTBS

Preliminary Technical Report, 1982).

Reliability is estimated by the internal consistency coefficients (Kuder-Richardson formula 20). Reliability coefficients of these two tests for seventh and eighth-grade students range from .90 to .93. Reliability coefficients of the composite range from .94 to .96 (CTBS, 1984). The content validity is adequately presented in the technical report.

Data Collection

Parents' permission was requested for each child in schools A and C by means of letter written in English and/or the parents' native languages. Follow-up contacts were made by telephone to the parents who did not return the written permissions. All the parents of the sample students gave their permissions for their children to participate in this study. Since the school administrators in school B believed that participation in this study was relevant to education, the letters of permission were viewed as unnecessary for the subjects from this school.

The school libraries or multiple-purpose rooms were reserved in advance for the administration of the tests. The tests were scheduled in period 1,3, or 6. Students were called in from other classes. There were about equal numbers of students from each ethnic group in each testing period. Eight regular testing periods and three make-up testing periods for absentees were conducted in the last two weeks of

March, 1985.

The Space Relations test and the Fennema-Sherman Mathematics Attitude Scales were administered in each testing period by the investigator. The administrations of both tests followed the directions as described in the booklets for each instrument. At the beginning of each testing period, the school counselor or the principal introduced the author to the students, briefly described the purpose of this study, assured anonymity, and asked for their coorporation. The two tests took a total testing time of approximately sixty minutes. Each answer sheet for SR and FSMAS was hand-scored by two people to assure the accuracy of the scoring.

The CTBS Form U was administered to all the junior high students in the Stockton Unified School District by district personnel in the last week of April and the first week of May, 1985. The investigator hand scored the mathematics portion of the CTBS Form U for the students in the sample.

Statistical Analyses

Descriptive statistics were provided for all the variables involved in this study. Other appropriate statistical procedures also were used to analyze the data. The significance level was set at 0.10. Statistical analyses were accomplished by using the Statistical Package for the Social Sciences (Nie, et al., 1975; Hull & Nie, 1981) on the Burroughs 6700 computer at the University of the Pacific.

Based on the available empirical research findings, the following research hypotheses were investigated:

Research Hypotheses I. Among seventh and eighth-grade students there are ethnic differences in mean scores among the three ethnic groups, Caucasian, Chinese-American, and Hispanic-American, with respect to:

(a) mean scores of the total math of CTBS Form U. Chinese-American students are expected to score the highest while Caucasian students score higher than Hispanic-American studnents. There is no sex difference within each ethnic group.

(b) mean scores of Space Relations (SR), DAT Form S. There is no difference among ethnic groups. There are sex differences within each ethnic group with males outperforming females.

(c) mean scores of each scale of FSMAS. There is no difference between Caucasian and Chinese-American students. Both groups have more positive attitudes than Hispanic-American students. Males show more positive attitudes than females within each ethnic group.

Null hypotheses were stated for each research hypothesis. Two-way ANOVA procedures were used to test the null hypotheses with sex and ethnicity as factors and mean scores of each scale as dependent variable.

Research Hypotheses II. There are significant correlations between CTBS total math scores and

(a) SR scores of male students within each ethnic group. The

Pearson correlation coefficients (r) are positive and significant.

(b) SR scores of female students within each ethnic group. The Pearson correlation coefficients are positive and significant.

(c) scores of each scale of FSMAS of male students within each ethnic group. The Pearson correlation coefficients are positive and significant for all of the eight attitude scales.

(d) scores of each scale of FSMAS of female students within each ethnic group. The Pearson correlation coefficients are positive and significant for all of the eight attitude scales.

The Pearson Correlation Coefficient (r) was used to measure these relationships. T-tests were used to test the significance of r.

Research Hypotheses III. The correlations between SR scores and the total mathematics scores of CTBS differ among Caucasian, Chinese-American, and Hispanic-American groups. The correlation coefficient of the Caucasian group is higher than those of Chinese-American and Hispanic-American groups. There is no difference between Chinese and Hispanic groups.

Three null hypotheses were stated. Z-test for independent samples was used to test the null hypotheses.

Research Hypotheses IV. The correlations between the total mathematics scores and the scores of each attitude scale (r) do not differ among three ethnic groups.

A null hypothesis was stated for each hypothesis. Z-tests for independent samples were used to test each null hypothesis.

Research Hypothesis V. The variables Spatial Visualization and Mathematics Attitudes jointly correlate with Mathematics Achievement to a significant higher degree than when correlated individually.

Summary

Some research reports have shown ethnic differences in mathematics achievement (Anick et al., 1981; Backman, 1972; Matthews et al., 1984; Matthews, 1984). The purposes of this study were to examine the patterns, the relationships, and the possible ethnic distinctions of attitudes toward mathematics, spatial visualization ability, and achievement in mathematics among ethnic groups. It is assumed that such data provide bases for improving math achievement as well as instructional methodologies.

This study was conducted in coorporation with the Stockton Unified School District which has high percentages of ethnic minority students. Students who met the selection criteria of 1) fully proficient in English, 2) not receiving free or partially free lunches, 3) not enrolled in special education programs, and 4) have completed at least 4 years of education in the United States were selected to participate in this study. A total of 105 7th and 8th-grade students representing three ethnic groups were tested by using DAT-SR test, CTBS Form U, and FSMAS.

Descriptive statistics were provided for all the variables involved in this study. Appropriate statistical procedures were used to test the five research hypotheses. All statistical analyses were accomplished by using the SPSS on the Burroughs 6700 computer at the University of the Pacific.

Chapter 4

THE ANALYSES OF THE DATA

The data consisted of ten measurements from female and male students in grades 7 and 8 from three ethnic groups. There was one spatial visualization variable, one mathematics achievement variable, and eight mathematics attitude variables. Descriptive statistics were reported for females, males and for each ethnic group. Means and standard deviations are listed in Table 3.

The data were analyzed in relation to each hypothesis of the study. The null hypothesis was stated first. The results of the statistical analyses were then used to test the null hypothesis. The level of significance was set at .10 for all tests.

Findings

Statistical hypothesis I is concerned with ethnic and sex differences of the mean scores of the ten variables in this study. A two-factor analysis of variance (two-way ANOVA) was used to explain how the data were related to ethnicity and sex. The Least Significant Difference (LSD) method of multiple comparisons was applied when the null hypothesis of no difference in a two-way ANOVA had been rejected for ethnic differences.

Table 3

Means and Standard Deviations of Eight Attitudes Variables, Spatial Visualization, and Mathematics Achievement Classified by Ethnicity and Gender

			Usefulness		Male Domain		Confidence		Mother		Father	
Ethnicity	Sex	N	M	S	M	S	M	S	M	S	M	S
Chinese-American	F	20	51.0	6.2	50.3	7.9	49.1	7.7	49.9	7.7	51.1	7.1
	M	15	52.1	5.1	50.3	5.5	49.4	8.5	50.2	6.9	51.5	6.5
	Comb.	35	51.5	5.7	50.3	6.9	49.2	7.9	50.0	7.2	51.3	6.8
Caucasian	F	20	50.9	6.9	53.5	6.8	43.4	10.5	49.3	6.6	47.9	6.7
	M	15	46.4	7.8	44.5	7.7	44.4	11.0	49.3	7.9	47.9	7.5
	Comb.	35	49.0	7.5	49.7	8.4	43.7	10.6	49.3	7.0	47.9	6.9
Hispanic-American	F	20	49.7	6.0	48.8	5.7	43.0	10.8	48.2	8.0	49.4	7.8
	M	15	48.1	6.2	45.8	6.1	46.8	7.3	45.0	5.7	48.1	7.0
	Comb.	35	49.0	6.1	47.5	6.0	44.6	9.5	46.8	7.2	48.8	7.4

Table 3. Continued

			Teacher		Success		Motivation		Spat. Vis.		Total Math		
Ethnicity	Sex	N	M	S	M	S	M	S	M	S	N	M	S
Chinese-American	F	20	47.4	7.7	51.0	6.6	46.5	7.8	24.7	10.6	19	735.8	19.1
	M	15	46.1	4.4	51.3	2.9	47.0	7.5	34.7	10.8	15	748.6	32.2
	Comb.	35	46.9	6.4	51.1	5.3	46.7	7.5	29.0	11.7	34	741.4	26.1
Caucasian	F	20	45.4	9.0	51.2	6.7	42.4	10.3	26.9	9.8	19	722.5	18.4
	M	15	42.7	9.8	47.3	7.6	39.9	8.0	28.9	13.3	15	725.8	18.8
	Comb.	35	44.2	9.3	49.5	7.3	41.3	9.3	27.8	11.3	34	723.9	18.4
Hispanic-American	F	20	43.8	7.3	50.0	7.3	41.5	10.1	22.8	8.9	17	716.0	18.4
	M	15	44.0	6.0	49.6	7.7	42.1	8.0	22.3	7.4	12	722.0	8.1
	Comb.	35	43.9	6.7	49.8	7.4	41.7	9.1	22.6	8.2	29	718.5	15.1

Null hypotheses Ia:

1. There are no differences among the means of the total mathematics scores of CTBS Form U among Caucasian, Hispanic, and Chinese-American students.

2. There is no sex difference between the means of the total mathematics scores of CTBS Form U.

3. There is no interaction between ethnicity and sex with respect to the total mathematics scores of CTBS Form U.

Table 4 presents the results of the two-way ANOVA. As indicated in Table 4, the main effects of ethnicity ($\underline{F}$ = 8.439, $\underline{P}$ < .001) as well as sex ($\underline{F}$ = 3.151, $\underline{P}$ < .10) were significant while the interaction between ethnicity and sex was not significant.

The Least Significant Difference method of multiple comparisons was used to test for pairwise ethnic differences. The mean of Chinese-American students ($\underline{M}$ = 741.4, $\underline{s}$ = 26.05) was significantly higher than those of Caucasian students ($\underline{M}$ = 723.9, $\underline{s}$ = 18.37) and Hispanic students ($\underline{M}$ = 718.5, $\underline{s}$ = 15.13). There was no significant difference between Caucasian and Hispanic students. The males (M = 732.9, s = 25.20) scored significantly higher than females ($\underline{M}$ = 725.1, $\underline{s}$ = 20.08).

Null hypotheses Ib:

1. There is no difference among the mean scores of the Space Relations test among Caucasian, Hispanic, and Chinese-American students.

2. There is no sex difference between the mean scores of the Space Relations test.

3. There is no interaction between ethnicity and sex with respect to the mean scores of Space Relations test.

Table 5-1 presents the results of the two-way ANOVA. As indicated in Table 5-1, the main effect of ethnicity ($\underline{F}$ = 3.902, $\underline{p}$ < .023) and sex ($\underline{F}$ = 3.638, $\underline{p}$ < .059), and the interaction ($\underline{F}$ = 2.492, $\underline{p}$ < .088) were statistically significant. A graph of interaction between ethnicity and sex is presented in Figure 1.

Since a significant interaction between ethnicity and sex was found, a One-Way ANOVA (see Table 5-2) and Least Significant Difference (LSD) method of multiple comparisons were used to test for pairwise ethnicity-sex differences. The results of LSD is presented in Table 5-3. As indicated in Table 5-3, Chinese-American males had significantly higher spatial visualization abilities than Chinese-American females, Caucasian females, Hispanic males, and hispanic females; Also, Caucasian males had significantly higher scores in spatial visualization than did Hispanic males and Hispanic females.

Null hypotheses 1c:

A. For the Fennema-Sherman Mathematics Attitude Scales (FSMAS) variable, Mathematics Usefulness:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 6 presents the results of the two-way ANOVA. As indicated in Table 6, there were no significant differences.

Table 4

Summary Table for the Analysis of Variance of Mathematics Achievement Scores Analyzed by Ethnicity and Gender

Source of Variation	SS	DF	MS	F	p
Ethnicity	9190.759	2	4595.380	10.941	0.000
Sex	1323.414	1	1323.414	3.151	0.079
2-Way Interactions	398.198	2	199.099	0.474	0.624
Within	38221.895	91	420.021		
Total	49253.938	96	513.062		

Table 5-1

Summary Table for the Analysis of Variance of Spatial Visualization Scores Analyzed by Ethnicity and Gender

Source of Variation	SS	DF	MS	F	p
Ethnicity	815.219	2	407.610	3.902	0.023
Sex	380.051	1	380.051	3.638	0.059
2-Way Interaction	520.692	2	260.346	2.492	0.088
Within	10342.000	99	104.465		
Total	12057.962	104	115.942		

Table 5-2

summary Table for the One-Way Analysis of Variance of Spatial Visualization Scores Analyzed by Each Gender in Each Ethnic Group

Source of Variation	SS	DF	MS	F	P
Between	1715.962	5	343.192	3.285	0.009
Within	10342.000	99	104.465		
Total	12057.962	104			

Table 5-3

Significance of Differences in Spatial Visualization Scores Among Ethnic and Gender Groups

Mean	Group	Hisp M	Hisp F	Chin F	Cau F	Cau M	Chin M
22.3	Hisp M						
22.8	Hisp F						
24.7	Chin F						
26.9	Cau F						
28.9	Cau M	*	*				
34.7	Chin M	*	*	*	*		

* Significance level = .10

Neither the main effects of ethnicity or sex, nor the interaction effect was statistically significant.

B. For the FSMAS variable, Mathematics as a Male Domain:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 7-1 presents the results of the two-way ANOVA. As indicated in Table 7-1, there was a significant main effect for sex ($F = 9.073$, $p < .003$) and for the interaction effect ($F = 3.913$, $p < .002$). The main effect for ethnicity was not significant. A graph of interaction between ethnicity and sex is presented in Figure 2.

Since a significant interaction between ethnicity and sex was found, a One-Way ANOVA (see Table 7-2) and Least Significant Difference method of multiple comparisons were used to test for pairwise ethnicity-sex differences. The results of LSD is presented in Table 7-3. As indicated in Table 7-3, Caucasian males had significantly lower scores in the variable, Math as a Male Domain, than did Caucasian females, Chinese-American males, Chinese-American females, and Hispanic females; Also, Caucasian Females had significantly higher score than Hispanic males, and Hispoanic females.

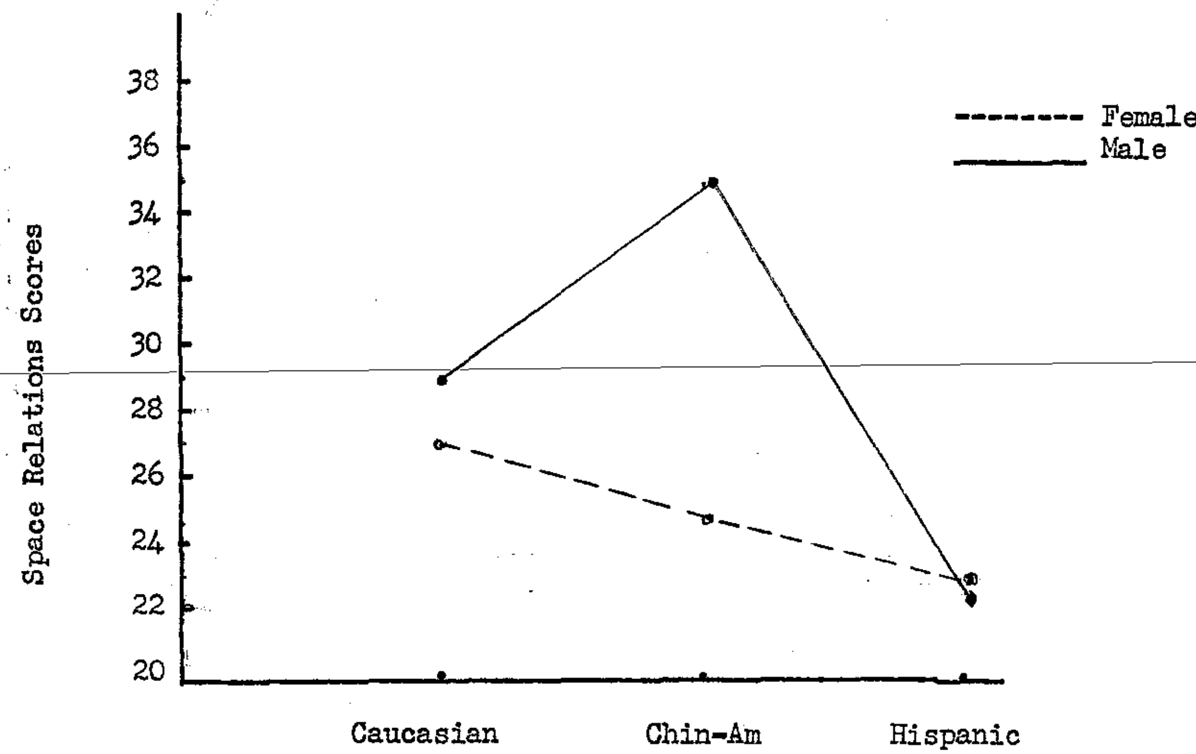

Figure 1. Graph of Interaction of Ethnicity and Gender for Spatial Visualization

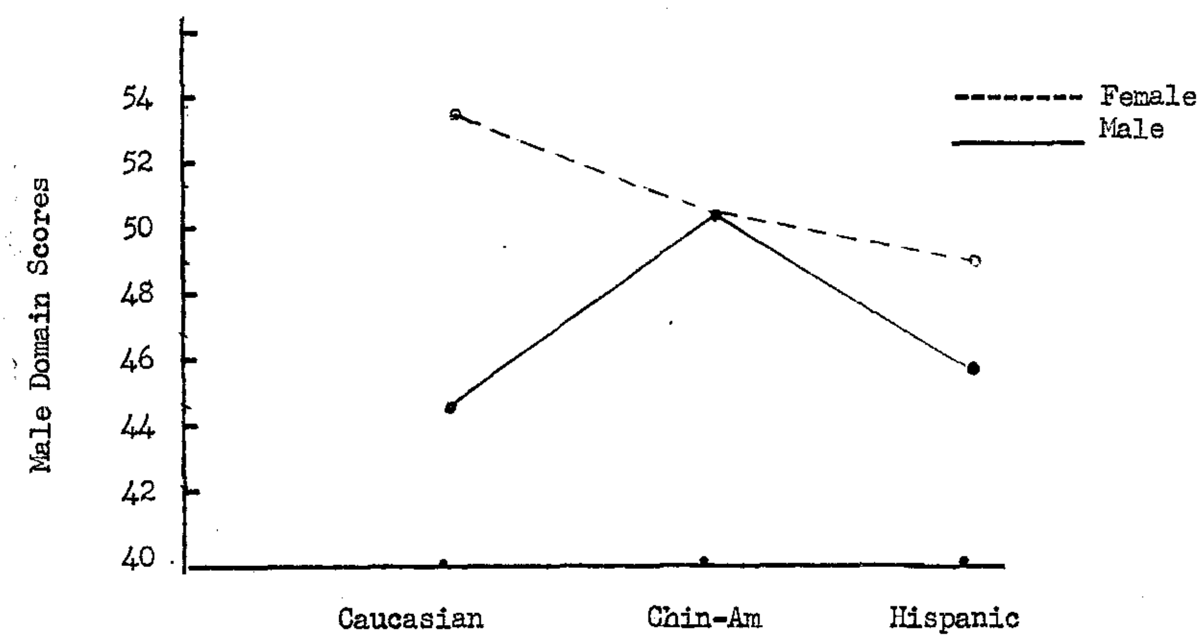

Figure 2. Graph of Interaction of Ethnicity and Gender for Attitude Toward Mathematics As A Male Domain

Table 6

Summary Table for the Analysis of Variance of Attitude Toward Mathematics Usefulness Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	p
Ethnicity	144.229	2	72.114	1.749	0.179
Sex	69.537	1	69.537	1.687	0.197
2-Way Interaction	136.083	2	68.041	1.651	0.197
Within	4081.067	99	41.223		
Total	4430.914	104	42.065		

Table 7-1

Summary Table for the Analysis of Variance of Attitudes Toward Mathematics as A Male Domain Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	p
Ethnicity	147.790	2	73.895	1.630	0.201
Sex	411.429	1	411.429	9.073	0.003
2-Way Interaction	354.876	2	177.438	3.913	0.023
Within	4489.467	99	45.348		
Total	5403.562	104	51.957		

Table 7-2

Summary Table for the One-Way Analysis of Variance of Attitudes Toward Mathematics as a Male Domain Scores Analyzed by Each Gender in Each Ethnic Group

Source of Variation	SS	DF	MS	F	p
Between	843.264	5	168.653	3.628	0.005
Within	4601.729	99	46.482		
Total	5444.991	104			

Table 7-3

Significance of Differences in Attitudes Toward Mathematics As a Male Domain Scores Among Ethnic and Gender Groups

Mean	Group	Cau M	Hisp M	Hisp F	Chin M	Chin F	Cau F
44.5	Cau M						
46.3	Hisp M						
49.4	Hisp F	*					
50.3	Chin M	*					
50.3	Chin F	*					
53.5	Cauc F	*	*	*			

Significance Level = .10

C. For the FSMAS variable, Confidence in Learning Mathematics:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 8 presents the results of the two-way ANOVA. As indicated in Table 8, there is a significant main effect for ethnicity (F = 3.447, p < .036). The main effect for sex as well as the interaction effect were not significant.

The Least Significant Difference method of multiple comparisons was used to test for pairwise differences between ethnic groups. Chinese-American students (M = 49.2, s = 7.9) scored significantly higher than Caucasian (M = 43.7, s = 10.6) and Hispanic students (M = 44.6, s = 9.5). There was no statistically significant difference between Caucasian and Hispanic students.

D. For the FSMAS variable, Mother Scale:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 9 presents the results of the two-way ANOVA. As indicated in Table 9, there was no significant effect for ethnicity, sex, or their interaction.

E. For the FSMAS variable, Father Scale:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.

Table 8

Summary Table for the Analysis of Variance of Confidence of Learning Mathematics Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	p
Ethnicity	618.133	2	309.067	3.447	0.036
Sex	69.537	1	69.537	0.775	0.381
2-Way Interaction	63.554	2	31.772	0.354	0.703
Within	8873.033	99	89.667		
Total	9628.248	104	92.579		

Table 9

Su ary Table for the Analysis of Variance of Mother Scale Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	P
Ethnicity	216.705	2	108.352	2.104	0.127
Sex	26.870	1	26.870	0.522	0.472
2-Way Interaction	58.240	2	29.120	0.566	0.570
Within	5097.233	99	51.487		
Total	5399.048	104	51.914		

2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 10 presents the results of the two-way ANOVA. As indicated in Table 10, there is no significant effect for ethnicity, sex, or their interaction.

F. For the FSMAS variable, Attitudes toward Success in Mathematics:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 11 presents the results of the two-way ANOVA. As indicated in Table 11, there was no significant effect for ethnicity, sex, or their interaction.

G. For the FSMAS variable, Teacher Scale:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 12 presents the results of the two-way ANOVA. As indicated in Table 12, there was no significant effect for ethnicity, sex, or their interaction.

H. For the FSMAS variable, Effectance Motivation:

1. There is no difference among the mean scores of Caucasian, Hispanic, and Chinese-American students.
2. There is no sex difference in the mean scores.
3. There is no interaction between ethnicity and sex.

Table 13 presents the results of the two-way ANOVA. As indicated in Table 13, there was a significant main effect

Table 10

Summary Table for the Analysis of Variance of Father Scale Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	p
Ethnicity	214.686	2	107.343	2.116	0.126
Sex	1.476	1	1.476	0.029	0.865
2-Way Interaction	13.225	2	6.613	0.130	0.878
Within	5021.250	99	50.720		
Total	5250.629	104	50.487		

Table 11

Summary Table for the Analysis of Variance of Attitudes Toward Success in Mathematics Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	P
Ethnicity	49.048	2	24.524	0.546	0.581
Sex	43.087	1	43.087	0.959	0.330
2-Way Interaction	87.697	2	43.848	0.976	0.380
Within	4448.417	99	44.934		
Total	4628.248	104	44.502		

Table 12

Summary Table for the Analysis of Variance of Teacher Scale Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	P
Ethnicity	187.219	2	93.610	1.597	0.208
Sex	40.179	1	40.179	0.685	0.410
2-Way Interaction	38.148	2	19.074	0.325	0.723
Within	5804.417	99	58.630		
Total	6069.962	104	58.365		

Table 13

Summary Table for the Analysis of Variance of Effectance Motivation in Mathematics Scores Analyzed by Ethnicity and Sex

Source of Variation	SS	DF	MS	F	P
Ethnicity	630.686	2	315.343	4.065	0.020
Sex	5.207	1	5.207	0.067	0.796
2-Way Interaction	49.748	2	24.874	0.321	0.726
Within	7680.417	99	77.580		
Total	8366.057	104	80.443		

for ethnicity ($F = 4.065$, $p < .020$). There was no significant main effect for sex nor for the interaction between ethnicity and sex.

The Least Significant Difference method of multiple comparisons was used to test the pairwise differences between ethnic groups. The results indicated that the mean score of the Chinese-American students ($M = 46.7$, $s = 7.5$) was significantly higher than those of the Caucasian ($M = 41.3$, $s = 9.3$) and Hispanic ($M = 41.7$, $s = 9.1$) students. The difference between Caucasian and Hispanic students was not significant.

Research hypothesis II is concerned with relationships between the total mathematics scores of CTBS and the other nine variables of this study. The Pearson Correlation Coefficient (r) was used to quantify the degree of relationship. The t-test was used to test the significance of r. The results are presented in Table 14 and 17.

Null hypothesis IIa:

> For each ethnic group, there is no correlation between the total mathematics scores of CTBS and the following variables:
> a) Space Relations (SR);
> b) Usefulness of Mathematics;
> c) Math as a Male Domain;
> d) Confidence in Learning Math;
> e) Mother;
> f) Father;
> g) Attitude toward Success in Math;
> h) Teacher;
> i) Effectance Motivation in Math.

As indicated in Table 14 and 17, there were several positive and significant relationships between mathematics

Table 14

Correlation Coefficient Between Mathematics Achievement and Other Variables

	Caucasian			Chinese-American			Hispanic-American			Total		
	F	M	F & M	F	M	F & M	F	M	F & M	F	M	F & M
Variable	(N=19)	(N=15)	(N=34)	(N=19)	(N=15)	(N=34)	(N=17)	(N=12)	(N=29)	(N=55)	(N=42)	(N=97)
Spa. Vis.	.57	.75	.66	.75	.24	.50	.59	-.35	.38	.58	.47	.54
Useful	.26	.47	.31	.14	.52	.34	.60	-.22	.40	.30	.47	.35
M Domain	.13	.04	.03	.40	.09	.15	.21	.16	.11	.22	.16	.13
Confi.	.47	.63	.54	.26	.47	.37	.22	.37	.26	.38	.49	.43
Mother	.02	.20	.11	.01	.27	.14	.49	.39	.40	.20	.30	.23
Father	.47	.30	.38	-.12	.36	.15	.53	.28	.45	.30	.37	.33
Success	.25	.12	.16	.23	.20	.19	.58	-.05	.41	.32	.17	.23
Teacher	.37	.47	.39	.22	.26	.19	.40	.02	.33	.35	.33	.31
Motiv.	.40	.35	.36	.15	.53	.35	.30	.21	.24	.33	.52	.39

scores and SR scores in the three ethnic groups. For Hispanic male and Chinese-American male students, there was no significant relationship. The Pearson Correlation Coefficients for female students in each ethnic group were all positive and significant.

The correlation of mathematics achievement and attitudes toward usefulness of mathematics was positive and significant for each ethnic group. The stereotyping of mathematics as a male domain did not relate to mathematics achievement for any of the three ethnic groups.

Interestingly, in contrast to Caucasian students and Hispanic students, Chinese-American students' perceptions of their mother's, father's, and teacher's interest, encouragement, and confidence in their ability in mathematics did not correlate significantly to their mathematics achievement.

Confidence in learning mathematics and Effectance Motivation were related to mathematics achievement for both Caucasian and Chinese-American students. The motive to avoid success in mathematics, as measured by Attitude toward Success Scale, did not relate to mathematics achievement for Caucasian and Chinese-American students.

Null hypothesis III is concerned with the ethnic differences and sex differences in relationships between mathematics achievement and spatial visualization. The Z-test for independent samples was used to test null hypothesis III.

Null hypotheses IIIa:

> There is no difference in the correlation coefficient between the total mathematics scores of CTBS and SR scores for
> a) Caucasian and Chinese-American students;
> b) Caucasian and Hispanic students;
> c) Chinese and Hispanic students.

The results of the Z-tests are presented in table 15. As indicated in table 15, the null hypotheses IIIa were all retained. No significant ethnic differemce was detected in the correlations of Mathematics achievement and Space Relations.

Null hypothesis IIIb:

> There is no difference in the correlation between the total mathematics scores of CTBS and SR scores for male students and female students.

The results of the Z-test are presented in Table 16. As indicated in Table 16, significant sex difference in the relationship between mathematics achievement and spatial visualization occurred in Chinese-American and Hispanic students.

Null hypotheses IV are concerned with the ethnic differences of the Pearson Correlation Coefficient between the total mathematics scores and each of the scores of each attitude scale. Z-test for indepedent samples was used to test the null hypotheses. The results are presented in Table 15.

Null hypotheses IVa:

> There is no difference for
> a) Caucasian and Chinese-American students,
> b) Caucasian and Hispanic studenta,

c) Chinese-American and Hispanic students,
in the correlation between the total mathematics of CTBS and the following eight FSMAS variables:

1) Mathematics Usefulness;
2) Mathematics as a Male Domain;
3) Confidence in Learning Mathematics;
4) Mother Scale;
5) Father Scale;
6) Attitudes toward Success in Mathematics;
7) Teacher Scale;
8) Effectance Motivation.

The null hypotheses IVa were all retained as indicated in table 15. There were no significant ethnic differeces of the relationships between the total mathematics scores of CTBS and the scores of each attitude scale of FSMAS.

The null hypotheses IVb:

There is no difference for male and female students in the correlation between the total mathematics of CTBS and the following eight FSMAS variables:

1) Mathematics Usefulness;
2) Mathematics as a Male Domain;
3) Confidence in Learnin g Mathematics;
4) Mother Scale;
5) Father Scale;
6) Attitudes toward Success in Mathematics;
7) Teacher Scale;
8) Effectance Motivation.

The results of the Z-test are presented in Table 16. As indicated in Table 16, significant sex differences in the relationship between mathematics achievement and mathematics attitudes were found in the variables of Usefulness of Mathematics and the Attitude toward Success in Math for Hispanic students.

Research hypotheses V are concerned with the estimaton of total mathematics scores of CTBS, from a linear combination of 11 independent variables, which includes

Table 15

Ethnic Differences of Correlation Coefficients between Mathematics Achievement and Other Variables

	Caucasian vs Chin-Am		Caucasian vs Hispanic		Chin-Am vs Hispanic	
Variable	Z	p	Z	p	Z	p
Spat. Vis.	.96	n.s.	1.48	n.s.	.56	n.s.
Useful	.13	n.s.	.39	n.s.	.26	n.s.
Male	.48	n.s.	.30	n.s.	.89	n.s.
Confi.	.85	n.s.	1.27	n.s.	.15	n.s.
Mother	.12	n.s.	1.18	n.s.	1.06	n.s.
Father	.98	n.s.	.32	n.s.	1.26	n.s.
Success	.12	n.s.	1.03	n.s.	.92	n.s.
Teacher	.87	n.s.	.26	n.s.	.57	n.s.
Motiv.	.05	n.s.	.50	n.s.	.45	n.s.

Significance level = .10

Table 16

Sex Differences of Correlation Coefficients between Mathematics Achievement and Other Variables

	Caucasian		Chin-Am		Hispanic		Total	
Variable	Z	p	Z	p	Z	p	Z	p
Spat. Vis.	.85		1.91	<.10	2.44	<.01	.72	
Useful	.64		1.14		2.14	<.01	.94	
Male	.24		1.35		.12		.06	
Confi	.60		.64		.38		.64	
Mother	.48		.36		.29		.51	
Father	.52		1.30		.71		.37	
Success	.35		.08		1.67	<.10	.76	
Teacher	.32		.11		.95		.10	
Motiv.	.15		1.15		.23		.77	

spatial visualization, sex, ethnicity and eight mathematics attitudes variables. The Stepwise procedure of SPSS using ethnicity as a dummy variable was used to establish the multiple regression equation.

The results are presented in Table 18 and 19. Spatial visualization was the first variable to enter the multiple regression equation. Twenty-nine percent of the variation in mathematics achievement could be explained by this variable. The second variable to enter the equation was the Chinese-American ethnicity (D1). This variable accounted for additional 12% of the variation in mathematics achievement. The third predictor, Confidence of Learning Mathematics, also had a significant regression coefficient, B, and accounted for additional 5% of the variation in mathematics achievement. These three predictors jointly explained 46% of the variation in mathematics achievement with standard error of 16.8 (see Table 19).

Table 17

Significance of Correlation Coefficients Between Mathematics Achievement and Other Variables

	Caucasian			Chinese-American			Hispanic-American			Total		
Variable	F	M	F & M	F	M	F & M	F	M	F & M	F	M	F & M
Spat. Vis.	**	***	***	***		***	**		**	***	***	***
Useful		*	*		**	**	**		**	**	***	***
M Domain				*								
Confi.	**	**	***		*	**				***	***	***
Mother							**		**		*	**
Father	**		**				**		**	**	**	***
Success							**		**	**		**
Teacher		*	**						*	***	**	***
Motiv.	*		**		**	**				***	***	***

* : $p < .10$
** : $p < .05$
*** : $p < .01$

Table 18

Multiple Regression of Mathematics Achievement

Variable	B	F	P
Spat. Vis.	0.8820	29.16	<.01
Ethnic Variable (*)	14.6346	15.75	<.01
Confidence	0.5731	9.23	<.01
Constant	673.0713		

* Ethnic Variable = Chinese-American = 1

Table 19

Multiple Correlations between Mathematics Achievement and Three Predictor Variables

Step	R	R Square	F	p
Step 1 Spatial Vis.	.54	.29	38.37	<.001
Step 2 Spatial Vis. Ethnicity (*)	.64	.41	32.88	<.001
Step 3 Spatial Vis. Ethnicity Confidence	.68	.46	26.92	<.001

* Ethnicity = Chinese-American

Summary

The analyses of mathematics achievement data provided the following findings: (1) Chinese-American students achieved significantly higher than Caucasian and Hispanic students; (2) there was a significant sex difference; (3) there was no significant interaction between ethnicity and sex, that is, the ethnic differences in mathematics were not related to the gender of the students.

The findings from the statistical analyses of spatial visualization ability, as measured by the Space Relations subtest of Differential Aptitude Test battery, are summarized as following: (1) there was a significant interaction between ethnicity and sex; therefore, ethnic groups could not be pooled on sex and compared; (2) Chinese-American male students scored significantly higher than Chinese-American female, Caucasian male, Hispanic male, and Hispanic female students, but not significantly higher than Caucasian male students; (3) Caucasian male students had significantly higher scores than did Hispanic males and Hispanic females.

For the affective domain, the findings for mathematics attitudes are stated as follows:

(1) significant ethnicity-related differences were found for only two variables: Confidence in Learning Mathematics and Effectance Motivation (see Tables 8 and 13); The results indicate that Chinese-American were significantly more confident of their ability to

learn mathematics than Caucasian and Hispanic students; Chinese-American students showed significantly more willingness than Caucasian and Hispanic students to enjoy and to seek challenge in mathematics; there were no significant differences between Caucasian and Hispanic students in these two attitudes.

(2) significant interaction between ethnicity and sex was found for only one variable, Mathematics as a Male Domain; Caucasian males had significantly lower scores than did Caucasian females, Chinese-American males and females, and Hispanic females; Caucasian females had significantly higher scores than Hispanic males and females (see figure 2).

(3) there was no significant effects of ethnicity, sex, or interaction in the other affective variables.

The relationships between the total mathematics scores and the other nine variables are summaarized as the followings (see Table 14 and Table 17):

(1) for the female students in each ethnic group ($\underline{r}$ ranged from .57 to .75), the relationships with spatial visualization ability were all positive and significant; such a relationship also existed in Caucasian male students ($\underline{r}$ = .75); for Hispanic and Chinese-American male students, the relationships were not statistically significant;

(2) the relationships with attitudes toward the usefulness of mathematics were found positive and

significant for Caucasian and Chinese-American male students, and also for Hispanic female students (*r* ranged from .31 to .60);

(3) positive and significant relationship with sex stereotyping in mathematics existed only in Chinese-American female students (*r* = .40);

(4) the relationships with confidence in one's ability to learn and to perform well in mathematics were found positive and significant for Caucasian male students and female students (*r* = .63 and .47 respectively), and Chinese-American male students (*r* = .47).

(5) the relationship with the students' perception of their mothers' interest, encouragement, and confidence in the students' ability in mathematics was found positive and significant only for Hispanic female students (*r* = .49);

(6) the relationships with the students' perception of their fathers' interest, encouragement, and confidence in the students' ability in mathematics were found positive and significant for Caucasian and Hispanic female students (*r* = .47 & .53 respectively);

(7) positive and significant relationship with attitudes toward success in mathematics was found only in Hispanic female students (*r* = .58);

(8) the relationship with the students' perception of their teachers' attitudes toward them as learners of

mathematics was found positive and significant for Caucasian male students (r = .47);

(9) the relationship with effectance motivation in mathematics was found positive and significant for Chinese-American male students (r = .53) and Caucasian female students (r = .40).

There was no significant ethnic-related difference regarding the relationships between spatial visualization ability and mathematics achievement (see table 15). There was also no significant ethnic-related difference with respect to the relationships between mathematics achievement and each of the eight variables of attitudes toward mathematics.

The results of multiple regression analysis indicated that spatial visualization as well as ethnicity were the significant predictors of mathematics achievement for the student population in this study. The variable, Confidence of Learning Mathematics, was the only attitude variables which significantly predicted mathematics achievement.

Chapter 5

DISCUSSIONS AND CONCLUSIONS

The purposes of this study were to investigate possible ethnic and gender distinctions among the variables of mathematics achievement, spatial visualization ability, and attitudes toward mathematics. This study also examined the correlation between mathematics achievement and the other variables in study. All subjects in this study met four requirements: 1) fully proficient in English, 2) not receiving free or partially free lunches, 3) not enrolled in special education programs, and 4) have completed at least four years of education in the United States. An effort was made to determine if the research hypotheses of this study would be confirmed by the results of the data analyses. The results and findings, which were presented and summarized in chapter 4, are discussed below.

Ethnic Differences and Sex Differences in Mathematics Achievement

The results of this study suggested that there were ethnic-related differences in mathematics achievement. Significant sex differences also were found in this study.

Seventh and eighth grade Chinese-American students, males and females, clearly outperformed their Caucasian and Hispanic schoolmates in mathematics achievement. The results of this study are consistent with the findings in Backman's (1972) and Tsang's (1976, 1984) research.

In contrast to previous studies (Anick et al., 1981; Fernandez et al., 1975; Matthews et al., 1984), Hispanic students' performance was not shown to be inferior to that of Caucasian students, particularly the Hispanic male students who scored at the same level as the Caucasian males and females.

The results of a two-way ANOVA revealed that female students achieved significantly lower than male students in mathematics. This finding agreed with the research conducted by McGee (1979) and Garrard (1981) but conflicted with the studies of Armstrong (1981), Fennema (1980), and Fennema and Sherman (1977, 1978). By examining the raw scores, Chinese-American and Hispanic male students attained a wider lead over their female counterparts than did Caucasian males.

Some socio-cultural factors may facilitate Chinese-American students' performance in mathematics. Chinese-American students may be encouraged and pressured by their parents to excel in school. They tend more often to choose mathematics-related fields as their focuses of future studies and career goals. Research data are consistent in reporting higher mathematics achievement of Chinese-American students.

Hispanic students were found consistently to achieve at a lower level than Caucasian students in previous studies. However, most studies reviewed in this report did not take the students' English proficiency and family-income level into consideration.

As indicated in the district documents, the majority of Hispanic students in the Stockton Unified School District come from low income families. Many of them are classified as limited-English-proficient students. The present opinion among educators and researchers seems to be that limited-English-proficiency and low family-income negatively affect the students' academic performance in school. When English proficiency and family-income levels are controlled, the results may show a different pattern. The data of this study, which included only students who were fully English proficient and not from low-income families, did not indicate that Hispanic students perform at a significantly lower level than Caucasian students.

Ethnic and Sex Differences in Spatial Visualization Ability

Ethnic-related differences in spatial visualization were found in many studies (Backman, 1972; Lesser et al., 1965; Loehlin et el., 1975; Stodolsky & Lesser, 1967; Werner et al., 1968). Dason (1972) suggested that development of mental abilities can be determined by biological factors, interaction with the physical and social environments, and social-cultural elements. In these studies, Chinese-American and Caucasian students showed higher spatial visualization ability as compared to some other ethnic students.

The data of the spatial visualization variable in this study indicated that there was a significant interaction between ethnicity and gender. Chinese-American male students scored significantly higher than Hispanic male students and female students of each ethnic group. Also, Caucasian males had significantly higher scores than did Hispanic males and Hispanic females.

Spatial visualization, although it might be a hereditary trait, seems to be shaped by cultural and social environment. In Chinese tradition, women may be given fewer opportunities than males to explore the activities which may enhance the development of spatial skills. This factor may have some effect on the Chinese females' relatively modest spatial ability scores.

Interestingly, Hispanic males scored almost the same as Hispanic females. Traditionally, Hispanic females are placed in a subordinate role to males (Wong, 1982), and they consequently may be denied the opportunities to develop their spatial visualization abilities. However, a tenable explanation as to why Hispanic males performed at the same level as their female counterpart is not readily apparent.

Maccoby and Jacklin (1974) have hypothesized that changes in the role of women in society has changed their achievement patterns, and thus could narrow sex-related differences in intellectual abilities. Some results of the more recent studies of Fennema & Sherman (1977, 1978) reported no sex-differences in spatial visualization, which obviously are consistent with this hypothesis. Garrard (1981), however, indicated that eighth grade male students outperformed females in spatial visualization while in the same year Armstrong found that 13-year old females performed better than males in this mental ability. The results of this study are in accord with Garrard's findings.

Ethnic and Sex Differences in Attitudes Toward Mathematics

The results of this study provided very few ethnic or sex differences in attitudes toward mathematics. Chinese-American students, who achieved at significantly higher level in mathematics, also reported more confidence in their ability to learn mathematics than Caucasian and Hispanic students. Confidence in learning mathematics was not significantly different between Caucasian and Hispanic groups. However, Hispanic male students tended to have more confidence than Caucasian students, or Hispanic female students.

In contrast to Fennema & Sherman's finding (1978), middle school male students in this study did not report more confidence in their abilities to learn mathematics than did female students. However, Hispanic male students tended to have more confidence than Hispanic female students.

The data of this study showed significant ethnic differences in Effectance Motivation in Mathematics, but no sex difference was found. This finding indicated that female middle school students had similar intrinsic or investigative interest in mathematics as their male counterparts. Such a result conflicts with the common belief that girls are not as interested as boys in mathematics, but was consistent with previous studies conducted by Fennema & Sherman (1977, 1978).

The data showed that neither males nor females of any of the three ethnic group labeled mathematics as a male domain. There was a significant sex by ethnicity interactions, which indicated that the sex difference in this variable for Chinese-American students tended to be narrower than those of the other ethnic groups (see figure 2). Caucasian males perceived mathematics as a male domain at a significantly higher level than did Caaucasian females, Hispanic females, and both genders of Chinese-Americans. Also, Hispanic females and Hispanic males perceived mathematics as a male domain at a significantly higher level than Caucasian females.

Students of each ethnic group and gender strongly agreed on the usefulness of mathematics currently and in relationship to their future education. The finding of a non-significant sex difference in attitudes toward usefulnss of mathematics in middle school was somewhat consistent with a study of Fennema & Sherman (1977). However, Fennema & Sherman's study showed that middle school males, compared to females, perceived mathematics as more useful, and such difference became significant in high schools.

The results of this study suggest that male students do not perceive their parents and teacher as more positive toward them as learners of mathematics than do females. Moreover, no ethnic differences were found. The students of both genders from all three ethnic groups perceived high and positive attitudes about themselves as learners of mathematics from their parents and teachers.

The Relationship between Mathematics Achievement and Spatial Visualization

Previous studies (Aiken, 1973; Fennema, 1974; Fennema & Sherman, 1978; Garrard, 1981; Moses, 1978, Sherman, 1979) consistently reported positive relationships between mathematics achievement and spatial visualization. Fennema & Sherman (1978) found that a significant correlation between spatial visualization and mathematics achievement was similar for males and females. The results of this study ($\underline{r}$ = .58 for all females, $\underline{r}$ = .47 for all males) agreed with their findings.

By examining each gender of the three ethnic groups, the correlation between mathematics achievement and spatial visualization were found significant and positive for females in each ethnic group with correlation coefficients ranging from .57 to .75. For males, the positive and significant relationship between these two variables was only found in Caucasian students ($\underline{r}$ = .75). The relationship was not significant for Chinese-American students ($\underline{r}$ = .24). Surprisingly, the data for the Hispanic male students showed a negative relationship ($\underline{r}$ = -.35) between mathematics achievement and spatial visualization scores.

The Relationship between Mathematics Achievement and Mathematics Attitudes

The results of this study showed mixed relationships between mathematics achievement and the eight variables of mathematics attitudes across the ethnic groups. One variable, Mathematics Usefulness, was significantly related to mathematics achievement in Chinese-American ale ($\underline{r}$ = .52), Caucasian males ($\underline{r}$ = .47) and Hispanic female ($\underline{r}$ = .60) students. Mathematics as a Male Domain was expected to have a close relationshiop with females' mathematics achievement. In contrast to the Fennema & Sherman's (1978) findings, the results of this study showed that this attitude was not generally related to mathematics achievement for both females and males with the exception of

Chinese-American females (*r* = .40). The r ranged from *r* = -.09 to *r* = .40.

The variable, Confidence in Learning Mathematics, was significantly related to mathematics achievement for Caucasian and Chinese-American male students, and Caucasian females. Father scale and Teacher scale were closely related to the mathematics achievement for Caucasian and Hispanic students.

Attitudes toward Success in Mathematics highly related to mathematics achievement for Hispanic females, but the relationship was not significant for other groups of student. Effectance Motivation Scale in Mathematics highly related to mathematics achievement for Chinese-American males.

There were no significant ethnic differences in the relationships between mathematics achievement and attitudes toward mathematics (see table 15). Significant sex differences were found only in two variables, Usefulness of Mathematics and Attitude toward Success in Math, in Hispanic students (see Table 16).

The Predictions of Mathematics Achievement

Some studies have demonstrated that spatial visualization is a significant predictor of mathematics achievement in secondary school (Sherman, 1979; Cramond, 1983). It is not surprising that spatial visualization is a heavily weighted predictor of mathematics achievement since both measures of abilities are within the same domain as stated in Cramond's study (1983). Spatial visualization accounted for 29% of the variation of mathematics achievement in this study. The result of this study was in accord with Cramond's finding.

Ethnicity had the second highest predictive ability of mathematics achievement among all independent varialbes in this study. As indicated in Table 18 and 19, being Chinese-American contributed positively and significantly toward mathematics achievement scores. Confidence of Learning Mathe atics was the only attitude variable which significantly predicted mathematics achievement.

Conclusions

Based on the findings and discussions in this study, the following conclusions are made:

1. The subjects in this study were selected from the students who were fully English proficient and were not from low-income families in three middle schools in the Stockton Unified School District. The results indicated that Chinese-American students achieved significantly higher than Caucasian and Hispanic students in mathematics. As the results of this study suggest, when English proficiency and

family-income levels are controlled, Hispanic students (males and females combined) did not achieve at a significantly lower level than did Caucasian students as suggested in previous studies. It appears that if variables such as spatial visualization ability, attitudes, parental expectations, socioeconomic status, English proficiency, child-rearing practice etc. are considered, mathematics achievement may not differ between ethnic groups or genders.

2. There was a significant sex difference in mathematics achievement for middle school students. The males scored significantly higher than females.
3. Chinese males scored at significantly higher level than Chinese females in spatial visualization. However, there was no significant sex difference in Caucasian and Hispanic groups.
4. Students of both gender and all ethnic groups showed strongly positive attitudes toward mathematics.
5. There were very few significant sex differences or ethnic differences in attitudes toward mathematics. Chinese-American male and female students showed more confidence in their ability to learn mathematics. Hispanic male students also tended to have good confidence in mathematics.
6. When all three ethnic groups were combined, females had a significant higher correlation between

mathematics achievement and spatial visualization than did males.

7. There was no significant ethnic difference in the relationships of mathematics achievement and mathematics attitudes.

8. Spatial visualization, ethnicity and confidence of learning mathematics were significant predictors of mathematics achievement for the student population of this study.

Recommendations for Further Studies

This study made some contributions to our understanding of the patterns of mathematics achievement and their relationships to spatial visualization and attitudes toward mathematics of three ethnic groups. However, these relationships as well as ethnic distinctions in mathematics achievement require further study.

There is a need to investigate mathematics achievement of Southeast Asian refugee students, who represent various ethnic groups previously residing in Southeast Asia. It would also be a valuable study to compare ethnic Chinese students who came from different areas such as mainland China, Taiwan, Hong Kong, and Southeast Asia.

More research is needed to examine the relationship between mathematics achievement and family-incomes within and across ethnic groups. A study using longitudinal samples of students from first grade to high school is also desirable in order to determine the inception age of ethnic divergences, if any, in mathematics achievement, and in cognitive and affective domains in mathematics learning. Increasingly, valid and reliable instruments for the measurement of affective and cognitive domains of younger students need to be developed.

Since ethnic and sex differences in spatial visualization were found in this study, it would be beneficial to conduct studies of aptitude-treatment interaction (ATI) to various ethnic groups and both genders. The most suitable mathematics pedagogy may be discovered in these kinds of studies for each ethnic group and gender.

LIST OF REFERENCES

Aiken, L. R. & Dreger, R. M. The effect of attitudes on performance in mathematics. *Journal of Education Psychology*, 1961, *52*, 19-24.

Aiken, L. R. Attitudes toward mathemtics. *Review of Educational Research*, 1970, *40*, 551-596.

Aiken, L. R. Research on attitudes toward mathematics. ~~*Arithmetic Teacher*, 1972, *19*, 229-234.~~

Aiken, L. R. Ability and Creativity in mathematics. *Review of Educational Research*, 1973, *43*, 405-432.

Aiken, L. R. Update on attitude and other affective variables in learning mathematics. *Review of Educational Research*, 1976, *46*, 293-311.

Anick, C. M., Carpenter, T. M., & Smith, C. Minorities and mathematics: results from the National Assessment of Educational Progress. *Mathematics Teacher*, 1981, *74*, 560-568.

Armstrong, J. M. Achievement and participation of women in mathematics: results of two national surveys. *Journal for Research in Mathematics Education*, 1981, *12*, 356-372.

Backman, M. E. Pattrerns of mental abilities: ethnic, socioeconomic, and sex difference. *American Educational Research Journal*, 1972, *9*, 1-12.

Battista, M. The interaction between two instructional treatments of algebraic structures and spatial visualization ability. *Journal of Educational Research*, 1981, *74*, 337-341.

Battista, M. T., Wheatley, G. H., Talsma, G. The importance of spatial visualization and cognitive development for geometry learning in preservice elementary teacher. *Journal for Research in Mathematics Education*, 1982, *13*(5), 1982, 332-340.

Bennett, G. K., Seashore, H. G., & Ivesman, A. G. *Differential Aptitude Tests, Form S and T* (4th ed.). New York: Psychological Corp., 1973.

Bergeson, T. M. A comparison of two methods of improving mathematics attitudes in intermediate teachers and councelors (Doctoral dissertation, University of

Washington. 1982). Dissertation Abstracts International. 1982. 43. 1809A-1810A. (University Microfilms No. 82-26. 521)

Brassell. A. Petry. S.. Brooks. D. M. Ability grouping. mathematics achievement, and pupil attitude toward mathematics. Journal for Research in Mathematics Education. 1980. 11. 22-28.

Brinkman. E. H. Programmed instruction as a technique for improving spatial visualization. Journal of Applied Psychology, 1966. 50, 179-184.

Burbank, I. k. Relationships between parental attitude toward mathematics and student attitude toward mathematics, and between student attitude toward mathematics and student achievement in mathematics (Doctoral dissertation, Utah State University, 1968). Dissertation Abstract International, 1970, 30, 3359A-3360A. (University Microfilms No. 70-2427)

Callahan. W. J. Adolescent attitudes toward mathematics. Mathematics Teacher, 1971, 64, 751-755.

Coleman. R. H. An analysis of certain components of mathematical abilities and an attempt to predict mathematical achievement in a specific situation. Dissertation Abstract, 1956, 16, 2062.

Comprehensive Tests of Basic Skills: Preliminary Technical Report, Form U and V. Monterey, California: California Test Bureau/McGraw-Hill. 1982.

Comprehensive Tests of Basic Skills: Technical Report, Forms U and V. Montery, California: California Test Bureau/McGraw-Hill. 1984.

Cramond, B. L. Predicting mathematics achievement of gifted adolescent females (Doctoral Dissertation, University of Georgia, 1982). Dissertation Abstract International, 1983, 43, 2136A-3139A. (University Microfilms No. 822-8677)

Cronbach ,L. J. The two disciplines of scientific psychology. American Psychology, 1957, 12, 671-682.

Dasen, P. R. Cross-cultural Piagetian research: a summary. Journal of Cross-cultural Psychology, 1972, 3, 23-40.

Davidson. A. R., & Thomson, E. Cross-cultural studies of attitudes and beliefs. In H. C. Triandis & R. W. Brislin (eds.), Handbook of Cross-cultural Psychology (vol. 5). Boston: Allyn and Bacon, Inc, 1980.

DuRapau, V. J., & Carry, L. R. Interaction of general reasoning ability and processing strategies in geometry instruction. Journal for Research in Mathematics Education, 1981, 12, 15-26.

Eastman, P. M., & Carry, L. R. Interaction of spatial visualization and general reasoning abilities with instructional treatment in quadratic inequalities: a further investigation. Journal for Research in Mathematics Education, 1975, 6, 142-149.

Eastman, P. M., & Salhab, M. The interaction of spatial visualization and general reasoning abilities with instructional treatment on absolute value equations. Journal for Research in Mathematics Education, 1978, 9, 152-154.

Echols, P. S. A study of the relationships among students' attitudes toward mathematics and the variables of teacher attitude, parental attitude, achievement, ability, sex of the student and grade level of the student (Doctoral dissertation, University of Houston, 1981). Dissertation Abstract International, 1982, 42, 4752A. (University Microfilms No. 82-10-431)

Fennema, E. Mathematics, spatial ability and the sexes. Madison, Wisconsin: University of Wisconsin, 1974. (ERIC Document Reproduction Service No. ED 089 998)

Fennema, E., Sherman, J. Fennema-Sherman mathematics attitude scales: instruments designed to measure attitudes toward the learning of mathematics by females and males. APA: JSAS Catalog of Selected Documents in Psychology, 1976, 6 (2)®, 31. (Ms. 1225)

Fennema, E. & Sherman, J. Sex-related differences in mathematics achievement, spatial visualization and affective factors. American Educational Research Journal, 1977, 14, 51-71.

Fennema, E. H., & Sherman, J. A sex-related differences in mathematics achievement and related factors: a further study. Journal for Research in mathematics Education, 1978, 9, 189-203.

Fennema, E., & Behr, M. Individual differences and the learning of mathematics. In R. J. Shumway (Ed.), Research in mathematics education. Reston, Va: National Council of Teachers of Mathematics, 1980.

Ferendez, C., Espinosa, R. W., & Dornbusch S. M. Factors perpetuating the low academic status of Chicano high school students. Palo Alto, Calif.: Stanford University, 1975. (ERIC Document Reproduction Service No. ED 110 241)

Fox, L. H. A mathematics Program for fostering precocious achievement. In J. Stanley, D. P. Keating, & L. H. Fox (Eds.), Mathematical Talent: Discovery Description and Development. Baltimore: John Hopkins University Press, 1974.

Fruchter, B. Measurement of spatial abilities: history and background. Educational and Psychological Measurement, 1954, 14 (2), 387-395.

Garrard, S. W. Sex differences, spatial visualization ability and the effects of induced and imposed imagery on problem solving performance (Doctoral dissertation, University of Southern California, 1980). Dissertation Abstracts International, 1981, 43, 115A.

Gibson, E. J. Improvement in perceptual judgment as a function of controlled practice or training. Psychological Bulletin, 1953, 50, 401-431.

Greenfield, P. M., & Runer, J. S. Culture and cognitive growth. In D. A. Goslin (Ed.), Handbook of Sociolization Theory and Research. New York: Rand McNally, 1969.

Guttman, R., & Guttman, B. Cross-cultural stability of an intercorrelation pattern of abilities: a possible test for a biological basis. Human Biology, 1963, 33, 53-60.

Haladyna, T., Shaughnessy, J., & Shaughnessy, J. M. A causal analysis of attitude toward mathematics. Journal for Research in Mathematics Education, 1983, 14, 19-29.

Herman, W. L., Potterfield, J. E., Dayton, C. M., & Amershek, K. G. The relationship of teacher-centered activities and pupil-centered activities to pupil achievement and interest in 18 fifth-grade social studies classes. American Educational Research Journal, 1969, 6 (2), 227-239.

Hull, C. H., & Nie, N. H. Statistical package for the social sciences update 7-9. New York: McGraw-Hill, 1981.

Jackson, R. E. The attitudes of disadvantaged students toward mathematics (Doctoral dissertation, Indiana Univversity, 1973). Dissertation Abstract International, 1974, 34, 3690A. (University Microfilms No. 74-380)

Knight, G. P., Kagan, S., & Nelson, W. J. Acculturation of second- and third-generation Mexican American children: field independence, locus of control, selfesteem, and school achievement. *Journal of Cross-cultural Psychology*, 1978, *9*, 87-97.

Lesser, G. S., Fifer, G., & Clock, D. H. Mental abilities of children from different social-class and cultural groups. *Monograph of the Society for Research in Child Development*, 1965, *30*, 1-115.

Loehlin, J. C. Lindzey, G., & Spuhler, J. N. *Race differences in intelligence*. San Francisco: Freeman, 1975.

Maccoby, E. E. & Jacklin, C. N., *The Psychology of Sex Differences*, Stanford University Press, Stanford, CA. 1974.

MacCorquodale, P. *Psycho-social influences on the accomplishments of Mexican-American students*. Tucson, Arizona: Arizona University, 1980. (ERIC Document Reproduction Service No. ED 200 355)

Majoribank, K. Ethnic and environmental influences on mental abilities. *American Journal of Sociology*, 1972, *78*, 323-337.

Martin, B. L. Spatial visulization abilities of central Washington State College prospective elementary and secondary teachers of mathematics (Doctoral dissertation, Oregon State University, 1966). *Dissertation Abstract*, 1966, 27, 2427A. (University Microfilms No. 67-730)

Mattews, W. Race- and sex-related differences in high school mathematics enrollment (Doctoral dissertation, University of Chicago, 1980). *Dissertation Abstract International*, 1881, *41*, 3934A.

Mathews, W. Influences on the learning and participation of minorities in mathematics. *Journal for Research in Mathematics Education*, 1984, *15*, 84-95.

Matthews, W., Carpenter, T., Lindquist, M. M., Silver, E. A. The third national assessment: minorities and mathematics. *Journal for Research in Mathematics Education*, 1984, *15*, 165-171.

Mayeske, G. W., Okada, T., Beaton, A. E.,Jr., Cohen, W., & Wisler, C. E. *A study of the achievement of our nation's students*. Washington, D. C.: Office of Education (DHEW), 1973. (ERIC Document Reproduction Service No. ED 085 626)

McGee, M. G. Human spatial abilities: psychometric studies and environmental, genetic, hormonal, and neurological influences. Psychological Bulletin, 1979, 86, 889-918.

Moses, B. E. The nature of spatial ability and its relationship to mathematical problem solving (Doctoral dissertation, Indiana University, 1977). Dissertation Abstract International, 1978, 38, 4640A. (University Microfilms No. 73-30,309)

Muscio, R. D. Factors related to quantitative understanding in the sixth grade. Arithmetic Teacher, 1962, 9, 258-262.

Neale, D. C. The role of attitudes in learning mathematics. Arithmetic Teacher, 1969, 16, 631-640.

Nelson, L. T., Jr. The relationship between verbal, visual-spatial, and numerical abilities, and the learning of the mathematical concept of function (Doctoral dissertation, University of Michigan, 1968). Dissertation Abstract Internationa, 1969, 30, 218A.

Nevin, M. Sex differences in participation rates in mathematics and science at Irish schools and universities. International Review of Education, 1973, 19, 88-91.

Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., & Bent, D. H. Statistical package for the social sciences. New York: McGraw-Hill, 1975.

Poffenberger, T. & Norton, D. Factors in the formation of attitudes toward mathematics. Journal of Educational Research, 1959, 52, 171-176.

Ramirez, M., & Castaneda, A. Cognitive styles and cultural democracy in education. Social Science Quarterly, 1973, 53, 895-904.

Ramirez, M., & Castaneda, A. Cultural democracy, bicognitive development, and education. New York: Academic Press, 1974.

Ramirez, M., & Price-Williams, D. R. Cognitive styles of children of three ethnic groups in the United States. Journl of Cross-cultural Psychology, 1974, 5, 212-219.

Roberge, J. J., & Flexer, B. K. Cognitive style, operativity, and mathematics achievement. Journal for Research in Mathematics Education, 1983, 14, 344-353.

Sherman, J. Problem of sex differences in space perception and aspects of intellectual functioning. Psychological Review, 1967, 74, 290-299.

Sherman, J. Predicting mathematics performance in high school girls and boys. Journal of Educational Psychology, 1979, 79, 242-249.

Sherman, J. Mathematics, spatial visualization, and related factors: changes in girls and boys, grades 8-11. Journal of Educational Psychology, 1980, 72, 476-482.

Spickerman, W. R. A study of the relationships between attitudes toward mathematics and some selected pupil characteristics in a Kentucky high school (Doctoral dissertation, University of Kentucky, 1965). Dissertation Abstract International, 1970, 30, 2733A. (University Microfilms No. 70-731)

Stafford, R. E. Sex differences in spatial visualization as evidence of sex-linked inheritance. Perceptual and Motor Skills, 1961, 13, 428.

Stafford, R. E. Hereditary and environmental components of quantitative reasoning. Review of Education Research, 1972, 42, 183-201.

Sternberg, R. J., & Well, E. M. An aptitude x strategy interaction in linear syllogistic reasoning. Journal of Educational Psychology, 1980, 72, 226-239.

Stodolsky, S. S., & Lesser, G. Learning patterns in the disadvantaged. Harvard Educational Review, 1967, 37, 546-593.

Tsang, S. L. The effects of the language factor and the cultural content factors of mathematics achievement tests on Chinese and Chicano students ʻDoctoral dissertation, Stanford University, 1976). Dissertation Abstract International, 1977, 37, 714A. (University Microfilms No. 76-18, 808)

Tsang, S. L. The mathematics education of Asian Americans. Journal for Research in Mathematics Education, 1984, 15, 114-122.

Valverde, L. A. Underachievement and underrepresentation of Hispanics in mathematics & mathematics-related careers. Journal for Research in Mathematics Education, 1984, 15, 123-133.

Vernon, P. E. Ability factors and environmental influences. American Psychologist, 1965, 20, 723-733.

Werner, E. E., Simonion, K., & Smith, R. S. Ethnic and socioeconomic status differences in abilities and achievement among preschool and school age children in Hawaii. Journal of Social Psychology, 1968, 75, 43-59.

Wrigley, J. Factorial nature of ability in elementary mathematics. British Journal of Educational Psychology, 1958, 28, 61-78.

Wong, P. C. Relationship of two field-dependent-independent measures to reading and mathematics achievement of Anglo-American, first-generation Chinese-and Mexican-American elementary school children (Doctoral dissertation, University of the Pacific, 1982). Dissertation Abstract International, 1982, 43, 1416A. (University Microfilms No. 82-83, 922)