A STUDY OF SEX-RELATED DIFFERENCES IN SPATIAL VISUALIZATION AND MATHEMATICS ACHIEVEMENT OF GRADE 9 STUDENTS

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A STUDY OF SEX-RELATED DIFFERENCES IN SPATIAL VISUALIZATION AND MATHEMATICS ACHIEVEMENT OF GRADE 9 STUDENTS

by

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A Thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Education

Department of Curriculum and Instruction
Memorial University of Newfoundland

January 1987

St. John's Newfoundland

ISBN 0-315-37024-6

ABSTRACT

The purpose of this study was to examine the relationships between sex, student achievement, and performance in both spatial visualization and mathematics.

A sample of 16 schools was randomly selected from the population of all schools offering the grade 9 mathematics program on the Avalon Peninsula in the province of Newfoundland for the school year 1986 - 1987. In schools with more than one grade 9 class, a single class was randomly selected for testing purposes. This resulted in a sample of 401 students, consisting of 211 males and 190 females. Each student was administered a teacher-constructed mathematics achievement test and a standardized test of spatial ability.

The initial analysis of the data showed no significant differences related to sex. However, when age was utilized as a covariate, an analysis of data showed significant differences in spatial visualization and mathematics achievement in favor of males. Sex differences in spatial visualization and mathematics achievement had been masked by differences in age.

Significant differences in achievement in favor of males were found on transformational geometry, geometry in general, and overall mathematics. However, using spatial visualization as a covariate, there differences became nonsignificant. Therefore, it was concluded that spatial

visualization was a major contributing factor to sex-related differences in these areas of mathematics.

ACKNOWLEDGEMENTS

I would like to thank all the students, teachers, and principals who participated in this study for their cooperation.

Sincere appreciation is extended to my supervisor, Dr. Lionel Mendoza, for his guidance, interest, and encouragement as well as to Mr. Wilbert Boone for his advice and interest.

Special thanks is also extended to my girlfriend Anne for her support throughout this project.

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CHAPTER I

THE PROBLEM

Introduction

Since the publication of The Development of Sex Differences by Maccoby in 1966, it has been popular for researchers to look for sex differences in achievement. During the late sixties, with more and more women entering the workforce, the myths that had long defined women's place in society began to disintegrate.

In 1974, two Stanford University psychologists, Maccoby and Jacklin, directed attention towards equal opportunity with their now classic book, The Psychology of Sex Differences. Concurrent social change, particularly the women's movement, stimulated interest in this field, and over the past 15 years research into male-female differences has proliferated.

In Newfoundland, the Ministerial Advisory Committee on Women's Issues in Education has established the goal of equality of opportunity for females and males in education. This will be accomplished only if (1) all students have equal access to all courses and programs offered by the schools, (2) both sexes are actively encouraged to take advantage of the full course offerings, and (3) both sexes receive adequate and unbiased guidance to encourage them to participate in courses which have been dominated by one sex in the past (Department of Education, 1984).

One must look at mathematics within the context of equal opportunity. The study of mathematics is important in the intellectual development and career choices of all individuals. In today's technological society, mathematics acts as a critical filter for a multitude of mathematics-related professions. The poor mathematics background of many women is an obstacle which shuts the door to careers in many scientific and technological fields.

Over the last 15 years the area of sex differences in mathematics has received considerable attention, especially from female mathematics educators in the United States. The National Council of Teachers of Mathematics has committed itself to the principle that girls and women should be full participants in all aspects of mathematics (NCTM, 1980). This will be accomplished only if many of the present beliefs pertaining to sex differences in mathematics are eradicated. Two such beliefs are: (1) the learning of mathematics is a male domain; and (2) females are not as good at mathematics as males.

The relationship between the learning of mathematics and the sex of the learner is a multifaceted problem with a number of interrelated variables which contribute to sex-related differences. The sex factor and mathematics is a complex issue which must be analyzed within the context of teaching and learning mathematics.

Rationale

Fennema (1978) identified educational achievement and participation in the study of mathematics as the two main issues relating to sex differences in mathematics.

In the United States, fewer females than males elect to study mathematics beyond the minimum requirements at both the high school and post secondary levels. The differential number of years females and males spend formally studying and using mathematics is one variable which has been positively identified as causing sex-related differences in mathematics (Fennema, 1978). In contrast, the structure of the Newfoundland high school system does not allow students to opt out of mathematics. Therefore, male-female differences in participation rates are virtually nonexistent.

While some studies often show no differences in mathematics achievement between the sexes, a large percentage of those that do, show differences favoring males. In particular, the middle grades (5-9) have been identified as crucial for girls in mathematics (Fennema, 1982). During the elementary grades few sex-related differences in learning mathematics are found. Near the end of middle school boys often outperform girls on many mathematical tasks. By the end of high school this difference in performance between males and females is often both statistically and educationally significant. The largest and most consistent sex differences have been on high-level cognitive tasks and particularly among higher-ability students. However, studies during the last decade have shown declines in these differences (Fennema & Sherman, 1977; Fennema, 1978; Armstrong, 1981, Senk & Usiskin, 1983).

Since sex differences in mathematics achievement are influenced by cognitive development, it was helpful to look at cognitive variables that were thought to be associated with sex-related differences. One such variable which has recently received considerable attention is spatial visualization. Fennema (1981) suggested that spatial visualization was the only variable which might be helpful in understanding sex-related differences in mathematics achievement. McGee (1979a) defined spatial visualization as follows:

> Spatial visualization is the ability to mentally manipulate, rotate, twist or invent pictorially presented visual stimuli. (p. 3)

Such ability seems to be related to the study of mathematics and especially to the study of transformational geometry. It has been shown that spatial visualization ability can be improved through appropriate instruction in geometry (Battista, Wheatley, & Talsma, 1982).

Sex differences in spatial task performance favoring males is one of the most persistent and best documented findings in the mental abilities literature (McGee, 1979a). Male superiority in spatial abilities becomes evident in adolescence and increases with age. Differences in spatial ability between the sexes appear at nearly the same age as do differences in mathematics achievement. Some researchers interpret sex differences in mathematics achievement as a secondary consequence of differences with respect to spatial visualization (McGee, 1979a; Sherman, 1979). Female performance at lower levels than males on tests of spatial visualization and less adequate development of this ability may partially explain female's lower performance in mathematics.

In Newfoundland the junior high school has recently been reorganized with emphasis on the cognitive nature of the child. Since mathematics learning is considered important to the cognitive development of the adolescent, there exists a need for research to determine if sex differences exist in mathematics performance at the junior high level in this province.

Over the years many psychological, environmental, and social factors have been put forward to try to explain any observable sex differences in achievement. As public demand for educational equality for all students increases, educators must take an active role in identifying specific factors which contribute to sex-related differences in mathematics achievement.

It is important that educators base their teaching upon a sound awareness of student abilities and inherent difficulties. Only then is it possible that a firm basis for equal opportunity in scientific and technological fields may become a reality for men and women.

Purpose of the Study

The purpose of this study was to examine the extent to which sex differences affect student performance in spatial visualization and mathematics at the grade 9 level. Specifically it investigated the following questions.

Question 1: Is there a difference between female and male performance in spatial visualization?

Question 2: Is there a difference between female and male performance in mathematics?

Question 3: Is there a differential relationship between spatial visualization and mathematics performance for males and females?

Question 4: Does spatial visualization contribute to sex-related differences in mathematics performance?

It is hoped that the results of this study will be used to determine if intervention programs designed to eliminate sex differences in spatial visualization ability in Newfoundland are actually needed.

Hypotheses

From the questions the study was designed to answer the following null hypotheses were formulated for testing.

Hypothesis 1: There is no significant difference in spatial visualization between males and females in grade 9.

Hypothesis 2: There is no significant difference in overall mathematics achievement between males and females in grade 9.

Hypothesis 3: There is no significant difference in numeracy/algebra achievement between males and females in grade 9.

Hypothesis 4: There is no significant difference in geometry achievement between males and females in grade 9.

Hypothesis 5: The relationship between spatial visualization and overall mathematics achievement is not significantly different for males and females in grade 9.

Hypothesis 6: The relationship between spatial visualization and numeracy/algebra achievement is not significantly different for males and females in grade 9.

Hypothesis 7: The relationship between spatial visualization and geometry achievement is not significantly different for males and females in grade 9.

Hypothesis 8: Spatial visualization does not significantly contribute to sex-related differences in overall mathematics achievement in grade 9.

Hypothesis 9: Spatial visualization does not significantly contribute to sex-related differences in numeracy/algebra achievement in grade 9.

Hypothesis 10: Spatial visualization does not significantly contribute to sex-related differences in geometry achievement in grade 9.

CHAPTER II

REVIEW OF RELATED LITERATURE

In this chapter the literature related to sex differences in mathematics is reviewed, focusing on mathematics achievement and spatial visualization. The chapter is organized into four main sections plus a summary. The main sections are (1) mathematics achievement, (2) spatial visualization, (3) spatial visualization and mathematics, and (4) other factors related to sex differences in mathematics.

Mathematics Achievement

One of the major issues in the study of sex-related differences in mathematics is that of achievement. Fennema (1974, 1978) indicated that there is no consensus on whether sex-related differences in mathematics achievement exists. Where they exist, they tend to favor males and only start to become evident during adolescence.

Wolleat, Pedro, Becker, and Fennema (1980) stated:

> Achievement in mathematics has been one of the most significant sex-related differences observed in late adolescence and adulthood. (p. 356)

In Canada, in 1978, sex differences in mathematics achievement were systematically examined at grades 3, 6, 9, and 12 using test items written at three cognitive levels over five areas of mathematics content (Sawada, Olson, & Sigurdon, 1981). Significant differences in favor of males were found at each grade level, these differences varying directly with cognitive level and grade level. Out of 462 instances of comparison, 146 gave rise to significant differences and 116 of these favored boys. Specifically, at grade 3, 6, 9, and 12, boys outperformed girls 17 to 11, 26 to 10, 28 to 6, and 45 to 3 respectively. This would seem to suggest that sex differences in mathematics achievement increase with grade level.

In order to study sex-related differences in mathematics achievement, the mathematics background of the students must be controlled (Fennema, 1981). In many studies males have been compared with females who have taken fewer high school mathematics courses. Since few studies have controlled for students' mathematics background, it is possible that the sex differences in achievement could be explained by differential mathematics participation (Armstrong, 1981; Fennema & Sherman, 1977). Fennema (1978) suggested that if the amount of time spent learning mathematics is kept constant, educationally significant sex-related differences in mathematics performance will disappear.

Male superiority over females in mathematics achievement was found within all ten countries which participated in the first International Study of

Educational Achievement (Fennema, 1978). Sherman (1980) found that boys in grade 11 performed significantly better than girls even with mathematics background controlled. It was also noted that girls' attitudes toward mathematics became less favorable from grade 8 to 11. The presence or absence of a sex-related difference in achievement covaried with the presence or absence of a more positive attitude toward mathematics among males.

Ethington and Wolfle (1984) found that sex continued to have a significant effect on mathematics achievement even after controlling for sex differences in spatial ability, background in mathematics, and interest in mathematics.

In the third National Assessment of Educational Progress (NAEP), Carpenter, Lindquist, Matthews, and Silver (1983) found no significant differences in performance at ages 9 and 13. However, achievement by males was higher by 3 percentage points at age 17. Males achievement exceeded that of females for each category of course background even when the number of courses were held constant.

The International Study of Achievement in Mathematics (Husen cited in Fennema, 1979; Husen cited in Swetz, Langgulung, & Johar, 1983) found that males scores higher on the mathematics tests in all 12 populations studied both on computation and on verbal problems. It also indicated that a positive relationship existed between socioeconomic standing and mathematical performance. Giesbrecht (1980) found that a statistically significant difference existed between male and female high school students in mathematical competency attainment in favor of males.

Fennema and Sherman (1977) found that when students, grades 9-12, with similar mathematics background were studied, differences between males and females in achievement were small and significant in only 2 of the 4 schools considered. Fennema (1979) and de Wolf (1981) also found that sex differences in achievement were reduced after controlling for specific patterns of high school mathematics coursework taken.

Hanna (1986) in a recent study of the mathematics achievement of 8th graders in Ontario found significant sex differences in achievement in favor of males even though students were matched on socio-economic level, amount of formal training, and quality of teaching.

Different levels of cognitive tasks in mathematics have resulted in sex differences in achievement. While there is a tendency for females to do better at computation tasks, males seem to excel at higher level cognitive tasks like problem solving (Armstrong, 1975; Armstrong, 1981; Carpenter et al., 1983).

Fennema and Sherman (1977) while investigating mathematics achievement in grades 6-8, found significant differences in favor of females on low level cognitive tasks and significant differences in favor of males on higher level cognitive tasks. Schonberger (1978) found evidence of male superiority in problem solving in a number of pre-1975 studies. However, overwhelming evidence of male superiority should be tempered by the limitations of these studies. Lack of controls, sex-biased content, and a tendency to use only high-ability students might have influenced the findings.

In the Women in Mathematics Project, grade 12 students were administered a test which consisted of four subtests dealing with computational skills, algebraic skills, problem-solving skills, and spatial visualization. Even when differences in participation were taken into account, sex differences in achievement favored males in all four subtests; the only statistically significant difference was on the problem-solving subtest (Armstrong, 1981). Linn and Pulos (1983) found that males performed better than females on proportional reasoning tasks but found no evidence that a single aptitude might explain these differences.

Doolittle (1985) found a substantial gender effect on mathematics achievement that could not be explained by instructional differences at the secondary school level. Geometry and word problems tended to have the greatest negative impact on female examinees. When differences in entering geometry knowledge were controlled Senk and Usiskin (1983) found that males and females in grades 7-12 learned both geometry problems and proof writing equally well when differences in entering geometry knowledge were taken into account. They proposed that when test items cover material that is taught and learned almost exclusively in the classroom, no pattern of sex differences tend to be found.

At the grade 6 level, Marshall (1984) found that girls were more successful in solving computations while boys were more successful in solving word problems. The middle grades (5-9) have been identified as crucial for girls and mathematics (Fennema, 1982). Up until that time, few sex-related differences in learning mathematics are found. Near the end of middle school males often start to pull ahead of females.

A cognitive variable very often associated with sex-related differences in mathematics achievement is precocious mathematics ability. This refers to the development of high mathematical ability much earlier than normal.

In 1972 a study of the precocious mathematics ability of adolescents found that 19% of the boys scored higher than the highest scoring girl when given a scholastic aptitude test in mathematics (Fox, 1975). The Study of Mathematical Precocious Youth (Benbow & Stanley, 1982) identified 873 math talented students in a 1976 talent search. Students then took the Scholastic Aptitude Test (SAT), both the mathematics and verbal parts. While there was no significant difference in the verbal part, there was a statistically significant difference in favor of males on the mathematics part.

In a study of gifted young women by Fox it was found that 42% were discouraged by counselors from taking advanced mathematics courses (Burton, 1979). Fox (1982) found that mothers of children with precocious mathematical ability tended to notice this ability in their sons at a much earlier age than in their daughters. Teachers also were found to overlook giftedness in females.

An analysis of most major mathematics contests at the high school level suggested that males consistently performed better than females. It must be noted that fewer females competed in these contests.

Benbow and Stanley (1980) suggested that course taking alone cannot account for sex differences because more precocious boys than girls are found prior to ages when math courses become elective.

Fennema (1978) summed up research in the U.S. by suggesting there are no sex-related differences in achievement evident in elementary school. After elementary school, differences do not always appear. If they do appear, they tend to favor males on higher level cognitive tasks. Many studies prior to 1978 have lacked background controls or have been inadequately reported. The inconsistency of post 1978 studies on mathematics achievement point to a definite need for more research.

Spatial Visualization

Since the 1930's, studies have provided support for the existence of at least two distinct spatial abilities: spatial visualization and spatial orientation.

> Spatial visualization is an ability to mentally manipulate, rotate, twist, or invert pictorially presented visual stimuli. The underlying ability seems to involve a process of recognition, retention, and recall of a configuration in which there is movement among the internal parts of the configuration, or of an object manipulated in 3-D space, or the folding or unfolding of flat patterns. (McGee, 1979a, pp. 3-4)

> Spatial orientation involves the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented, and the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem. (McGee, 1979a, p. 4)

Sex differences in spatial task performance favoring males is one of the most persistent and best documented findings in the mental abilities literature (Maccoby & Jacklin, 1974; McGee, 1979a).

It is indicated that male superiority in spatial abilities becomes evident in adolescence and increases with age. Baker (1983) suggested that the magnitude of this difference depends upon the degree to which an individual is stereotypically masculine or feminine, the type of test, and experience.

Wattanawaha and Clements (1982) found that males significantly outperformed females on questions requiring

3-D thinking or mental manipulation of visual images in grades 7-9.

In most cultures sex-related differences in favor of males appear from adolescence on many tasks that require so called spatial skills (Fennema, 1979; McGee, 1979a, Maccoby & Jacklin, 1974; Sherman, 1980). Numerous studies have consistently shown male superiority in spatial visualization ability, especially during and after adolescence (Guay & McDaniel, 1977; Mitchelmore, 1980; Liben & Golbeck, 1980; Richmond, 1980). Taylor (1977) found that sex differences in spatial visualizing ability were nonsignificant with preadolescents in Newfoundland and Labrador.

Since spatial differences between the sexes do not exist to the same extent in all cultures (Sherman, 1978; Van Leeuwen, 1978), some writers have proposed that some of the differences in spatial ability can be accounted for by the differential treatment of the male and the female as a child. It has been suggested that this differential treatment is related to the type of toys children are given and in the games in which they are encouraged to participate (Gimmestad, 1986; Potegal, 1982). Mothers encourage nurturing rather than mathematics skills in girls. Through play, boys learn basic mathematics skills early: sorting, ordering, reasoning, and manipulating 2-D and 3-D objects in space (North York Board of Education, 1986).

Sherman (1980) and de Wolf (1981) found that when the mathematics background of high school students was controlled, no sex-related differences in spatial visualization developed. Jacklin (cited in Wattanawaha, 1982) found that sex-related differences in visuospatial ability were reduced when the number of mathematics courses taken by high school students was partialled out.

Fennema and Sherman (1977) claim that:

> Covarying out the differences between the sexes in number of space related courses taken eliminates the sex-related differences in spatial visualization. This is consistent with the hypothesis that practice and relevant experience are factors in the difference between sexes in spatial visualization. (p. 66)

When 2-D geometrical puzzles were used to test the spatial visualization skill of students in grades 4-8, it was found that girls outperformed boys. It was also found that instruction on spatial visualization did not have a differential effect on boys and girls (Smith, Frazier, Ward, & Webb, 1983). On the other hand, Smith and Schroeder (1981) found that instruction for preadolescent students can improve spatial visualization as early as grade 4. Sherman (cited in Bishop, 1979) pointed to the need for spatial training, especially in the education of females.

Many different factors have been proposed as a possible source of sex differences in spatial ability.

Karl, Stevenson, and Black (1984) tested and rejected the premise that sex differences in performance on some spatial tasks may be due to differences in algorithm usage. On the other hand, social factors have been proposed as explanations for sex differences in spatial ability (McGee, 1979a; Sherman, 1978; Lips and Colwill, 1978).

A review of clinical and experimental data indicate that the right cerebral hemisphere is specialized for spatial processing and that the cerebral hemispheres of males and females tend to show differences in specialization for verbal and spatial functions. It suggests quite conclusively that males have greater right hemisphere specialization than females (Levy cited in Burnett, Lane, & Dratt, 1979; McGee, 1979a; McGee, 1979b; Sherman, 1978; Potegal, 1982). Waber (1976, 1977) proposed that timing of maturation, by influencing the extent of brain lateralization for spatial skills, was responsible for the sex differences in spatial ability.

Genetic factors have also been proposed as a possible source of sex differences in spatial ability. Komnenich, Lane, Dickey, and Stone (cited in Burnett et al., 1979) found that performance on a spatial test depended on measured levels of estrogen. Gowan (1984) found that spatial ability was correlated positively with the volume of the hormone testosterone. It was suggested that male sex hormones may affect the ability to mentally visualize and manipulate objects, the key components of mathematical skills (McGee, 1979a; Potegal, 1982; Sherman, 1978).

Spatial visualization has been shown to be more highly correlated with success in a number of technical, vocational, and occupational domains than is verbal ability (McGee, 1979a). Gimmestad (1986) found that spatial visualization ability was the most important predictor of success in an engineering design course. According to the U.S. Employment Service many occupations require top level spatial ability. Guay and McDaniel (1977) define high level spatial ability as the visualization of 3-D configurations and their mental manipulation.

While the existence of sex-related differences in spatial functioning seems obvious, there is less certainty over why these differences exist. Whether differences in spatial visualization are due to genetic, hormonal, neurological, or environmental sources; their continued existence has important implications for all educators.

Spatial Visualization and Mathematics

Fennema (1981) suggested that spatial visualization was the only cognitive variable which might be helpful in understanding sex-related differences in mathematics achievement.

Fennema (1979) defined spatial visualization as follows:

> Spatial visualization involves the visual imagery of objects, movements by the objects themselves or changes in their properties. (p. 392)

The relationship between mathematics and spatial visualization is logically evident (Piemonte, 1982). Spatial visualization requires that objects be mentally rotated, reflected, and translated. Such ability seems to be related to the study of mathematics and especially to the study of geometry. Fennema (1978) stated:

> If spatial visualization items are geometrical in character and if mathematical thought involves geometrical ideas, spatial visualization and mathematics are inseparably intertwined. (p. 10)

Even though there seems to be strong pedagogical reasons to believe spatial visualization and mathematics are related, results from empirical studies have been inconsistent (Fennema, 1978). A review of pre-1975 studies by Schonberger (1978) indicated that sex-related differences may be found only on problems whose content is spatial or sex-biased. Recent studies indicate superiority in problem solving and spatial ability are not necessarily related.

Sherman (1980) found that no differences in spatial visualization developed when mathematics background was controlled in grades 8-11. It was determined that spatial visualization was a significant predictor of mathematics performance, especially for girls. Females tended to develop and use verbal facility when spatial ability might be more effective. Fennema and Sherman (1977) found that when females and males were carefully matched according to mathematics and related subjects studied, the differences in their performance on spatial visualization tests were reduced.

The correlation between mathematics achievement and spatial visualization is found to be just as high as the correlation between mathematics achievement and verbal ability. Scores on tests of spatial visualization and mathematics achievement often correlate in the range of 0.3 to 0.6 and spatial visualization appears to account for some of the variance in ability to solve mathematics problems (Schonberger, 1976; Fennema et al., 1985).

McGee (1979a) suggested that sex differences in mathematics achievement can be interpreted as a secondary consequence of differences with respect to spatial visualization. Fennema (1974) suggested that a relationship may exist between mathematics learning and spatial visualization. Females performed at lower levels than males on tests of spatial visualization and less adequate development of this ability may partially explain females' lower performance in mathematics.

Maccoby and Jacklin (1974) suggested that a differential ratio in the use of spatial and verbal skills might explain sex-related differences in mathematics achievement. Sherman (1979) found that differences in spatial visualization were one cause of problem solving differences. In a study involving college students, Johnson (1984) found that sex differences in problem solving were closely related to sex differences in mathematical aptitude and spatial ability.

A number of studies have found that sex differences in spatial ability contribute to sex differences in mathematics achievement (Benbow and Stanley, 1983; Burnett et al., 1979). While no significant differences in either mathematics achievement or spatial visualization skills have been reported in the four to eight year old group, concurrent development of sex-related differences in favor of males in mathematics achievement and spatial visualization skills do often develop during adolescence (Fennema, 1974; Fennema, 1978; McGee, 1979a). It is suggested that the extent of the relationship between spatial visualization and mathematics is influenced by the learner's culture (Bishop, 1979b; Mitchelmore, 1980).

On the other hand, some studies tend not to support the existence of a link between sex-related differences in spatial visualization and mathematics achievement. Fennema and Sherman (1977, 1978) investigated the relationship between mathematics and spatial visualization skills and found few sex-related differences in either mathematics achievement or spatial visualization. The data did not support the idea that spatial visualization is helpful in explaining sex-related differences in mathematics achievement. Fennema and Tartre (1985) found that students in grades 6-8 who were discrepant in spatial visualization and verbal skills differed in the processes used to solve mathematics problems, but not in their ability to solve problems. Boys low in spatial visualization and high in verbal ability showed the highest achievement. Low spatial visualization skills tended to inhibit girls not boys. Armstrong (1981) found no sex-related differences in spatial ability in the achievement data from the Women in Mathematics Study and the 2nd NAEP mathematics assessment after controlling for course taking in mathematics.

Studies have shown that the spatial visualization of females can be improved through appropriate instruction in geometry (Battista et al., 1982). Burnett and Lane (1980) found a significant correlation between improvement in tested spatial ability and the number of mathematics courses taken by college students. It was also shown that females improved more than males.

Many studies are finding that spatial visualization is related to mathematics achievement differently for males and females. Ethington and Wolfe (1984) found that women have less spatial ability than men and the effects of this variable on mathematics are greater for women. Fennema et al. (1985) suggested that low spatial skill may be more debilitating to girls' mathematical problem solving than to boys. Fennema (1983) found that in grades

6-8 students with high spatial skills tended to use them more than those with low spatial skills, with girls who were low in spatial skill using them least of all.

With the inclusion of transformational geometry as part of the mathematics curriculum, spatial representations have been increasingly included in the teaching of mathematics. As a result, some studies that have examined the relationship between spatial visualization and mathematical problem solving have restricted the mathematical tasks to those with an obvious spatial component. The relationship of spatial visualization to a broader spectrum of mathematics is still unclear. The inconsistency of previous studies on the relationship between spatial visualization and mathematics achievement indicates a need for further research in this area.

Other Factors Related to Sex Differences in Mathematics

The relationship between the learning of mathematics and the sex of the learner is a multifaceted problem with a number of interrelated variables contributing to differences. A review of a number of these interrelated variables is necessary in order to understand the seriousness and complexity of the problem of sex-related differences in mathematics.

Research into the area of sex differences in mathematics reveals that one of the main problems is the participation rate in high school mathematics courses. In the United States, fewer females than males elect to study mathematics beyond the minimum requirements at both the high school and post-secondary levels (Fennema & Sherman, 1977). The International Study of Achievement in Mathematics found sex differences in mathematics participation in nearly every country studied (Armstrong, 1981). Tobias (1978) described this failure of many females to take mathematics beyond the minimum requirements as the 'math avoidance' syndrome.

Research suggests that math anxiety is strongly, but negatively related to math confidence. Students with low anxiety tended to have confidence in mathematics (Fennema, 1978). Fennema (1982) indicates that girls report less confidence in their ability to learn mathematics even when achieving as well as boys. Females tended to be more anxious about mathematics than males. Aiken (1972, 1974) reported that confidence in learning mathematics was related to achievement.

While some students perceive mathematics as a worthwhile and necessary subject for future careers, others see mathematics as a waste of time. Fennema and Sherman (1977) found a significant difference in the perceived usefulness of mathematics favoring males. Boys, perceiving mathematics as more useful than girls, continue to study mathematics more than girls do (Perl, 1982).

Society's stereotyping of mathematics as a male domain contributes significantly to sex-related differences in mathematics. The Fennema-Sherman study (1977) indicated that males stereotyped mathematics as a male domain at significantly higher levels than did females.

The teacher is the most important educational influence on students' learning of mathematics. Many studies indicated teachers treat female and male students differently. Becker (1981), in a study of ten high school geometry teachers, found that teachers treated the sexes unequally. Teachers gave more attention to males and referred to them more often in class questions.

The differential treatment of females and males in mathematics class has resulted in a condition known as 'learned helplessness'. Under this condition students see failure as due to a lack of ability and therefore uncontrollable. It was found that females were more likely than males to display this condition (Fennema, 1980; Wolleat et al., 1980).

The remediation of sex-related differences in mathematics and the equalizing of career opportunities for female students require educators to be knowledgeable of the far-reaching consequences of sex-related differences in mathematics.

Summary

As indicated in Chapter I, an investigation of sex differences in mathematics achievement and spatial visualization is important if equity in mathematics is to be realized. It was apparent from searching the literature that research in this area was inconclusive. Whether sex-related differences in mathematics achievement and spatial visualization exist and are more pronounced in certain branches of mathematics than others, is yet to be determined.

CHAPTER III

METHODOLOGY

In this chapter the design used in the investigation is described. In the first section the population and sampling procedure are specified. Following this, the selection, development, and piloting of the instrument are explained, and the limitations inherent in the design are indicated. Finally, the procedure followed for the distribution of the instrument is explained and the methods used to analyze the data are reported.

Population and Sample

The population consisted of all first time grade 9 students on the Avalon Peninsula in the province of Newfoundland who were taking mathematics. Since the first differentiation of students with respect to their high school program occurs at the beginning of the 10th grade, the grade 9 population would be more heterogeneous, more variable, and more reliable with respect to mathematics achievement. To identify the members of this population it was necessary to determine which schools on the Avalon Peninsula offered a grade 9 program of study.

The Avalon Peninsula contains 10 of the 35 school boards and approximately 1/3 of the students in the province of Newfoundland. The schools which offer grade 9 mathematics can be rural or urban, single-sex or co-ed, and listed as either all grade, elementary, junior high, or high school. Classes in these schools can be single-grade or multi-grade and large schools will often have more than one grade 9 class.

It was determined that 64 schools on the Avalon Peninsula in the province of Newfoundland offered the grade 9 mathematics programs during the 1986-1987 school year. From these 64 schools, 16 were randomly selected as the sample. In schools with more than one class of grade 9 students, a single class was randomly selected.

In this way the sample chosen would be representative of the population of grade 9 mathematics students in Newfoundland.

Selection of the Spatial Visualization Test

The spatial visualization ability of the students in the sample was tested by using the Space Relations test, a subtest of the Differential Aptitude Tests (DAT), form V. The most recent revision was chosen because it had been Canadianized (Harcourt Brace Jovanovich Publishers, copyright 1982). The Space Relations test is a measure of ability to deal with concrete materials through visualization. It requires the mental manipulation of objects in three-dimensional space. The test consists of 60 multiple-choice questions which must be answered in 25 minutes. The use of the DAT assures a high degree of validity and reliability. The reliability coefficient for grade 9 students on the Space Relations Test was 0.93.

Development of the Mathematics Test

The mathematics performance of the students in the sample was tested by using a self-constructed achievement test based on material from the grade 8 mathematics program. The test was divided into two separate sections, Numeracy/Algebra and Geometry.

An analysis of the suggested instructional time for core topics in grade 8 and 9 mathematics was necessary in order to determine which components would be emphasized in the achievement test.

Table 1

Suggested Instructional Time for Core Topics in Grade 8 and 9 Mathematics

Core Topic	Instructional Time (8)	Instructional Time (9)
Numeracy	45%	15%
Geometry	25%	40%
Measurement	10%	5%
Graphing	10%	10%
Algebra	10%	30%

The considerable amount of instructional time suggested for numeracy at the grade 8 level dictated that it be tested. The importance of algebra and geometry was ascertained from the significant increase in instructional time each received from grade 8 to grade 9. With this in mind, the numeracy, algebra, and geometry strands were selected for inclusion in the mathematics achievement test. Since algebra can be considered to be generalized arithmetic whereby concepts of numeracy are dealt with in general terms, numeracy and algebra were combined to form the first component of the achievement test. Geometry is a life skill and is considered to be an integral part of the mathematics curriculum at all grade levels. Thus geometry would comprise the second component of the achievement test. This component could be subdivided into plane, transformational, and coordinate geometry.

The time of administration and restrictions on classroom time made a multiple-choice test the most practical and convenient type of achievement test. A thorough analysis of various standardized tests and the intermediate curriculum guide for grades 7-9 made it possible to develop a set of 60 multiple-choice items to be piloted.

Pilot Study

Two pilot studies were carried out using two intact grade 9 mathematics classes during the week of October 6th, 1986. The major aims of the studies were: (1) to ensure that the time allotted for the completion of the test items was sufficient; (2) to check the difficulty of the individual items and the complete test; and (3) to identify any basic weaknesses in the wording or arrangement of the written test.

For each pilot study an item analysis was conducted to determine the difficulty index and discrimination power of the items. As a result of both student and teacher feedback the items to be used in the main study were selected. The final instrument used to test mathematics achievement in the study consisted of 40 items, 20 numeracy/algebra items (odd #'s) and 20 geometry items (even #'s). A time limit of 30 minutes was found to be adequate.

The reliability of the mathematics achievement test was assured, through piloting and then conducting an item analysis. Validity was maintained by following the clearly stated objectives suggested in the intermediate mathematics curriculum guide, grades 7-9. A complete text of the final instrument for measuring mathematics achievement is found in Appendix A.

Procedure

A letter of introduction, together with a letter of support for this study from the Department of Education, were sent to each of the six superintendents of the school boards involved with the study. A sample copy of these letters are found in Appendix B.

Half of the 16 classes participating in the study were first administered a test of spatial visualization and then a test of mathematics achievement. The other half received the tests in reverse order. The administering of all tests was carried out by the researcher. Specific instructions and a specified time limit were rigidly adhered to for each test. The directions for each test were read aloud, students were given an opportunity to ask questions before the test began, and two examples were previewed in order to familiarize students with the recording procedure. Since answer sheets were provided and tests were reusable, inspection of test booklets between testing sessions was necessary. Following each testing section the answer sheets were placed inside an envelope upon which a memorandum was written. This included group tested, name of teacher, name of school, date, time of testing, number of answer sheets, and an account of any disturbances.

The students were told not to be discouraged if some of the questions were too difficult for them or they didn't finish the test, but to try their best in the time allotted.

In order to interpret the results of the mathematics achievement test fairly, it was necessary to try to determine what material had actually been taught. Therefore, a short questionnaire was prepared and given to the mathematics teachers who taught the students in the study during the 1985-1986 academic year. A copy of the questionnaire is found in Appendix C.

Limitations of the Study

As in the case with all research of this type there are several limitations which were inherent in the design.

1. The study was delimited to just one grade level.
2. The study did not attempt to determine the actual amount of instructional time spent on numeracy/algebra and geometry in grade 8.
3. There was no attempt to assess any previous experience of students with spatial task training or instruction.

Analysis of Data

In this study the answers to four basic questions were sought. These questions, as well as the analysis used to describe the data, are now discussed.

Question 1: Is there a difference between female and male performance in spatial visualization?

Question 2: Is there a difference between female and male performance in mathematics?

Question 3: Is there a differential relationship between spatial visualization and mathematics performance for males and females?

Question 4: Does spatial visualization contribute to sex-related differences in mathematics performance?

An analysis of variance procedure was used to test both question (1) and (2). To test question (3) the Pearson product moment correlation was calculated and Fisher's Z-transformation was used to test for significance. To test question (4) an analysis of covariance was performed using spatial visualization ability as a covariate. The 0.05 level of significance was used for all tests.

CHAPTER IV

ANALYSIS OF DATA

The main purpose of this study was to examine the extent to which sex differences affect student performance in spatial visualization and mathematics at the grade 9 level. In this chapter the data which were collected according to the procedures outlined in Chapter 3 are examined in terms of the stated questions and the associated null hypothesis. The population considered for the study consisted of all grade 9 students taking mathematics for the first time on the Avalon Peninsula in the province of Newfoundland for the school year 1986-1987.

Research Questions and Results

For each of the stated questions, the associated null hypotheses are presented and the data are analyzed.

Question 1: Is there a difference between male and female performance in spatial visualization?

From question (1) the following hypothesis was formulated testing.

Hypothesis 1: There is no significant difference in spatial visualization between males and females in grade 9.

In Table 2 the criterion variable of spatial visualization is broken down by sex.

Table 2

Mean Spatial Visualization Scores by Sex

Group	Mean	SD	Cases
Males	30.34	10.56	211
Females	28.31	10.53	190
Entire Population	29.38	10.58	411

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for spatial visualization scores.

Table 3

Analysis of Variance of Spatial Visualization Scores by Sex

Source	SS	df	MS	F	P
Between Groups	412.27	1	412.27	3.71	0.05(5)
Within Groups	44346.11	399	111.14		

From the ANOVA it was concluded that there was no significant difference in spatial visualization by sex, thus hypothesis (1) was accepted.

As a result of the acceptance of hypothesis (1), male and female performance in spatial visualization were not considered different.

Question 2: Is there a difference between male and female performance in mathematics?

From question (2) the following three hypotheses were formulated for testing.

Hypothesis 2: There is no significant difference in overall mathematics achievement between males and females in grade 9.

Hypothesis 3: There is no significant difference in numeracy/algebra achievement between males and females in grade 9.

Hypothesis 4: There is no significant difference in geometry achievement between males and females in grade 9.

In Table 4 the criterion variable of overall mathematics is broken down by sex.

Table 4

Mean Overall Mathematics Scores by Sex

Group	Mean	SD	Cases
Males	24.10	6.05	211
Females	23.56	6.41	190
Entire Population	23.85	6.22	401

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for overall mathematics scores.

Table 5

Analysis of Variance of Overall Mathematics Scores by Sex

Source	SS	df	MS	F	P
Between Groups	29.27	1	29.27	0.76	0.39
Within Groups	15464.45	399	38.76		

From the ANOVA it was concluded that there was no significant difference in overall mathematics achievement by sex, thus hypothesis (2) was accepted.

In Table 6 the criterion variable of numeracy/algebra is broken down by sex.

Table 6

Mean Numeracy/Algebra Scores by Sex

Group	Mean	SD	Cases
Males	13.00	3.60	211
Females	12.99	3.76	190
Entire Population	13.00	3.67	401

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for numeracy/algebra scores.

Table 7

Analysis of Variance of Numeracy/Algebra Scores by Sex

Source	SS	df	MS	F	P
Between Groups	0.01	1	0.01	0.00(1)	0.98
Within Groups	5389.99	399	13.51		

From the ANOVA it was concluded that there was no significant difference in numeracy/algebra achievement by sex, thus hypothesis (3) was accepted.

In Table 8 the criterion variable of geometry is broken down by sex.

Table 8

Mean Geometry Scores by Sex

Group	Mean	SD	Cases
Males	11.10	3.25	211
Females	10.57	3.43	190
Entire Population	10.85	3.34	401

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for geometry scores.

Table 9

Analysis of Variance of Geometry Scores by Sex

Source	SS	df	MS	F	P
Between Groups	28.20	1	28.20	2.54	0.11
Within Groups	4437.52	399	11.12		

From the ANOVA it was concluded that there was no significant difference in geometry achievement by sex, thus hypothesis (4) was accepted.

As a result of the acceptance of hypotheses (2), (3), and (4), male and female performance in mathematics was not considered different.

Question 3: Is there a differential relationship between spatial visualization and mathematics performance for males and females?

From question (3) the following three hypothesis were formulated for testing.

Hypothesis 5: The relationship between spatial visualization and overall mathematics achievement is not significantly different for males and females in grade 9.

Hypothesis 6: The relationship between spatial visualization and numeracy/algebra achievement is not significantly different for males and females in grade 9.

Hypothesis 7: The relationship between spatial visualization and geometry achievement is not significantly different for males and females in grade 9.

In Table 10 the Pearson product-moment correlation was computed for spatial visualization with the dependent variables of numeracy/algebra, geometry, and overall mathematics.

Table 10

Correlation Between Spatial Visualization and the Dependent Variables by Sex

Group	Spatial Visualization and Numeracy/Algebra	Geometry	Overall Mathematics
Males	0.47*	0.52*	0.56*
Females	0.53*	0.50*	0.58*
Entire Population	0.49*	0.52*	0.57*

* $p < 0.001$

Fisher's Z-transformation of r was conducted to determine if the correlation between spatial visualization and each of the dependent variables was significantly different by sex.

Table 11

Fisher's Z-test of the Correlation Between Spatial Visualization and Overall Mathematics by Sex

Group	r	N	Zr	Z	P
Males	0.56	211	0.63	0.30	0.76
Females	0.58	190	0.66		

From Fisher's Z-test it was concluded that there was no significant difference in the correlation between spatial visualization and overall mathematics achievement by sex, thus hypothesis (5) was accepted.

Table 12

Fisher's Z-test of the Correlation Between Spatial Visualization and Numeracy/Algebra by Sex

Group	r	N	Zr	Z	P
Males	0.47	211	0.51	0.81	0.42
Females	0.53	190	0.59		

From Fisher's Z-test it was concluded that there was no significant difference in the correlation between spatial visualization and numeracy/algebra achievement by sex, thus hypothesis (6) was accepted.

Table 13

Fisher's Z-test of the Correlation Between Spatial Visualization and Geometry by Sex

Group	r	N	Zr	Z	P
Males	0.52	211	0.58	0.30	0.76
Females	0.50	190	0.55		

From Fisher's Z-test it was concluded that there was no significant difference in the correlation between spatial visualization and geometry achievement by sex, thus hypothesis (7) was accepted.

As a result of the acceptance of hypotheses (5), (6), and (7), the relationship between spatial visualization and mathematics performance for males and females was not considered different.

Question 4: Does spatial visualization contribute to sex-related differences in mathematics performance?

From question (4) the following three hypotheses were formulated for testing.

Hypothesis 8: Spatial visualization does not significantly contribute to sex-related differences in overall mathematics achievement in grade 9.

Hypothesis 9: Spatial visualization does not significantly contribute to sex-related differences in numeracy/algebra achievement in grade 9.

Hypothesis 10: Spatial visualization does not significantly contribute to sex-related differences in geometry achievement in grade 9.

An analysis of covariance by sex, spatial visualization as the covariate, was conducted to determine if the difference between the means was significant for overall mathematics scores.

Table 14

Analysis of Covariance of Overall Mathematics Scores by Sex

Source	SS	df	MS	F	P
Covariate	5015.02	1	5015.02	190.52	0.00
Main Effects	1.94	1	1.94	0.07	0.79
Explained	5016.96	2	2058.48	95.29	0.00
Residual	10476.77	398	26.32		
Total	15493.72	400	38.73		

From the ANCOVA it was concluded that there was no significant difference in overall mathematics achievement by sex, thus hypothesis (8) was accepted.

An analysis of covariance by sex, spatial visualization as the covariate, was conducted to determine if the difference between the means was significant for numeracy/algebra scores.

Table 15

Analysis of Covariance of Numeracy/Algebra Scores by Sex

Source	SS	df	MS	F	P
Covariate	1309.23	1	1309.23	128.05	0.00
Main Effects	11.48	1	11.48	1.12	0.29
Explained	1320.71	2	660.36	64.59	0.00
Residual	4069.29	398	13.48		

From the ANCOVA it was concluded that there was no significant difference in numeracy/algebra achievement by sex, thus hypothesis (9) was accepted.

An analysis of covariance by sex, spatial visualization as the covariate, was conducted to determine if the difference between the means was significant for geometry scores.

Table 16

Analysis of Covariance of Geometry Scores by Sex

Source	SS	df	MS	F	P
Covariate	1199.48	1	1199.48	146.34	0.00
Main Effects	3.98	1	3.98	0.49	0.49
Explained	1203.46	2	601.73	73.41	0.00
Residual	3262.26	398	8.20		
Total	4465.72	400	11.16		

From the ANCOVA it was concluded that there was no significant difference in geometry achievement by sex, thus hypothesis (10) was accepted.

In Tables 14, 15, and 16, using spatial visualization as a covariate did not produce significant differences in means for any of the dependent variables. As a result of the acceptance of hypotheses (8), (9), and (10), it was concluded that spatial visualization does not contribute to sex-related differences in mathematics performance.

Exploratory Analysis

During the collection, scoring, and coding of the data certain trends became evident that indicated further analysis would be worthwhile. An exploratory analysis would allow a better understanding of the data as well as provide possible questions for future research.

First, it was noticed that the numeracy/algebra mark was higher than the geometry mark in the majority of cases. For the entire population, the mean numeracy/algebra score was 13 while the mean geometry score was 10.85. Therefore, a new variable referred to as "mathdiff" was computed for each student where mathdiff equals numeracy/algebra score minus geometry score. In Table 16 the criterion variable of mathdiff is broken down by sex.

Table 17

Mean Mathdiff Scores by Sex

Group	Mean	SD	Cases
Males	1.91	3.22	211
Females	2.43	3.27	190
Entire Population	2.15	3.25	401

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for mathdiff scores.

Table 18

Analysis of Variance of Mathdiff Scores by Sex

Source	SS	df	MS	F	P
Between Groups	27.15	1	27.15	2.58	0.11
Within Groups	4190.57	399	10.50		

From the ANOVA it was concluded that there was no significant difference in mathdiff scores by sex.

Second, the higher mean spatial visualization score for males and the possible spatial component of a section of the geometry subtest made an investigation into transformational geometry seem worthwhile. The conclusions drawn from the analyses of the transformational geometry subtest should be tempered by the fact that this subtest consisted of only eight items. In Table 18 the Pearson product-moment correlation was computed for transformational geometry with the dependent variables of spatial visualization, numeracy/algebra, geometry, and overall mathematics.

Table 19

Correlation Between Transformational Geometry and the Dependent Variables by Sex

Group	Spatial Visualization	Numeracy/ Algebra	Geometry	Overall Mathematics
	Transformational Geometry and			
Males	0.38*	0.39*	0.79*	0.66*
Females	0.38*	0.44*	0.84*	0.71*
Entire Population	0.38*	0.41*	0.82*	0.68*

* $p < 0.001$

In Table 20 the criterion variable of transformational geometry is broken down by sex.

Table 20

Mean Transformational Geometry Scores by Sex

Group	Mean	SD	Cases
Males	5.09	1.83	211
Females	4.64	1.89	190
Entire Population	4.88	1.87	401

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for transformational geometry.

Table 21

Analysis of Variance of Transformational Geometry Scores by Sex

Source	SS	df	MS	F	P
Between Groups	20.97	1	20.97	6.07	0.01*
Within Groups	1378.05	399	3.45		

* $p < 0.05$

From the ANOVA it was concluded that there was a significant difference in transformational geometry achievement by sex. As a result, an analysis of covariance was conducted using spatial visualization as a covariate.

Table 22

Analysis of Covariance of Transformational Geometry Scores by Sex

Source	SS	df	MS	F	P
Covariate	206.69	1	206.69	69.60	0.00
Main Effects	10.33	1	10.33	3.48	0.06
Explained	217.02	2	108.51	36.54	0.00
Residual	1181.99	398	2.97		
Total	1399.01	400	3.50		

From the ANCOVA it was concluded that there was no significant difference in transformational geometry achievement by sex. With spatial visualization as a covariate, the significant difference in means by sex for transformational geometry had disappeared.

Third, a wide range in the ages of grade 9 students made an investigation into the age factor seem worthwhile. In Table 23 the frequency of age is broken down by sex.

Table 23

Frequency of Age by Sex

Group	13	14	15	16	17	18
Males	3	148	43	15	1	1
Females	2	157	22	8	1	0
Entire Population	5	305	65	23	2	1

In Table 24 the criterion variable of age is broken down by sex.

Table 24

Mean Age by Sex

Group	Mean	SD	Cases
Males	14.36	0.70	211
Females	14.21	0.55	190
Entire Population	14.29	0.64	401

A one-way analysis of variance by sex was conducted to determine if the difference between the means was significant for age.

Table 25

Analysis of Variance of Age by Sex

Source	SS	df	MS	F	P
Between Groups	2.55	1	2.55	6.36	0.01*
Within Groups	159.90	399	0.40		

From the ANOVA it was concluded that there was a significant difference in age means by sex.

In Table 26 the Pearson product-moment correlation was computed for age with the dependent variables of spatial visualization, numeracy/algebra, geometry, and overall mathematics.

Table 26

Correlation Between Age and the Dependent Variables by Sex

Group	Spatial Visualization	Numeracy/ Algebra	Age and Geometry	Overall Mathematics
Males	-0.11**	-0.38*	-0.38*	-0.43*
Females	-0.14**	-0.37*	-0.26*	-0.36*
Entire Population	-0.11**	-0.37*	-0.32*	-0.39*

* $p < 0.001$

** $p < 0.05$

The significant correlation between age and each of the dependent variables made a one-way analysis of variance by age necessary.

Table 27

Analysis of Variance of Spatial Visualization Scores by Age

Source	SS	df	MS	F	P
Between Groups	1002.57	5	200.51	1.81	0.11
Within Groups	43755.81	395	110.77		

Table 28

Analysis of Variance of Numeracy/Algebra Scores by Age

Source	SS	df	MS	F	P
Between Groups	752.32	5	150.46	12.82	0.00*
Within Groups	4637.68	395	11.74		

* $p < 0.0001$

Table 29

Analysis of Variance of Geometry Scores by Age

Source	SS	df	MS	F	P
Between Groups	476.02	5	95.20	9.43	0.00*
Within Groups	3989.70	395	10.10		

* $p < 0.0001$

Table 30

Analysis of Variance of Overall Mathematics Scores by Age

Source	SS	df	MS	F	P
Between Groups	2408.59	5	481.72	14.54	0.00*
Within Groups	13085.13	395	33.13		

* $p < 0.0001$

From the ANOVAs (Tables 27, 28, 29, and 30) it was concluded that there was a significant difference in each of numeracy/algebra achievement, geometry achievement, and overall mathematics achievement by age.

An analysis of covariance by sex, age as the covariate, was conducted to determine if the difference between the means was significant for spatial visualization.

Table 31

Analysis of Covariance of Spatial Visualization Scores by Sex

Source	SS	df	MS	F	P
Covariate	553.93	1	553.93	5.05	0.03
Main Effects	549.30	1	549.30	5.01	0.03*
Explained	1103.23	2	551.61	5.03	0.01
Residual	43655.16	398	109.69		
Total	44758.38	400	111.90		

* $p < 0.05$

An analysis of covariance by sex, age as the covariate, was conducted to determine if the difference between the means was significant for numeracy/algebra scores.

Table 32

Analysis of Covariance of Numeracy/Algebra Scores by Sex

Source	SS	df	MS	F	P
Covariate	736.97	1	736.97	63.21	0.00
Main Effects	12.45	1	12.45	1.07	0.30
Explained	749.42	2	374.71	32.14	0.00
Residual	4640.58	398	11.66		
Total	5390	400	13.48		

An analysis of covariance by sex, age as the covariate, was conducted to determine if the difference between the means was significant for geometry scores.

Table 33

Analysis of Covariance of Geometry Scores by Sex

Source	SS	df	MS	F	P
Covariate	443.32	1	443.32	44.58	0.00
Main Effects	64.17	1	64.17	6.45	0.01*
Explained	507.49	2	253.74	25.51	0.00
Residual	3958.23	398	9.95		
Total	4465.72	400	11.16		

* $p < 0.05$

An analysis of covariance by sex, age as the covariate, was conducted to determine if the difference between the means was significant for overall mathematics scores.

Table 34

Analysis of Covariance of Overall Mathematics Scores by Sex

Source	SS	df	MS	F	p
Covariate	2323.45	1	2323.45	70.93	0.00
Main Effects	133.15	1	133.15	4.07	0.04*
Explained	2456.60	2	1228.30	37.50	0.00
Residual	13037.12	398	32.76		
Total	15493.72	400	38.73		

* $p < 0.05$

From the ANCOVAs (Tables 31, 32, 33, and 34) it was concluded that there was a significant difference in each of spatial visualization, geometry achievement, and overall mathematics achievement by sex.

An analysis of covariance by sex, age and spatial visualization as covariates, was conducted to determine if the difference between the means was significant for geometry scores.

Table 35

Analysis of Covariance of Geometry Scores by Sex

Source	SS	df	MS	F	P
Covariates	1499.10	2	749.55	100.97	0.00
SV	1055.79	1	1055.79	142.22	0.00
Age	299.62	1	299.62	40.36	0.00
Main Effects	19.50	1	19.50	2.63	0.11
Explained	1518.61	3	506.50	68.11	0.00
Residual	2947.12	397	7.42		
Total	4465.72	400	11.16		

Note: SV = Spatial Visualization

An analysis of covariance by sex, age and spatial visualization as covariates, was conducted to determine if the difference between the means was significant for overall mathematics scores.

Table 36

Analysis of Covariance of Overall Mathematics Scores by Sex

Source	SS	df	MS	F	P
Covariates	6661.42	2	3330.71	150.01	0.00
SV	4337.97	1	4337.97	195.38	0.00
Age	1646.41	1	1646.41	74.15	0.00
Main Effects	17.84	1	17.84	0.80	0.37
Explained	6679.26	3	2226.42	100.28	0.00
Residual	8814.46	397	22.20		
Total	15493.72	400	38.73		

Note: SV = Spatial Visualization

From the ANCOVAs (Tables 35 and 36) it was concluded that there was no significant difference in either geometry achievement or overall mathematics achievement by sex. With spatial visualization as a covariate, as well as age, the significant difference in means by sex for both geometry and overall mathematics had disappeared.

Summary

From the analysis of the data according to the procedures outlined in Chapter 3 the following conclusions were reached. There was no significant difference between male and female performance in spatial visualization nor mathematics. The relationship between spatial visualization and mathematics performance for males and females was not significantly different. Spatial visualization does not significantly contribute to sex-related differences in mathematics performance.

However, an exploratory analysis did reveal a number of hidden relationships in the data. Males did significantly better than females on transformational geometry, a subsection of the geometry test. If differences in spatial visualization were controlled, then the significant difference between males and females on transformational geometry was removed. If differences in age were controlled, significant differences in both spatial visualization and mathematics between males and females began to emerge. Controlling for spatial visualization, as well as age, removed these significant differences. These results are discussed in Chapter 5.

CHAPTER V

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

In this chapter a summary of the study as well as a statement of the conclusions resulting from an analysis of the data is presented. Implications for teaching are discussed and recommendations for future research are presented.

Summary

The study of mathematics is important in the intellectual development and career choices of all individuals. In today's technological society, mathematics acts as a critical filter for a multitude of mathematics-related professions. Without an adequate mathematics background careers such as engineering, architecture, and computer studies may not be accessible. While some studies often show no differences in mathematics achievement between the sexes, a large number of studies show differences favoring males.

Spatial visualization is a cognitive variable which is thought to be associated with sex-related differences. Differences in spatial visualization between the sexes appear at nearly the same age as do differences in mathematics achievement. Consequently, it is possible that sex differences in mathematics achievement may be a secondary consequence of differences with respect to spatial visualization.

This study was designed to examine the relationships between sex, student achievement, and performance in spatial visualization and in mathematics. Investigations also involved other aspects including a questionnaire to teachers and an exploratory analysis of the data.

The sample for the study consisted of 401 grade 9 students, 211 males and 190 females. Each student was administered a teacher-constructed mathematics achievement test and a standardized test of spatial ability. The administering of all tests was carried out by the researcher. Specific instructions and a specified time limit (mathematics - 30 minutes, spatial visualization - 25 minutes) were rigidly adhered to for each test. The next section discusses the results of the study.

Discussion of Results

The detailed results of this study were presented in the previous chapter. In this section these results are discussed with reference to the stated questions.

The first question in this study was concerned with comparing male and female performance in spatial visualization. On the spatial visualization test the mean score for males was higher than the mean score for females. Overall, this difference in spatial visualization was not significant. However, using age as a covariate, the difference in spatial visualization between the sexes became significant. It was apparent that a significant difference between males and females in spatial visualization had been masked by differences in age.

In the review of literature it was indicated that some studies have found that sex-related differences in spatial visualization were reduced or disappeared when the mathematics background of students was controlled. In Newfoundland, the mathematics background of all students, up to and including grade 9, is virtually the same. This could explain why overall differences in spatial visualization between males and females in grade 9 were not significant. Previous research also indicated that male superiority in spatial abilities often became evident in adolescence and increased with age. Thus, it may be that the overall difference in spatial visualization observed in this study could become significant over time.

A wide range in the ages of grade 9 students in the sample made an investigation into the age factor seem worthwhile. Even though grade 9 repeaters were eliminated from the sample, ages still ranged from 13 to 18. The mean age for males was significantly higher than for females. This was probably due to the fact that males repeated earlier grades more often than females. As a result, there was a significant negative correlation between age and spatial visualization, for both males and females, with the correlation being stronger for females than for males. Therefore, it was necessary to control the age factor in order to ensure a fair comparison of spatial visualization ability for males and females. Covarying out the differences in age, the resultant significant difference in spatial ability between the sexes tended to support previous research findings of sex differences in spatial task performance favoring males. Since research suggests that the magnitude of the difference between the sexes in spatial visualization depends upon previous experience, social and environmental differences may possibly exert the greatest influences.

The second question in this study was concerned with comparing male and female performance in mathematics. Overall mathematics, numeracy/algebra, and geometry were considered separately for analysis purposes. Although the mean score for males was higher than the mean score for females in geometry and overall mathematics and differences in numeracy/algebra were negligible, the primary analysis found no significant difference between male and female performance in overall mathematics, numeracy/algebra, or geometry.

Since certain conspicuous trends became evident in the data gathered, further analysis was undertaken. It was noted that the mean difference between numeracy/algebra and geometry, referred to as "mathdiff", was lower for males than for females. The majority of the students in the sample had a higher mark in numeracy/algebra than in geometry. This might be due to the fact that certain parts of the grade 8 mathematics program were not covered because of limited time. In particular, geometry sections were covered less often than the numeracy/algebra sections, with transformational and coordinate geometry being neglected most of all. Twenty-eight percent of the teachers surveyed failed to cover transformational geometry, while forty-eight percent failed to cover coordinate geometry.

Spatial visualization requires that objects be mentally rotated, reflected, and translated. Such ability seems to be logically related to geometry, especially transformational geometry. When the analysis of data focused on transformational geometry, a subsection of the geometry test, the difference between male and female performance became significant in favor of males. This result supports the contention that sex-related differences in mathematics are especially common on problems whose content is spatial. A cautionary note is that transformational geometry comprised only eight of the total 40 items of the overall test.

When numeracy/algebra, geometry, and overall mathematics scores were broken down by age, an obvious negative relationship with age could be seen. The negative correlation between age and these variables could be explained by the presence of slower students who had repeated one or more earlier grades. The negative correlation between age and geometry was higher for males than for females.

An analysis of variance found that numeracy/algebra, geometry, and overall mathematics scores differed significantly by age. Therefore, it was necessary to control for differences in age. With age as a covariate, differences in geometry and overall mathematics by sex became significant in favor of males. As with spatial visualization, differences in geometry and overall mathematics achievement had been masked by differences in age.

In the review of literature some studies suggested that when the mathematics background of subjects was controlled, differences in mathematics achievement between the sexes were often small and insignificant. In contrast, the results of this study found significant differences in geometry and overall mathematics achievement between the sexes even though the mathematics background of the subjects was the same.

It is worth noting that the mathematics test used in this study was very general. It balanced the components of the program and consequently tested many skills. In contrast many previous studies tended to focus on specific content areas and tasks were often limited to one specific level. While many high level tasks such as proof writing often favored males, low level tasks such as computation often favored females. Therefore, to some extent, the results of this study are consistent with previous research.

The third question in this study was concerned with comparing the relationship between spatial visualization and mathematics performance for males and females. While the correlation between spatial visualization and geometry was higher for males, the correlation between spatial visualization and both numeracy/algebra and overall mathematics was higher for females. A Fisher's Z-test for independent samples determined that these correlations were not significantly different for males and females.

Spatial visualization was significantly correlated with numeracy/algebra, geometry, and overall mathematics for each sex. Research has concluded that spatial visualization and mathematics often correlate in the range of 0.3 to 0.6. The results of this study support this conclusion for both males and females.

The fourth question in this study was concerned with the contribution of spatial visualization to sex-related differences in mathematics performance. For the entire population, the correlation between spatial visualization and overall mathematics was 0.57. Therefore, spatial visualization accounts for approximately 30 percent of the variance in ability in mathematics achievement. In the primary analysis of data, the overall difference in mathematics performance between the sexes was not significant. Using spatial visualization as a covariate did not change the outcome. However, in cases where significant differences in mathematics achievement between the sexes did exist, spatial visualization was found to be a contributing factor.

First, consider the case of transformational geometry. In this case, a significant difference favoring males was found to exist. It is important to realize that when differences in spatial visualization were controlled, differences in transformational geometry between the sexes became nonsignificant. Thus, spatial visualization can be considered an important factor contributing to sex-related differences in transformational geometry. Females perform at lower levels than males on tests of spatial visualization and less adequate development of this ability may partially explain females lower performance in transformational geometry.

Second, consider the case of geometry and overall mathematics. In this case, using age as a covariate, a significant difference favoring males was found to exist in both geometry and overall mathematics achievement. However, with both spatial visualization and age as covariates, the difference between males and females in geometry and overall mathematics achievement became nonsignificant. Controlling for spatial visualization, as well as age, removed the significant difference between the sexes that was previously observed. Thus, it can be concluded that spatial visualization was a factor contributing to sex-related differences in geometry and overall mathematics achievement.

Overall, the results of this study suggest that spatial visualization was significantly related to mathematics achievement. Covarying out the differences in spatial visualization eliminated the differences between the sexes in transformation geometry, while covarying out the differences in both age and transformational geometry eliminated the differences in both geometry and overall mathematics achievement. These findings are consistent with the importance of spatial visualization to mathematics learning in general and to explaining some of the differences observed between the sexes in specific branches of mathematics.

Implications

As pointed out in chapter one, the existence of sex-related differences in mathematics results in inequity in education. The reduction of sex-related differences in mathematics and the equalizing of career opportunities for male and female students require educators to be knowledgeable of the far-reaching consequences of sex-related differences in mathematics when they exist.

The results of this study have several important implications for educators. Since sex-related differences in mathematics achievement have been found to exist, teachers must be made aware of where they exist and also encouraged to provide the appropriate learning experiences that would allow both sexes equal opportunity to attain greater success in mathematics.

The next question is what can be done to reduce and hopefully eliminate these differences? The main area of concern appears to be geometry, especially transformational geometry. This study has shown that a significant difference in achievement favoring males is evident in transformational geometry. It has also been shown that when age was controlled, differences between males and females in geometry and spatial visualization were significant. However, once spatial visualization was controlled, differences between the sexes in transformational geometry and geometry in general became nonsignificant. Therefore, it can be concluded that sex-related differences in geometry achievement can be reduced if the spatial visualization ability of females can be improved. Since previous research found that geometry instruction for students can improve spatial visualization as early as grade 4, teachers should be encouraged to develop spatial reasoning in elementary school as an integral part of instruction in geometry. This can be accomplished through the increased use of manipulatives in activities dealing with geometry.

It may be that the lack of instructional time spent on geometry is more detrimental to the mathematics performance of females than of males.

It is important to realize that the task of promoting equity through mathematics is not solely the responsibility of the teacher. Friends, parents, school counselors, and students themselves all have a role to play if sex differences in achievement are to be eliminated.

Recommendations for Future Research

The focus of this study was to determine whether sex-related differences in mathematics achievement and spatial visualization exist at the grade 9 level in the province of Newfoundland. Only through a recognition of individual differences and inherent abilities will the goal of equality of opportunity for females and males in education be accomplished. Therefore, it is necessary to explore and attempt to understand the existence of sex-related differences in mathematics achievement. This requires that carefully designed research be conducted into a number of areas beyond the scope of this study.

The results of this study suggest several recommendations for future research. First, since the present study was limited to the grade 9 level, a similar study should be conducted at other grades. At higher grades research should pay special attention to differences in the mathematics background of students. Previous research suggests that the greatest sex-related differences in achievement may occur at higher level mathematical functioning. Since the spatial visualization test used in the present study is only appropriate for grade 8 and above, research below grade 8 would have to use an alternative test to measure spatial visualization ability.

Second, future research should attempt to identify which specific components of the algebra or geometry programs are related to spatial visualization. In geometry, besides looking at transformational geometry, coordinate and plane geometry could be considered. In algebra, specific components such as solving equations and algorithm usage could be investigated.

Third, a study should be conducted to determine if spatial training has a differential effect on the mathematics achievement of males and females. As in the present study, mathematics achievement could be broken down into various components for comparison purposes.

In future research dealing with sex-related differences in mathematics achievement, the suppression effect of the age factor should be considered. Only by covarying out differences in age may a true comparison of mathematics performance between males and females be possible.

Since the present study has confirmed that when age is used as a covariate there exists sex-related differences in spatial visualization and mathematics achievement, future research should attempt to determine the underlying causes of these differences. It is important to realize that the relationship between the learning of mathematics and the sex of the learner is a multi-faceted problem with a number of interrelated variables which contribute to sex-related differences in mathematics. Only through extensive research will probable solutions to this complex problem be found.

REFERENCES

REFERENCES

Aiken, L.R. (1972). Research on attitudes toward mathematics. The Arithmetic Teacher, 19 (3), 229-234.

Aiken, L.R. (1974). Two scales of attitude toward mathematics. Journal for Research in Mathematics Education, 5 (2), 67-71.

Armstrong, J.R. (1975). Factors in intelligence and mathematical ability which may account for differences in mathematics achievement between the sexes. In E. Fennema (Ed.), Mathematics learning: What research says about sex differences (pp. 22-32). Columbus, Ohio: ERIC Center for Science, Mathematics, and Environmental Education. (ERIC: ED 128 195)

Armstrong, J.M. (1981). Achievement and participation of women in mathematics: Results of two national surveys. Journal for Research in Mathematics Education, 12 (5), 356-372.

Armstrong, J.M., and Price, R.A. (1982). Correlates and predictors of women's mathematics participation. Journal for Research in Mathematics Education, 13 (2), 99-109.

Baker, D.R. (1983). Can the difference between male and female science majors account for the low number of women at the doctoral level in science? Journal of College Science Teaching, 13 (2), 102-107.

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

Becker, J.R. (1981). Differential treatment of females and males in mathematics classrooms. Journal for Research in Mathematics Education, 12 (1), 40-53.

Benbow, C.P., and Stanley, J.C. (1980). Sex differences in mathematical ability: Fact or artifact? Science, 210 (4475), 1262-1264.

Benbow, C.P., and Stanley, J.C. (1982). Intellectually talented boys and girls: Educational profiles. Gifted Child Quarterly, 26 (2), 82-88.

Benbow, C.P., and Stanley, J.C. (1983). Sex differences in mathematical reasoning ability: More facts. Science, 222, (4627), 1029-1031.

Bishop, A.J. (1979a). Spatial abilities and mathematics - A review. Educational Studies in Mathematics, 11 (3), 257-269.

Bishop, A.J. (1979b). Visualising and mathematics in a pre-technological culture. Educational Studies in Mathematics, 10 (2), 135-146.

Burnett, S.A., and Lane, D.M. (1980). Effects of academic instruction on spatial instruction. Intelligence, 4 (3), 233-242.

Burnett, S.A., Lane, D.M., and Dratt, L.M. (1979). Spatial visualization and sex differences in quantitative ability. Intelligence, 3 (4), 345-354.

Burton, G.M. (1979). Regardless of sex. The Mathematics Teacher, 72 (4), 261-269.

Carpenter, T.P., Lindquist, M., Matthews, W., and Silver, E.A. (1983). Results of the third NAEP mathematics assessment: Secondary school. The Mathematics Teacher, 76 (9), 652-659.

de Wolf, V.A. (1981). High school mathematics preparation and sex differences in quantitative abilities. Psychology of Women Quarterly, 5 (4), 55-567.

Department of Education (1984). Policy statement on equality of opportunity for females and males in education. Newfoundland and Labrador.

Doolittle, A.E. (1985). Understanding differential item performance as a consequence of gender differences in academic background. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL. (ERIC: ED 263 218)

Ethington, C.A., and Wolfle, L.M. (1984). Sex differences in a causal model of mathematics achievement. Journal for Research in Mathematics Education, 15 (5), 361-377.

Fennema, E. (1974). Mathematics learning and the sexes: A review. Journal for Research in Mathematics Education, 5 (3), 126-139.

Fennema, E. (1978). Sex-related differences in mathematics achievement: Where and why? In J.E. Jacobs (Ed.), Perspectives on women and mathematics (pp. 1-20). Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Fennema, E. (1979). Women and girls in mathematics - Equity in mathematics education. Educational Studies in Mathematics, 10 (4), 389-402.

Fennema, E. (1980). Teachers and sex bias in mathematics. The Mathematics Teacher, 73 (3), 169-173.

Fennema, E. (1981). The sex factor. In E. Fennema (Ed.), Mathematics education research: Implications for the 80's (pp. 92-105). Reston, Va.: National Council of Teachers of Mathematics.

Fennema, E. (1982). Girls and mathematics: The crucial middle grades. In L. Silvey (Ed.), Mathematics for the middle grades (5-9) (pp. 9-19). Reston, Va.: National Council of Teachers of Mathematics.

Fennema, E. (1983). Research on relationships of spatial visualization and confidence to male/female mathematics achievement in grades 6-8. Washington, DC: National Science Foundation. (ERIC: ED 232 853)

Fennema, E., and Sherman, J. (1977). Sex-related differences in mathematics achievement, spatial visualization and affective factors. American Educational Research Journal, 14 (1), 51-71.

Fennema, E., and Sherman, J. (1978). Sex-related differences in mathematical achievement and related factors: A further study. Journal for Research in Mathematics Education, 9 (3), 189-203.

Fennema, E., and Tartre, L. (1985). The use of spatial visualization in mathematics by girls and boys. Journal for Research in Mathematics Education, 16 (3), 184-206.

Fennema, E., Wolleat, P.L., Pedro, J.D., and Becker, A.D. (1981). Increasing women's participation in mathematics: An intervention study. Journal for Research in Mathematics Education, 12 (1), 3-14.

Fox, L.H. (1975). Mathematically precocious: Male or female. In E. Fennema (Ed.), Mathematics learning: What research says about sex differences (pp. 1-12). Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education. (ERIC: ED 128 195)

Fox, L.J. (1982). The study of social processes that inhibit or enhance the development of competence and interest in mathematics among highly able young women. Washington, DC: National Institute of Education. (ERIC: ED 222 037)

Glass, G.V. and Stanley, J.C. (1970). Statistical methods in education and psychology. Englewood Cliffs, NJ: Prentice-Hall.

Giesbrecht, E. (1980). High school students' achievement of selected mathematical competencies. School Science and Mathematics, 80 (4), 277-286.

Gimmestad, B.J. (1986). Sex differences in spatial visualization and predictors of success in an engineering design course. Paper presented at the meeting of the National Council of Teachers of Mathematics, Washington, DC.

Gowan, J.C. (1984). Spatial ability and testosterone. Journal of Creative Behavior, 18 (3), 187-190.

Guay, R.B., and McDaniel, E.D. (1977). The relationship between mathematics achievement and spatial abilities among elementary school children. Journal for Research in Mathematics Education, 8 (3), 211-215.

Hanna, G. (1986). Sex differences in the mathematics achievement of eighth graders in Ontario. Journal for Research in Mathematics Education, 17 (3), 231-237.

Johnson, E.S. (1984). Sex differences in problem solving. Journal of Educational Psychology, 76 (6), 1359-1371.

Karl, R., Stevenson, M.R., and Black, K.N. (1984). Absence of a sex difference in algorithms for spatial problem solving. Intelligence, 8 (1), 37-46.

Liben, L.S., and Golbeck, S.L. (1980). Sex differences in performance on Piagetian spatial tasks: Differences in competence of performance? Child Development, 51 (2), 594-597.

Linn, M.C., and Pulso, S. (1983). Aptitude and experience influences on proportional reasoning during adolescence: Focus on male-female differences. Journal for Research in Mathematics Education, 14 (1), 30-46.

Lips, H.M., and Colwill, N.L. (1978). The psychology of sex differences. Englewood Cliffs, NJ: Prentice-Hall.

Maccoby, E.E. (1966). The development of sex differences. Stanford, Calif: Stanford University Press.

Maccoby, E.E., and Jacklin, C.N. (1974). The psychology of sex differences. Stanford, Calif: Stanford University Press.

Marshall, S.P. (1984). Sex differences in children's mathematics achievement: Solving computations and story problems. Journal of Educational Psychology, 76 (2), 194-204.

McGee, M.G. (1979a). Human spatial abilities. New York: Praeger.

McGee, M.G. (1979b). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. Psychological Bulletin, 86 (5), 889-917.

Mitchelmore, M.C. (1980). Three-dimensional geometrical drawing in three cultures. Educational Studies in Mathematics, 11 (2), 205-216.

National Council of Teachers of Mathematics (1980). A position statement on the education of girls and young women. Reston, VA: National Council of Teachers of Mathematics.

North York Board of Education (1986). Interface Newsletter from the Research Department, Unpublished manuscript.

Perl, T.H. (1982). Discriminating factors and sex differences in electing mathematics. Journal for Research in Mathematics Education, 13 (1), 66-74.

Piemonte, C. (1982). Mathematics - A visual experience. Curriculum Review, 21 (4), 413-415.

Potegal, M. (1982). Spatial abilities. New York: Academic Press.

Reyes, L.H. (1979). Sexual stereotyping in mathematics: Beyond textbooks. The Arithmetic Teacher, 26 (8), 25-26.

Richmond, P.G. (1980). A limited sex difference in spatial test scores with a preadolescent sample. Child Development, 51 (2), 601-602.

Sawada, D., Olson, A.T., and Sigurdon, S.E. (1981). Sex differences in mathematics learning in a Canadian setting. Canadian Journal of Education, 6 (2), 5-18.

Schonberger, A.K. (1978). Are mathematics problems a problem for women and girls? In J.E. Jacobs (Ed.), Perspectives on women and mathematics (pp. 21-34). Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Senk, S., and Usiskin, Z. (1983). Geometry proof writing: A new view of sex differences in mathematics ability. American Journal of Education, 91 (2), 187-201.

Sherman, J.A. (1978). Sex-related cognitive differences. Springfield, Illinois: Charles C. Thomas.

Sherman, J. (1979). Predicting mathematics performance in high school girls and boys. Journal of Educational Psychology, 71 (2), 242-249.

Sherman, J. (1980). Mathematics, spatial visualization and related factors: Changes in girls and boys, grades 8-11. Journal of Educational Psychology, 72 (4), 476-482.

Smith, F.M. (1984). Constructing and using achievement tests in the classroom. New York: Peter Lang.

Smith, W.S., and Schroeder, C.K. (1981). Preadolescents' learning and retention of a spatial visualization skill. School Science and Mathematics, 81 (8), 705-509.

Smith, W., Frazier, N., Ward, S., and Webb, M. (1983). Early adolescent girls' and boys' learning of a spatial visualization skill-replications. Science Education, 67 (2), 239-243.

Swetz, F.J., Langgulung, H., and Johar, A.R. (1983). Attitudes towards mathematics and school learning in Malaysia and Indonesia: Urban-rural and male-female dichotomies. Comparative Education Review, 27 (3), 394-402.

Taylor, L.J. (1977). Sex and psychological differentiation. Psychological Reports, 41 (1), 192-194.

Tobias, S. (1978). A clinical approach to reducing math anxiety. In J.E. Jacobs (Ed.), Perspectives on women and mathematics (pp. 113-117). Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Van Leeuwen, M.A. (1978). A cross-cultural examination of psychological differentiation in males and females. International Journal of Psychology, 13 (2), 87-122.

Waber, D.P. (1976). Sex differences in cognition: A function of maturation rates? Science, 192 (4239), 572-574.

Waber, D.P. (1977). Sex differences in mental abilities, hemispheric lateralization, and rate of physical growth at adolescence. Developmental Psychology, 13 (1), 29-38.

Wattanawaha, N., and Clements, M.A. (1982). Qualitative aspects of sex-related differences in performance on pencil-and-paper spatial questions, grades 7-9. Journal of Educational Psychology, 74 (6), 878-887.

Wolleat, P.L., Pedro, J.D., Becker, A., and Fennema, E. (1980). Sex differences in high school students' causal attribution of performance in mathematics. Journal for Research in Mathematics Education, 11 (3), 356-366.

APPENDICES

APPENDIX A

Instrument

MATHEMATICS ACHIEVEMENT TEST

DIRECTIONS

Do not open this test booklet until you are told to do so.

This test contains 40 multiple-choice questions.
It is not expected that you know everything on this test.

When you are told to begin:

1. Read each question carefully.
2. Decide upon the answer you think is most correct. There is only one correct answer to each question.
3. Using the pencils provided cross out the letter corresponding to your answer on your answer sheet.
4. Use the scrap paper provided for figuring or drawing. Do not mark on the test booklet.
5. If you want to change an answer, completely erase the 1st answer.
6. You will not be permitted to use a calculator.

Let us look at the following two examples.

X. Add 5 + 3

A) 5
B) 6
C) 7
D) 8
E) none of the above

Y. How many angles does a triangle have?

A) 1
B) 3
C) 2
D) 4
E) none of the above

You will have 30 minutes for the test.
Work as rapidly and as accurately as you can.
If you are not sure of an answer, mark the choice that is your best guess.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

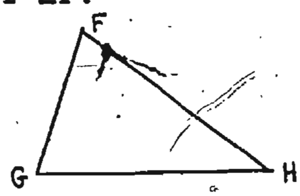
ODD: Numeracy/Algebra {1, 3, 5, ... 39}
EVEN: Geometry {2, 4, 6 .... 40}

(1) Divide

$2.4\overline{).72}$

(A) .03
(B) .3
(C) 3
(D) 30
(E) none of the above

(2) In the figure below H = 60° and G = 85°. What is the measure of ∠F?

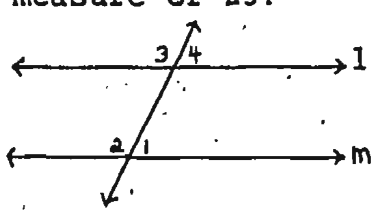


(A) 60°
(B) 85°
(C) 35°
(D) 95°
(E) none of the above

(3) What is the greatest common factor of 16 and 24?

(A) 2
(B) 4
(C) 8
(D) 48
(E) none of the above

(4) In the figure below ∠1 = 50° and lines l and m are parallel (l||m). What is the measure of ∠3?



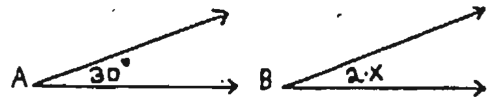
(A) 50°
(B) 130°
(C) 100°
(D) 150°
(E) none of the above

(5) What number should replace the question mark?

$\frac{3}{5} = \frac{?}{20}$

(A) 3
(B) 15
(C) 4
(D) 12
(E) none of the above

(6) In the figure below ∠A and ∠B are congruent (A ≅ B). What is the value of X?



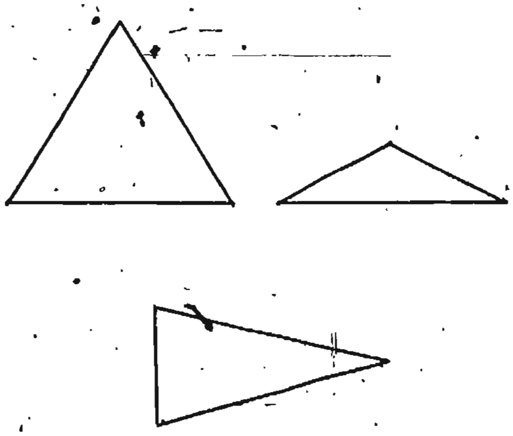
(A) 30°
(B) 60°
(C) 80°
(D) 15°
(E) none of the above

(7) What number should replace the question mark?

12 = 75% of ?

(A) 15
(B) 16
(C) 9
(D) .16
(E) none of the above

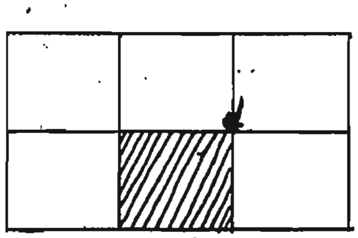
(8) An isosceles triangle is a triangle with 2 sides of equal length. Here are 3 examples.



Which of the following is true in every isosceles triangle?

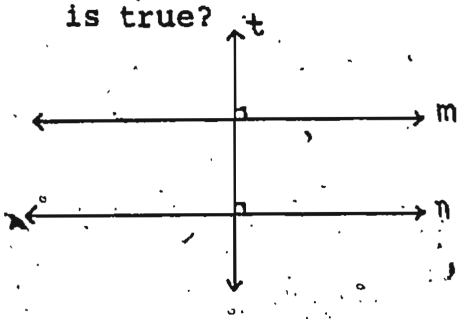
(A) The 3 angles must have the same measure.
(B) One side must have twice the length of another side
(C) There must be 2 angles with the same measure.
(D) The 3 sides must have the same length.
(E) None of the above.

(9) Which fraction represents the shaded region?



(A) $\frac{5}{6}$
(B) $\frac{1}{6}$
(C) $\frac{1}{3}$
(D) $\frac{1}{5}$
(E) none of the above

(10) In the figure below line m is perpendicular to line t ($m \perp t$) and line n is perpendicular to line t ($n \perp t$). Which of the following is true?



(A) lines m and n are perpendicular
(B) lines m and n are parallel
(C) lines m and t are parallel
(D) lines n and t are parallel
(E) none of the above

(11) Which of the following inequalities are true?

(A) $3 < 1$
(B) $-2 > 4$
(C) $0 = 3$
(D) $-5 > 0$
(E) none of the above

(12) How many sides does a polygon have?

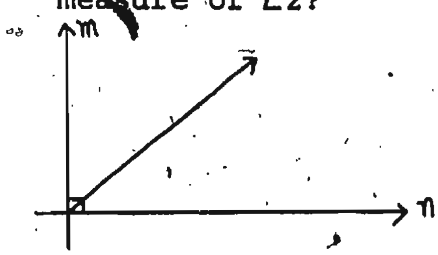
(A) exactly 3 sides
(B) 3 or more sides
(C) exactly 5 sides
(D) more than 3 sides
(E) none of the above

(13) Add

$\frac{4}{3} + \frac{3}{5}$

(A) $-\frac{7}{8}$
(B) $-\frac{11}{15}$
(C) $\frac{11}{15}$
(D) $\frac{1}{8}$
(E) none of the above

(14) In the figure below line m is perpendicular to line n ($m \perp n$) and $\angle 1 = 43^\circ$. What is the measure of $\angle 2$?

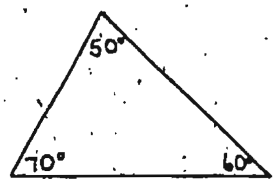


(A) 37°
(B) 57°
(C) 43°
(D) 137°
(E) none of the above

(15) Write .06 as a fraction in lowest terms.

(A) $\frac{3}{5}$
(B) $\frac{3}{50}$
(C) $\frac{6}{10}$
(D) $\frac{6}{100}$
(E) none of the above

(16) How can the following triangle be classified?

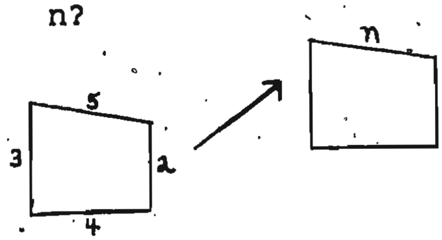


(A) obtuse
(B) acute
(C) isosceles
(D) right
(E) none of the above

(17) If a = 2 and b = 3, what is the value of $2a - b^2$?

(A) -5
(B) -2
(C) 13
(D) 1
(E) none of the above

(18) If the following diagram represents a translation (slide), what is the length of n?



(A) 1
(B) 2
(C) 3
(D) 4
(E) none of the above

(19) Which equation has <u>not</u> been built from x = 3?

(A) x + 6 = 9
(B) x - 8 = -5
(C) x + -8 = -11
(D) 9 + x = 12
(E) none of the above

(20) If "V" is rotated (turned) 270 in a clockwise direction, what will be the result?

(A) ^
(B) <
(C) >
(D) V
(E) none of the above

(21) What is the solution for the equation y - 6 = -2?

(A) y = 4
(B) y = -4
(C) y = -8
(D) y = 8
(E) none of the above

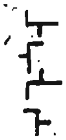
(22) If "" is rotated (turned) 180 in a counter-clockwise direction, what will be the result?

(A)–(D) 
(E) none of the above

(23) What is the mathematical expression for "a number doubled is increased by 3"?

(A) 3x + 2
(B) 2 (x + 3)
(C) 2x + 3
(D) 3 (x + 2)
(E) none of the above

(24). If "" is reflected (flipped) through a vertical line (y-axis), what will be the result?

(A)–(D) 
(E) none of the above

(25) Calculate

(-4)·(2) – (-6)

(A) -4
(B) -14
(C) 2
(D) 16
(E) none of the above

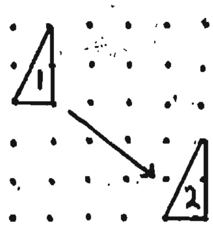
(26) If "" is reflected (flipped) through a horizontal line (x-axis), what will be the result?

(A)–(D) 
(E) none of the above

(27) There are 3 less boys than girls. There are 11 girls in the class. What is the ratio of the number of boys to girls?

(A) 14:11
(B) 11:3
(C) 8:11
(D) 8:14
(E) none of the above

(28) Which translation (slide) will map figure 1 onto to figure 2?



(A) [3R, 4D]
(B) [4R, 3D]
(C) [4L, 3U]
(D) [3L, 4U]
(E) none of the above

(29) The scale on a map is 1:250. What distance would you walk if the distance measured on the map is 5 cm?

(A) 50 cm
(B) 255 cm
(C) 1250 cm
(D) 1500 cm
(E) none of the above

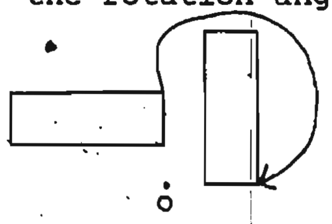
(30) If "E" is reflected (flipped) through the y-axis (vertical), what will be the result?

(A) Ǝ
(B) E
(C) ᗰ
(D) Ш
(E) none of the above

(31) A student picked 15 apples in 2 minutes. At that rate, how many apples will be picked in 12 minutes?

(A) 180
(B) 24
(C) 72
(D) 90
(E) none of the above

(32) For the following rotation (turn) about point 0, the original figure and the image are shown. What is the rotation angle?

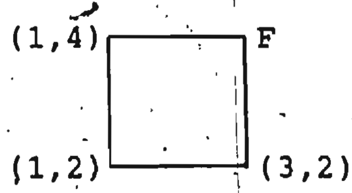


(A) 90° clockwise
(B) 180° counter-clockwise
(C) 90° counter-clockwise
(D) 180° clockwise
(E) none of the above

(33) Write $\frac{17}{25}$ as a percent.

(A) 17%
(B) 34%
(C) 68%
(D) 83%
(E) none of the above

(34) In the square below what are the coordinates of point F?



(A) (3,4)
(B) (2,4)
(C) (1,4)
(D) (2,3)
(E) none of the above

(35) If t = 3 and n = 6, what is the value of 4n - 5t?

(A) 9
(B) 39
(C) -18
(D) 42
(E) none of the above

(36) If the point A (1,2) is reflected (flipped) through the y-axis (vertical), what are the coordinates of the image point A'?

(A) (-1,2)
(B) (1,-2)
(C) (-1,-2)
(D) (2,1)
(E) none of the above

(37) What is the mathematical equation for "a number n increased by 3 is equal to 7"?

(A) 3n = 7
(B) $\frac{n}{3} = 7$
(C) n + 3 = 7
(D) n - 3 = 7
(E) none of the above

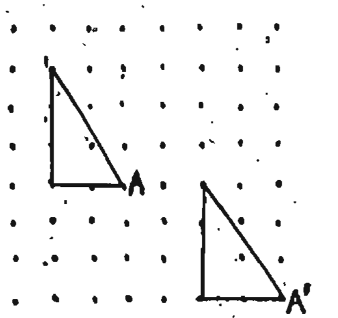
(38) If the point B (1,3) is rotated (turned) 90 counter-clockwise about the origin, what are the coordinates of the image point B'?

(A) (-3,1)
(B) (3,-1)
(C) (3,1)
(D) (-3,-1)
(E) none of the above

(39) What is the solution for the equation 2y - 13 = 25?

(A) y = 6
(B) y = 19
(C) y = -6
(D) y = 38
(E) none of the above

(40) In the translation (slide) below A has coordinates (5,4). What are the coordinates of the image point A'?



(A) (1,1)
(B) (9,1)
(C) (5,4)
(D) (-5,-4)
(E) none of the above

MATHEMATICS ACHIEVEMENT: ANSWER SHEET

NAME ______________________________
(Print) Last First Middle Initial

Your Grade ______ Today's Date ______

School ______________________________

City ______________________________

Age (as of Dec. 31, 1986) __________

SEX

__ Male

__ Female

STATUS

__ Repeater

__ Non-Repeater

EXAMPLES

X Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

Y Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	13 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	27 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	14 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	28 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	15 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	29 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	16 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	30 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	17 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	31 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	18 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	32 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	19 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	33 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	20 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	34 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	21 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	35 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
10 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	22 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	36 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
11 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	23 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	37 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
12 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	24 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	38 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
	25 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	39 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
	26 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	40 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

APPENDIX B

Letters to the Superintendents

(709) 722-2027
72 Flower Hill
St. John's
Newfoundland
A1C 4M3

October 20, 1986

To Whom It May Concern:

I am a graduate student presently working on a thesis in the Department of Curriculum and Instruction at Memorial University. The purpose of my thesis is to ascertain whether sex differences in spatial ability and mathematics achievement exist at the grade 9 level. I have randomly selected a sample of 16 schools (list enclosed). In each school one grade 9 class will be randomly chosen for testing. Each class will be given 2 one-period tests; a spatial visualization test (standardized) and a mathematics achievement test (teacher-made). It would be preferred if both tests could be given on the same day, possibly one in the morning and one in the afternoon.

Your cooperation in this endeavour will be deeply appreciated.

Yours sincerely,

ROBERT P. HIPDITCH

Encl.

October 17, 1986

To Whom It May Concern:

The Division of Evaluation and Research is gathering data and coordinating a number of research projects on "Sex differences in Mathematics". A summary report with recommendations will be compiled at a later date.

In the meantime, the Division is supporting the research of Mr. Robert Hipditch, a graduate student at Memorial University. His topic for a thesis, "Spatial Visualization of Grade Nine Students in Newfoundland", is one aspect of sex differences in Mathematics.

Your cooperation would be appreciated in this instance.

Sincerely yours,

LENORA PERRY FAGAN, Ph.D.
Director
Evaluation & Research

LPF:ref

APPENDIX C

Questionnaire to Teachers

To

Considering the time limits many mathematics teachers must contend with, it is often impossible to cover all the material as prescribed in the curriculum guide. This is especially true of the Grade 8 mathematics program

I have recently administered a mathematics achievement test to a class of students which you taught last year in Grade 8. The test was based on 3 of the 5 strands proposed for study in Grade 8; namely, the numeracy, algebra and geometry strands.

To interpret the results of my study fairly it is important to determine the material actually taught. Would you please be kind enough to indicate, to the best of your memory, the degree to which each of the following skills was covered.

Once completed, please mail this form in the enclosed self-addressed envelope. Your prompt response will be deeply appreciated.

Yours sincerely,

Robert B. Hipditch

NUMERACY	EMPHASIZED	COVERED BUT NOT EMPHASIZED	NOT COVERED
- finding the greatest common factor	____	____	____
- evaluating expressions with exponents	____	____	____
- dividing decimals	____	____	____
- writing fractions in lowest forms	____	____	____
- using inequalities to determine the order of integers	____	____	____
- multiplying and subtracting integers	____	____	____
- adding fractions with different signs	____	____	____
- writing fractions to represent a shaded region	____	____	____
- writing ratios	____	____	____
- interpreting scales on maps	____	____	____
- solving proportions for one missing value	____	____	____
- solving problems involving rate	____	____	____
- solving equations involving percent	____	____	____
- writing fractions as a percent	____	____	____

ALGEBRA	EMPHASIZED	COVERED BUT NOT EMPHASIZED	NOT COVERED
- evaluating expressions in two variables	____	____	____
- translating expressions from words to symbols	____	____	____
- translating equations from words to symbols	____	____	____
- solving equations in one variable (one step)	____	____	____
- solving equations in one variable (two step)	____	____	____
- identifying equations which are equivalent	____	____	____

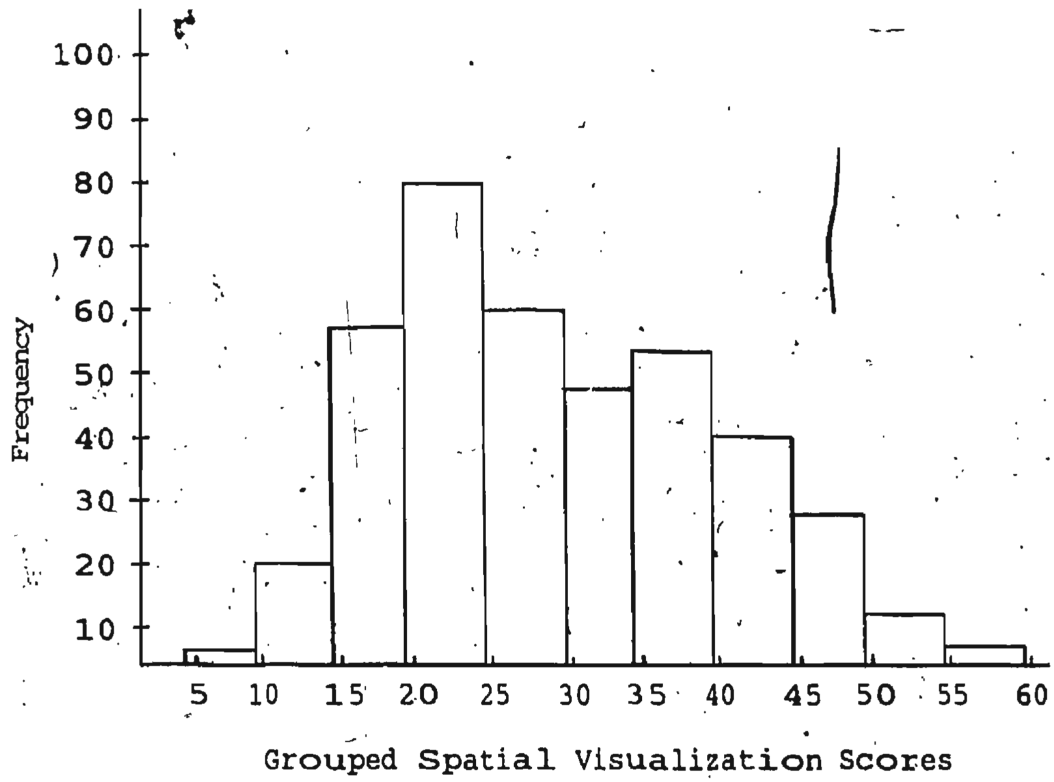
PLANE GEOMETRY	EMPHASIZED	COVERED BUT NOT EMPHASIZED	NOT COVERED
- finding the 3rd angle of a triangle, given the other two	____	____	____
- finding the measures of various angles, given parallel lines cut by a tramsversal	____	____	____
- finding values which make two angles congruent	____	____	____
- defining an isosceles triangle	____	____	____
- defining a pologon	____	____	____
- finding the complement of a given angle	____	____	____
- classifying triangles (acute, obtuse, etc.)	____	____	____
- identifying when lines are parallel	____	____	____

TRANSFORMATIONAL GEOMETRY	EMPHASIZED	COVERED BUT NOT EMPHASIZED	NOT COVERED
- finding the length of a side of the image figure in a translation	____	____	____
- rotating a figure 270° clockwise	____	____	____
- rotating a figure 180° counter - clockwise	____	____	____
- reflecting a figure through a vertical line	____	____	____
- reflecting a figure through a horizontal line	____	____	____
- writing the rule for a translation in correct symbols	____	____	____
- recognizing a reflection	____	____	____
- writing the rotation angle for a rotation	____	____	____

COORDINATE GEOMETRY	EMPHASIZED	COVERED BUT NOT EMPHASIZED	NOT COVERED
- writing the coordinates of a point	______	______	______
- finding the coordinates of a point reflected (flipped) through the y-axis	______	______	______
- finding the coordinates of a point rotated (turned) 90° counter-clockwise about the origin	______	______	______
- finding the coordinates of a point which has been translated (slide)	______	______	______

APPENDIX D

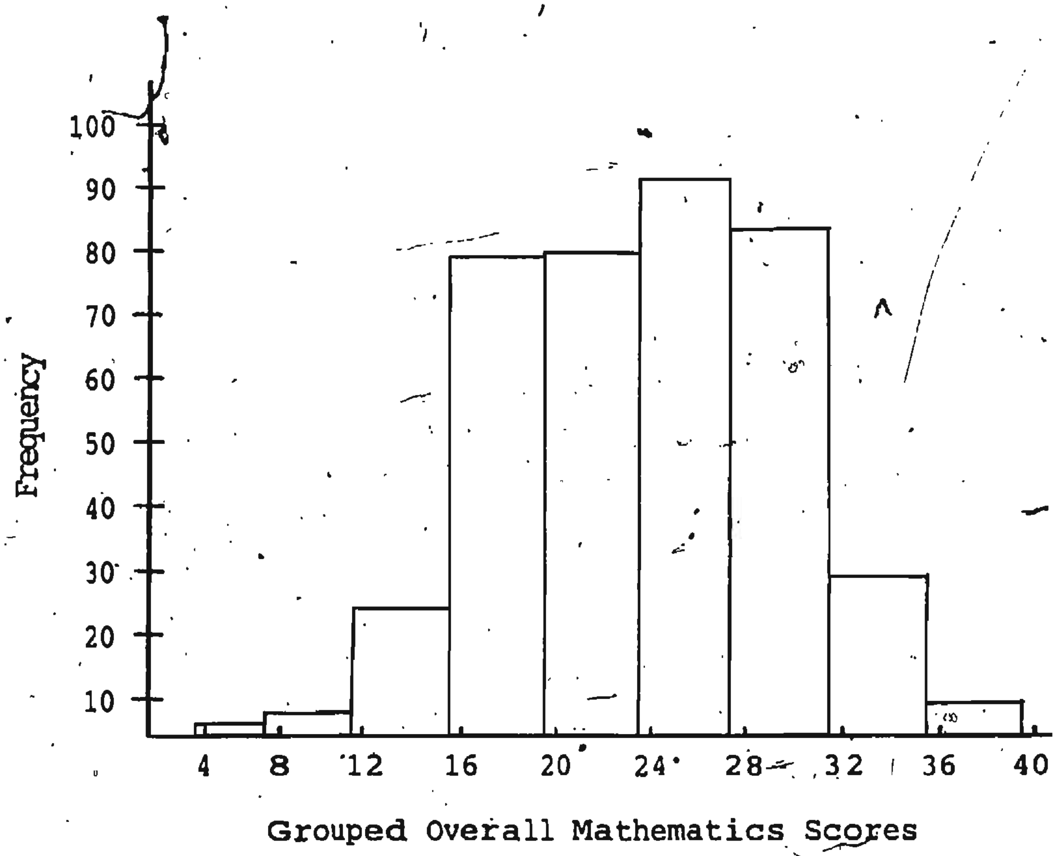
Grouped Frequency Distribution of the Dependent Variables



Range = 50 Mean = 29.38

Skewness = .355 SD = 10.58

Figure 1: Histogram of grouped spatial visualization scores



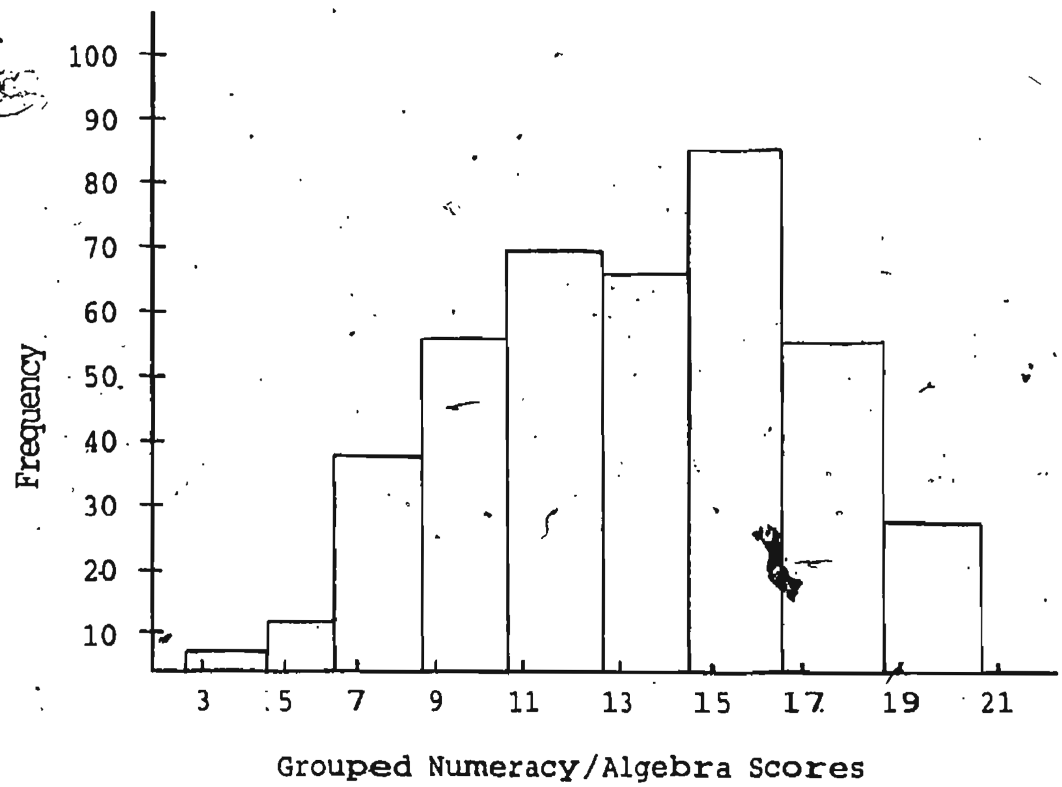
Range = 30

Mean = 23.85

Skewness = -.035

SD = 6.22

Figure 2. Histogram of grouped overall mathematics scores



Range = 17

Skewness = -.276

Mean = 13.00

SD = 3.67

Figure 3. Histogram of grouped numeracy/algebra scores

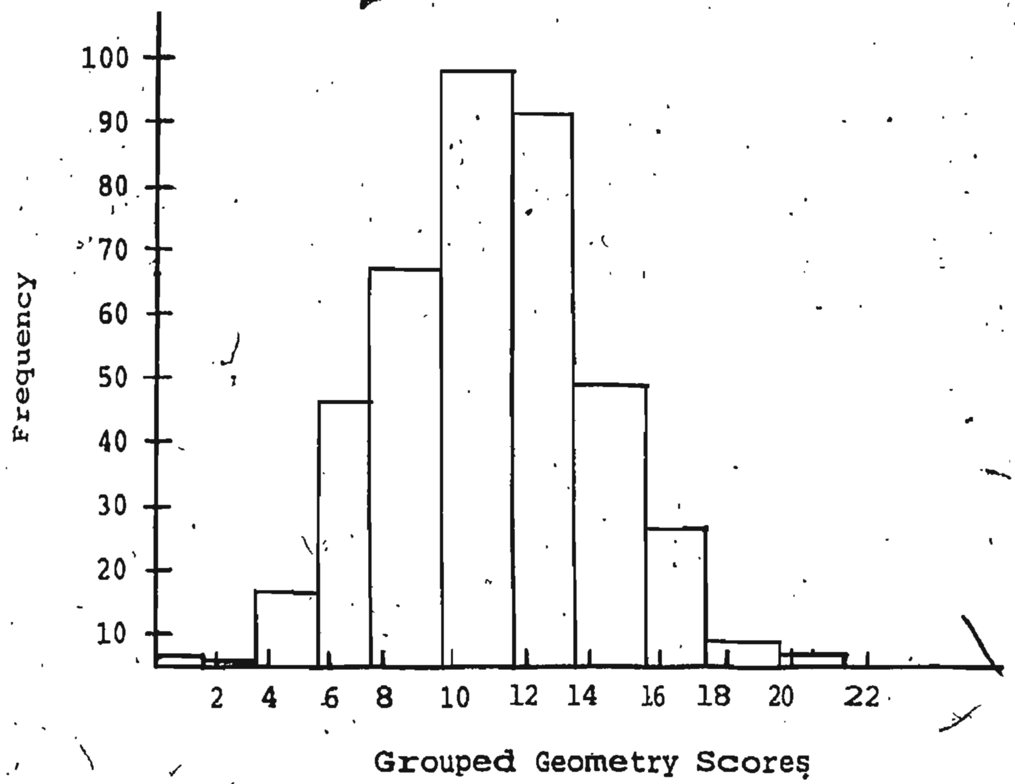


Figure 4. Histogram of grouped geometry scores