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The effects of changing from single-sex education to coeducation on males' and females' mathematics attitudes, affect and enrollment

Ruf, Thomas Philip, Ph.D.
The Ohio State University, 1992
THE EFFECTS OF CHANGING FROM SINGLE-SEX EDUCATION TO COEDUCATION ON MALES' AND FEMALES' MATHEMATICS ATTITUDES, AFFECT AND ENROLLMENT

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Doctor of Philosophy Degree in the Graduate School of The Ohio State University

By

Thomas P. Ruf, B.A., M.A.

****

The Ohio State University

1992

Dissertation Committee

J. L. Genshaft
L. Perosa
A. Miranda

Approved by

Adviser

College of Education
VITA

July 28, 1950...............Born - Dayton, Ohio

1973........................B.A., Ohio Wesleyan
University, Delaware, Ohio

1975-1976..................Social Worker, Cuyahoga
County Social Services
Department, Cleveland, Ohio

1976-1978..................Caseworker, Franklin County
Children Services, Columbus,
Ohio

1980......................M.A., Department of
Psychology, Cleveland State
University, Cleveland, Ohio

Mental Health Services, East
Cleveland, Ohio

1982-1984..................Clinical Counselor, Buckeye
Boys Ranch, Grove City, Ohio

1985-1987..................Clinical Director, Buckeye
Boys Ranch, Grove City, Ohio

1988-1989..................Intern School Psychologist,
Hilliard City Schools,
Hilliard, Ohio

1989-present...............Clinical Counselor,
Northwest Counseling
Services, Columbus, Ohio

1991-Present...............Psychology Intern, Private
Practice, Columbus, Ohio
FIELD OF STUDY

Major Field: Education
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CHAPTER I
INTRODUCTION

Background

For the past quarter century there has been increasing concern regarding women’s tendency to participate in less mathematics training than men do, and women’s underrepresentation in math-related fields (Tobias, 1976; Fennema & Sherman 77; Chipman, Brush & Wilson, 1985; Linn & Hyde, 1989; American Association of University Women, 1992). This concern stems, in part, from awareness that opportunities to advance in today’s increasingly technological society will depend more and more upon proficiency in mathematics and science concepts and techniques (Burton, 1984; Chipman et al., 1985; American Association of University Women, 1992). Sells (1973) provided early evidence of the disparity between male and female preparation in math. Sells found that 57% of the male freshmen entering Berkeley in 1972 had taken four years of high school mathematics, but that only 8% of the females had done so. Sells (1978) referred to mathematics in high school as a "critical filter" regarding women’s
careers. She observed that males and females generally enrolled in approximately the same number and level of mathematics courses through the tenth grade. However, in 11th grade, when taking mathematics courses becomes optional for the first time in most American schools, females participation dropped off noticeably. By choosing not to take advanced mathematics courses during high school, many young women thereby limited their career options in technical fields.

Since that time, researchers have continued to find evidence that females take fewer advanced mathematics courses in high school than males do (Sherman and Fennema, 1977; Armstrong, 1981; Pallas and Alexander, 1983; Dossey, Mullis, Lindquist & Chambers, 1988; National Science Board, 1989; American Association of University Women, 1992). In a summary of several studies reporting results of broad national samples of students, Chipman et al. (1985) concluded that there was still a substantial gender gap in participation in high school mathematics, with approximately 50% more males than females entering college well prepared in that subject. Although the gender gap in mathematics participation narrowed somewhat during the 1980’s, recent reports indicate that significantly more males than females continue to choose the most difficult mathematics courses available to them in high school.
Furthermore, there is also a considerable difference in the percentages of males and females engaged in mathematics and science careers. Although female participation has increased in recent years, it remains low; changing from 8.6% females in 1975 to 13.4% females in 1986 (National Science Board, 1989).

In addition to male-female differences in enrollment in mathematics courses, sex-related differences in achievement are found, particularly when above-average performance is considered. Although the empirical evidence of the extent and even the direction of sex differences in mathematics achievement varies somewhat among studies, the majority of inquiries into this topic reveal that boys and girls perform about equally in mathematics during the elementary years but that by junior high school male superiority begins to be seen and increases throughout high school (Armstrong, 1981; Fennema and Carpenter, 1981; Dossey et al., 1988).

A variety of explanations have been offered to explain why female participation in mathematics falls below that of males by the end of high school. During the mid-1970’s, Maccody and Jacklin (1974) published a widely influential report in which they suggested that the apparent gender gap in mathematics achievement was probably a reflection of
sex-related biological differences in cognitive make-up which made the performance of at least some mathematical tasks more difficult for females than males. Therefore, it was suggested that many girls opted out of mathematics because fewer girls than boys were capable of succeeding in the most difficult courses and were better suited for other areas of study, such as those emphasizing verbal ability. The notion that innate differences in males' and females' cognitive make-up were the cause of gender differences in mathematics achievement gained additional support in a series of articles presented by Benbow and Stanley (1980, 1982, 1983), which received considerable attention in the popular press (for example, Newsweek, 1980, p. 73; Time, 1980, p. 57).

However, findings from a number of more recent studies have presented serious challenges to the innate differences hypothesis. First of all, male superiority is not found in all samples which have been investigated (Fennema & Sherman, 1977; Armstrong, 1981; Rallis & Ahern, 1986; Brandon, Newton & Hammond, 1987; Hanna, 1989). Furthermore, researchers have found that females at all grade levels usually perform some mathematics operations as well as or better than males, such as computation (Armstrong, 1981; Dossey et al., 1988; Linn & Hyde, 1989; Hyde, Fennema & Lamon; 1990). Studies also reveal consistently that when achievement is measured by grades,
females do as well or better than males (Benbow & Stanley, 1980; Benbow and Stanley, 1982; deWolf, 1981; Pallas & Alexander, 1983; Rallis & Ahern, 1986; Kimball, 1989). Another challenge to the conclusion that any observed gender differences in mathematics achievement are due to inborn biological differences comes from studies which have shown that the gap in boys' and girls' mathematics performance is often reduced or eliminated when the amount of mathematics knowledge students have prior to entering mathematics courses is taken into account (Armstrong, 1981; Pallas and Alexander, 1983; Hanna, 1989; Senk and Usiskin, 1983; Dees, 1982). Another line of investigation indicates that in some countries there are no consistent sex differences in mathematics achievement, and that in other countries, girls outperform boys (Hanna, 1989). One of the strongest challenges to the innate differences viewpoint has been provided by meta-analyses which indicate that the gender gap in mathematics achievement has decreased or been eliminated in some areas of mathematics achievement over recent decades (Feingold, 1988; Linn and Hyde, 1989; Hyde, Fennema & Lamon, 1990). Overall, these findings suggest that environmental influences (i.e., experience), not just innate cognitive factors, may play a much greater role in determining males' and females' mathematics performance than was previously recognized.
Even if we conclude that differences in achievement are small, and in some cases do not occur when coursework and other factors are considered, there is no dispute over the finding that significantly fewer females than males enroll in upper level high school mathematics courses and pursue math-related careers. Why do many high school girls, sometimes even quite capable ones, choose not to pursue mathematics education?

Certain cognitive-affective variables have been found to be related to students' decisions to enroll in upper level high school mathematics courses. There is evidence that the perception that mathematics will be useful in one's future educational or career pursuits is a strong predictor of subsequent enrollment in mathematics courses for male as well as females students (Armstrong & Price, 1982; Pederson, Elmore & Blyer, 1985; Eccles, Alder, Futterman, Goff, Kaczala, Meece, & Midgely, 1985; Dossey et al., 1988; Hyde et al., 1990) and that males usually rate mathematics as more useful than females do (Meece, Parsons, Kaczala, Goff & Futterman, 1982; Dossey et al., 1988; Hyde et al., 1990). Furthermore, mathematics confidence, the belief in one's ability to accomplish successfully the challenges encountered in mathematics classes, is correlated with course enrollment for both boys and girls (Fennema & Sherman, 1988; Armstrong & Price, 1982; Eccles et al., 1985). In view of the fact that fewer females than
males enroll in advanced high school mathematics, it is not surprising numerous studies have revealed that by the beginning of high school males report higher confidence in their mathematics ability than females do (Fennema & Sherman, 1987; Armstrong & Price, 1982; Eccles et al. 1985; Dossey et al., 1988; Hyde et al., 1990).

Another variable related to course enrollment is mathematics anxiety. Several investigations have indicated that females tend to experience more mathematics anxiety than males (Wigfield & Meece, 1988; Hembree, 1990; Hyde et al., 1990), and that the higher an individuals' level of mathematics anxiety, the less likely it is that he or she will choose to take elective high school mathematics courses (Gilner, 1987; Eccles & Jacobs, 1986; Hembree, 19990).

Since these trends in affect and attitude have been found to emerge as early as the 6th grade, when achievement levels in mathematics are essentially the same for boys and girls, a student's realistic perceptions of his or her ability to master mathematics problems seems insufficient to account for all the differences. What could explain these findings?

A number of social factors in schools have been studied with respect to their role in the development of boys' and girls' interest in and beliefs regarding mathematics achievement and activities, including the
influence of teacher and peers, and the sex composition of the student population. There is evidence that teachers expect more mathematics competence from boys than girls and that they communicate this through differential attention and encouragement (Spender, 1982; McDermott, 1983; Sadker & Sadker, 1985; Croll, 1985; Becker, 1981). Teacher expectations of superior performance from boys than girls in mathematics has been found to have a significant effect on students' achievement (Midgely, Feldlaufer and Eccles, 1988; Brophy, 1983) and their decisions to take additional mathematics courses (Fennema and Sherman, 1976; McDermott, 1983; Armstrong & Price, 1982; Casserly & Rock, 1985).

With regard to the sex composition of the student population of schools and classes, there is evidence that single-sex academic environments may provide certain advantages. Lee and Bryk (1986) found that males and females in the single-sex Catholic schools had significantly more positive attitudes about mathematics and enrolled in more mathematics courses than their age-mates in coeducational Catholic schools. As noted above, positive attitudes regarding mathematics frequently predict subsequent enrollment in mathematics courses. Few differences in achievement were observed, but when they were, they favored students, in the single-sex schools.

The sex composition of individual class populations has been studied with regard to mathematics also. Rowe
(1988) found that males and females in single-sex classes had significantly more confidence in their ability to learn mathematics and also had a significantly greater tendency to enroll in more difficult mathematics courses for the following year than did students in mixed-sex classes. Evidence of more positive attitudes and mathematics achievement in single-sex schools and classes has been found by other researchers also (Trickett, Trickett, Castro & Schaffner, 1982; Brunson, 1983; Riordan, 1985).

The behavior of other students may provide an explanation for any advantages sometimes found for single-sex schools and classes. In those studies where greater teacher attention toward boys is reported, it is found also that boys tended to initiate more contacts with teachers than girls; and that they were often more persistent in their interactions with teachers (Spender, 1982; McDermott, 1983; Sadker & Sadker, 1985; Croll, 1985; Irvine, 1986; Becker, 1981; Jungwirth, 1991). Nix (1986) compared single-sex and mixed-sex classes and found that boys dominated interaction with teachers in mixed-sex classes, and that girls participated in class discussions more in single-sex classes than they did in mixed-sex classes.

Tidball and Kistiaikowsky (1976) suggest that in some cases, the faculty in single-sex schools may provide an advantage to students. They found that single-sex schools usually have a high percentage of faculty members of the
same sex as the students, thus providing important role models. Such teachers may be able to bolster the confidence and interest of students who take courses in subject areas which traditionally are not viewed as sex-appropriate, such as mathematics for girls.

In summary, there is a substantial body of research which indicates that females' affect and attitudes regarding mathematics are less positive than males', and that these factors may account for at least some of the gender differences in achievement and enrollment in mathematics that exist. Certain social processes within schools have been found to work against girls, at least with respect to success and participation in mathematics. There is also evidence that students, perhaps females in particular, may experience more positive attitudes and greater achievement and enrollment in mathematics in single-sex academic environments than in those that are coeducational.

**Statement of the Problem**

Females' lower rate of participation in upper level high school mathematics courses has been described. This enrollment pattern contributes to disparities in males' and females' preparation for the study of advanced mathematics courses at the university level as well as eventual entrance into a career in a technological field. The
factors which contribute to this gender gap in mathematics participation must be understood in order to establish better those conditions which encourage and involve as many students in mathematics as possible.

Purpose of the Present Study

The purpose of the present study was to assess the impact of changing from single-sex education to coeducation on males' and females' math-related attitudes, affect and course enrollment. In addition, this study was designed to compare males and females from two different developmental levels with respect to their reactions to the change in the nature of their schooling. The final purpose of this study was to add up-to-date data to the research literature regarding gender and mathematics-related variables.
CHAPTER II

LITERATURE REVIEW

During recent decades, there has been much concern about gender differences in mathematics achievement and enrollment, and the significant underrepresentation of women in technological careers. Many investigations have focused on the extent and possible reasons for any achievement differences that have been found. Other research has addressed the question of why so many females choose not to take advanced mathematics courses. This review will describe the available research pertaining to the extent and nature of gender differences in mathematics achievement and enrollment, and will examine the hypotheses and empirical data which have been offered to explain these patterns.

A Closer Examination of Studies Indicating Male
Superiority In Mathematics

Although some debate exists regarding the size and even the direction of gender differences in mathematics achievement, there is a substantial number of studies which point toward the conclusion that girls and boys achieve at
similar levels during the elementary grades but by junior high school differences in achievement appear and increase throughout the high school years. For example, Armstrong (1981) analyzed the results of two national surveys conducted during the 1977-1978 school year in order to examine students' achievement and participation in mathematics. In the first study, The Women in Mathematics Survey, 1452 13-year-olds from 82 schools and 1788 12th-grade students from 71 schools were given a 90-minute questionnaire which included mathematics achievement items taken from standardized tests. Four cognitive tasks in mathematics were assessed: computational skills, problem-solving (word problems), spatial visualization, and algebra. The results showed that for the 13-year-olds, females scored slightly but not significantly higher than males on the algebra subtest, were evenly matched with males on problem-solving ability, and significantly outscored males on the spatial visualization and computation sections. In the 12th-grade sample, sex differences in achievement favored males in all four areas, although only to a statistically significant extent on the problem-solving subtest.

The second survey, the Second National Assessment of Educational Progress (NAEP) Mathematics Assessment, included data from nationally representative samples of
approximately 15,000 9-year-olds, 24,000 13-year-olds and 26,000 17-year-olds. The assessment was conducted during the 1977-78 school year. The instrument used to measure mathematics achievement contained a range of open-ended and multiple-choice questions designed to measure proficiency across a range of content (e.g., numbers and operations, measurement, geometry, and algebra) and process areas (e.g., knowledge, skills, application, and problem solving). Many of the results were similar to those found in the Women in Mathematics study. Thirteen-year-old females scored significantly better than males on computation items. Unlike the subjects in the Women in Mathematics study, however, 13-year-old males in the larger NAEP assessment significantly outscored females on problem-solving tasks. For the 17-year-olds, no significant sex differences existed for computation or algebra, but males performed significantly better on the application (problem-solving) exercise set.

Overall, the data from these two large studies provided historical evidence that females left junior high school with mathematics skills that were as good or better than those of males. Thirteen-year-old females were better at computation and spatial visualization than their male counterparts, and the problem-solving skills of males and females were nearly equal. Yet, by the end of high school, a different pattern existed. Twelfth grade males achieved
superior scores on problem-solving measures, and females had lost their advantage in computation and spatial visualization.

This general pattern corresponds with findings from the first NAEP study conducted in 1972 (National Assessment of Educational Progress, 1975) and with the analysis of the data from the 1960 Project TALENT sample reported by Wise, Steel, and MacDonald (1979). In the Project TALENT study, mathematics achievement was measured with a 54-item test designed to measure skills in solving all types of mathematics problems encountered through high school, including computation, algebra, geometry, trigonometry and mathematics reasoning. Wise et al. found that there was only a small (.07 standard deviation) difference favoring males in mathematics achievement in 9th grade. In practical terms, this was interpreted as no sex difference at that age. However, more significant sex differences appeared in 10th grade for this sample and increased more sharply in the 11th and 12th grades. Among 12th graders, the difference was about 0.6 standard deviation. Approximately the same pattern was observed for the ninth grade students who were retested in 1963 as twelfth graders.

Two other NAEP studies have been conducted since 1978. Dossey, Mullis, Chambers & Lindquist (1988) reported the results of NAEP studies conducted during the 1981-82 and
1985-86 school years. Nearly identical sampling and measurement procedures were followed during those assessments as were utilized during previous NAEP studies. Analyses of the results indicated that while a greater proportion of males and females demonstrated proficiency in basic mathematics skills from 1978 to 1986, the gender gap at the upper levels of proficiency did not change significantly. As seen in previous studies, females consistently scored higher in the area of knowledge and skills; and males had an advantage in the area of higher-level applications.

Other studies have supported the view that males have an advantage in at least some areas of mathematics. In 1974, Maccoby and Jacklin published a review of the literature pertaining to gender differences in cognitive abilities and concluded that there was convincing evidence of sex differences in four areas: verbal ability, mathematical ability, spatial ability, and aggression. They stated that the differences in mathematics ability begin to emerge at the onset of adolescence and continue into adulthood.

In 1980, Benbow and Stanley added momentum to the view that males have greater mathematics aptitude than females when they reported the results of The Study of Mathematically Precocious Youth (SMPY). The subjects in the study were 9927 males (57%) and females (43%) who were
mostly in grades 7 and 8 during the six measurement times between 1972 and 1979. The data were gathered as part of a talent search aimed at identifying and describing promising students. Males and females who were in the top 2-5% of their age group in mathematics (depending on the year of the talent search), as measured by standardized achievement tests, were permitted to volunteer to participate in the study. As part of the talent search, students took the mathematics and verbal portions of the College Board's Scholastic Aptitude Test, the SAT-M and SAT-V, respectively. On the SAT-V, the boys and girls in the study performed about equally well. On the SAT-M, a large sex difference favoring boys was found in all six talent searches. Mean differences between boys' and girls' scores ranged from 30 to over 70 points, depending on the year of the measurement; approximately one-half of the females' standard deviation or more. Furthermore, over all the talent searches, the biggest differences observed were in the upper ranges of mathematics reasoning ability, where males outnumbered females by more than 2 to 1 in SAT-M scores over 500 and by a greater margin in scores over 600. Benbow and Stanley observed that these gender differences in mathematical reasoning ability were not a reflection of differences in formal training since they were found before the participants began to differ significantly in the number and types of mathematics courses taken. Thus, they
concluded that real differences in mathematics ability exist, especially when above-average performance is considered.

Benbow and Stanley reported also in their article the results of a follow-up survey of talent search participants who had graduated in 1977. They found that the 40-point mean difference in favor of males that existed when the group was in junior high school had increased to a 50-point mean difference by the date of graduation. However, the authors acknowledged that that trend could have been due, in part, to differences in the type and number of mathematics courses taken in high school by the subjects. Benbow and Stanley concluded that sex differences in mathematics achievement were the result of superior male mathematics ability (as distinct from skills/achievement).

In an analysis of more recent data from national college entrance examinations, Stanley (1992, unpublished manuscript) found that the gender gap in the percent of students scoring high in mathematics has remained essentially unchanged during the past 10 years. Although the number of females who scored above 700 on the SAT-M more than doubled between 1982 and 1991, the number of males scoring at that level increased substantially too, leaving the ratio of percent males to percent females scoring over 700 approximately the same as before.
Moreover, in comparing mean scores, the 45-point advantage males had on the SAT-M in 1982 remained at 44 points in 1991.

In the years that followed the initial Benbow and Stanley (1980) report, numerous articles appeared in popular publications which provided uncritical support for the view of significant and widespread male superiority in math. For example, Williams and Kine in *Newsweek* magazine (1980, p.73) asked the question "Do males have a mathematics gene?" They cited the Benbow and Stanley (1980) study as evidence which supported the conclusion that sex differences in mathematics appear to be inborn and that sex differences in brain organization may explain why members of one sex are overrepresented in some professions. In an article in *Time* magazine (1980, p.57), it was stated that "It is well known that teenage boys do better at mathematics than teenage girls..." Unfortunately, as a result of publications such as these, the impression was given to the public that a genetic basis for the sex differences in mathematics ability had been found, and male superiority in mathematics came to be stated as an undisputed fact (Beckwith, 1990). The evidence that many females are better at mathematics than many males often received minimal emphasis. Benbow herself strengthened the interpretation that the differences are pervasive and unchangeable when in a subsequent interview she stated that
"Women would be better off accepting their differences" and devoting their energies toward pursuits in which they could better excel (Kolata, 1980).

These and similar findings were cited also as explanations of why females enroll in fewer elective mathematics courses in high school than males: Many girls opt out of mathematics because fewer girls than boys are capable of succeeding in the most difficult courses and are better suited for other areas of study, such as those emphasizing verbal ability.

Challenges To the Male Superiority In Mathematics Ability Viewpoint

Although the view that males are superior to females in mathematics has been discussed sometimes as though it were an indisputable fact during recent decades, there have been a number of challenges to the general conclusion that boys have more mathematics ability and skill, and that observed disparities are due to innate biological differences between the sexes. There is an increasing body of evidence which indicates that the existence and direction of gender differences in mathematics performance can vary depending upon a number of variables, including the measure used to assess mathematics aptitude, the date of the study, the age and selectivity of the sample, the ethnic and racial composition of the sample, the influence
of affective and cognitive variables on mathematics performance, and differences in experiences between males and females.

The inaccuracy of the broad conclusion that males are better than females in mathematics is demonstrated by the fact that male superiority has not been found in all populations studied (Rallis & Ahern, 1986; Brandon, Newton & Hammond, 1987; Hanna, 1989). Sometimes a male advantage is found in some but not all of the classes or schools investigated (Fennema & Sherman, 1977; Armstrong, 1981; Mura, Cloutier, Kimball, Braconne, Caron, & Gagnon, 1985). Fennema and Sherman (1977) found no sex-related differences in scores on a standardized measure of mathematics achievement (the Test of Academic Progress) in two of the four schools they studied, and only small differences in the other two schools. Mura et al. (1985) found a significant sex difference for only one of the three schools studied. Occasionally, differences are found that favor females. Brandon, Newton and Hammond (1987) found that girls in grades 4-10 in Hawaii outscored their male peers on the mathematics portion of the Stanford Achievement Test.

Regarding the manner in which mathematics performance is measured, when sex-related differences in mathematics achievement are assessed by grades in mathematics classes, the results are very different than those found using
standardized achievement tests. When differences are found, they almost always favor females. This was the finding of Benbow and Stanley (1980) during their original study and again (Benbow and Stanley, 1982) during their continued investigation of the Study of Mathematically Precocious Youth conducted between 1972 and 1974. Studies using less select samples have revealed similar patterns. deWolf (1981) found that among the 2,000 high school students who completed the Washington Pre-College Testing program during the eleventh grade, females had higher mathematics grade point averages (GPA's) than males. Pallas and Alexander (1983) found that even though the females in their study took fewer upper-level high school mathematics courses than males, they achieved higher GPA's in the courses they took. Rallis and Ahern (1986) focused on the mathematics enrollment and achievement of the 1985 senior class in Rhode Island and discovered that females received significantly higher grades than males. However, other researchers such as Fennema (1983) have found that this only holds true until the upper levels of high school mathematics, at which point boys' superiority in grades emerges.

In an attempt to explain the gender differences sometimes found in math achievement, the influence of visual-spatial skills has been investigated. Much of this research stems from Maccoby and Jacklin's (1974) assertion
that males' superiority in this cognitive area was "well established" (p. 405) and the conclusion by others that visual spatial-skill is related to math achievement (e.g., Sanders, Soares, & D'Aquilla; 1982). Connor and Serbin (1985) investigated the gender differences in this ability as well as the relationship between visual-spatial skill and mathematics achievement. They defined visual-spatial ability as the ability to perceive spatial relationships and manipulate visual material mentally. However, they emphasized that research in this area is complicated by the fact that the term "visual-spatial" is not unidimensional. Nor is there a consensus regarding what specific skills or abilities should be measured or how to measure them. The subjects in the Connor and Serbin study included 134 7th graders and 205 10th graders (approximately equal proportions of each sex) in a suburban school district. Test materials included five visual-spatial tests selected from the Educational Testing Service Kit of Factor Referenced Tests (Ekstrom, French, Harmon, & Derman; 1976), an abbreviated (10 items) version of the Space Relations part of the Differential Aptitude Test (Bennett, Seashore, & Wesman, 1973), and the Gestalt Completion Test. This yielded a 121-item instrument designed to measure spatial orientation, flexibility and closure, speed of closure, and spatial visualization. An 18-item vocabulary test taken from the ETS kit was used also. In addition, a mathematics
test with 48 items adapted from standardized tests and intended to measure arithmetic, algebra and geometry was administered. Course grades, standardized achievement test scores and sixth-grade IQ scores were obtained from school records.

Results of an analysis of variance indicated that females did better on some but not all of the verbal measures in both 7th and 10th grades, and that males outperformed females on some but not all of the mathematics measures in 10th grade. These sex differences are in the direction of other studies (e.g., Maccoby and Jacklin, 1974; Armstrong, 1981; Dossey et al., 1988). With regard to visual-spatial ability, males performed better on the DAT Space Relations Test, more among 10th graders than 7th graders; and there were no sex differences in either grade on any of the five ETS visual-spatial tests. Connor and Serbin interpreted this last finding as evidence that the presence of sex differences in visual-spatial ability is highly dependent on the type of visual-spatial measure used.

With regard to the relationship between each student's visual-spatial ability and mathematics achievement, Connor and Serbin found that for boys, a strong correlation existed between achievement and some types of visual-spatial skills but not others. For girls, the correlations between visual-spatial ability and math achievement were
much smaller. Connor and Serbin concluded that sex differences in visual-spatial ability were not sufficient to account for all of the differences observed on the performance of the achievement measures. They suggested that sex differences in visual-spatial skill, verbal skill, and quantitative ability appear to be strongly influenced by "the measures used, the conditions of testing, and the learning experiences that girls and boys bring with them to the testing situation" (p. 167). They cautioned that it is misleading to make broad claims that males do better in the visual-spatial domain than girls.

Caplan, MacPherson, and Tobin (1985) issued a strongly-worded report about the state of knowledge regarding visual-spatial ability and advised against concluding that males are superior in this ability. They described limitations found in studies on this topic and concluded that the small size and inconsistency of sex differences make claims of male superiority unwarranted. Caplan et al. asserted that in most investigations into this area, researchers commit the methodological error of defining spatial-visualization ability according to whatever test is used to measure it in a particular study, and added that this has made it difficult to build understanding of this topic through comparisons of different studies. They concluded that the lack of consensus about a definition is so great that the absence
of construct validity should be acknowledged and addressed before further research in this area is conducted.

Methodological difficulties such as this may account for the inconsistent findings in other studies about spatial abilities. For example, in their meta-analysis comparing studies prior to and after 1974, Linn and Petersen (1985) found that gender differences in spatial ability have declined and in some types of tasks (e.g., spatial visualization) no longer exist. Other studies have confirmed the lack of consistent male superiority in performing tasks requiring spatial visualization (Fennema and Sherman, 1977; Armstrong, 1981; Feingold, 1988).

Even if sex differences in the performance of tasks intended to measure spatial ability exist, which is far from clear, such evidence would not necessarily prove that there is a biological basis for such findings. A persuasive body of evidence exists which supports the conclusion that spatial ability can be improved with training. For example, Lord (1985) found that male and female college students who participated in fourteen 30-minute visual-spatial training sessions were significantly better able to create and manipulate structures in their mind than were the students in the control group, even though the two groups were intellectually similar. Connor and Serbin (1985) provided visual-spatial training to 231 boys and 203 girls from 8th-grade mathematics classes in
two suburban junior high schools. Two visual-spatial skills, spatial orientation and spatial visualization, were taught to the students in the experimental group during just one half-hour session. Training materials included pictures of shapes, plastic pieces of geometric shapes, and other objects which the students could manipulate. Students in the training sessions were given problems in which they had to decide what an object would look like from another perspective, draw a mirror image of an object, draw an image of a combination of pictured shapes, and other exercises designed to encourage the students to imagine and manipulate mental images of shapes. Significant training effects were found for spatial-visualization and orientation skills as measured by two of the five instruments used to assess these processes.

The finding that significant increases in visual-spatial ability could take place after only one-half hour of training offers compelling evidence to support the notion that this ability is not an immutable trait that is determined solely by biology. Moreover, the fact that significant changes were found on only two of the five measures of these skills provides further testimony of the difficulties and unanswered questions that remain regarding the definition and measurement of the processes that are grouped together in the category of visual-spatial abilities. Thus, findings such as these should be
interpreted with caution. Halpern (1989) warned that evidence of the trainability of visual-spatial skills does not constitute proof that there are no sex-related biological components involved in these cognitive processes. More likely, stated Halpern, the extent to which an individual develops spatial ability depends on a number of interacting factors, as is the case with most traits.

**Differential Experiences Hypotheses**

Despite prevailing popular attitudes, there is a growing body of evidence to challenge the broad conclusion that males are born with greater potential for mastering mathematics than girls are. A frequent argument against the "innate differences" hypothesis is the "differential experiences" hypothesis. This view states that sex differences in mathematics achievement are partly or wholly due to the differences in the experiences males and females encounter as they grow up. One line of inquiry into environmental influences on mathematics achievement is what is often referred to as the "differential coursework hypothesis." Since it is known that high school males take more upper level mathematics courses than high school females, several investigators have examined whether or not achievement differences would be reduced or eliminated if the amount of coursework were experimentally controlled.
In their study of mathematics achievement and attitudes in four public high schools from different socioeconomic communities in Wisconsin, Fennema and Sherman (1977) found that when they statistically controlled for the number of mathematics and science courses which taught space-related concepts, the male-female gap in spatial relations scores on a standardized measure of mathematics achievement (the Test of Academic Progress) disappeared in two of the four schools they studied. deWolf (1981), found also that sex differences disappeared on two of the four quantitative tests and the spatial ability test administered to high school students in her study when coursework preparation was statistically controlled.

Pallas and Alexander (1983) examined the transcripts of a nationally-representative sample of approximately 6,000 high school students in order to measure the relationship between course enrollment and scores on standardized achievement tests. There were no significant differences in the background variables of race, 9th grade standardized achievement test scores, and parents' education. When sex differences in high school quantitative coursework were controlled, significant sex differences in SAT-M scores remained. However, a considerable portion of the deficit (about 60%) was eliminated when coursework was taken into account. Wise, Steel, and MacDonald (1979), in their analysis of data from
the 1960 Project TALENT sample, found that sex differences in 12th grade achievement were literally nonexistent after controlling for the amount of mathematics taken. However, caution should be used in interpreting those results, because the females who took advanced high school mathematics were a more select group than males with the same level of participation in that data set.

Even though there is some support for the differential coursework hypothesis, other studies have reported that significant achievement differences remain even when mathematics background is controlled. For example, Benbow and Stanley (1980) claimed that the results of their study of mathematically precocious youth refuted the differential coursework hypothesis, since significant sex differences in mathematics scores were observed in junior high school, before differences in coursework occurred. Armstrong’s (1981) analysis of the NAEP data from the 1977-78 school year led her to conclude that, even when levels of mathematics course enrollment are taken into account, males at nearly every level of participation have an advantage in solving one- and two-step word problems. Unlike the Benbow and Stanley study, Armstrong’s findings were based on a large study of a nationally representative sample.
Out-of-Class Experiences

Another factor which may account for the gender differences sometimes observed in mathematics achievement pertains to previous math-related experiences out of the classroom. Johnson (1987) found that boys reported significantly more experience making models from kits, creating models with Legos and other construction toys, taking things apart and putting them back together, playing with measuring devices such as stopwatches and yardsticks, playing pool and billiards, and playing chess. He concluded that such experiences may provide males with opportunities for an early understanding of mathematics-related concepts such as measurement, rate, ratio, and so on. Furthermore, these experiences may facilitate the development of an appreciation of the usefulness of information encountered later in mathematics and science classes and give males an experiential framework within which to organize such information. Other researchers have documented males' more extensive math-related experience outside of the classroom (Fennema & Sherman, 1977; Linn & Petersen, 1986; Kahle, 1990).

Dees' (1982) findings may reflect the impact of these differential experiences on mathematics performance. In her study of a nationwide sample of 1392 males and 1307 females in grades seven through twelve, Dees found that boys had significantly more knowledge of geometry concepts
upon entering geometry courses than females. Interestingly, when year-end test scores were adjusted for this entering knowledge, gender differences in learning geometry content and proof writing disappeared. Senk and Usiskin (1983) obtained similar results in their study of over 1350 students from 11 high schools in 5 states. These findings support the interpretation that females learn what is taught in mathematics classes as well as males. Thus, it appears that a partial explanation for the gender differences which are sometimes observed in mathematics achievement could be due to differential experiences outside of the classroom in which boys may have more opportunity to gain math-related knowledge than girls.

Cross-Cultural Comparisons

Additional support for the role of personal experience as an influence on mathematics achievement comes from studies which reveal that gender-related differences in mathematics skills vary considerably both within and among countries. Hanna (1989) analyzed data from the Second International Mathematics Study in which mathematics achievement among thirteen year-olds from twenty countries was compared. Actually, some of the "countries" were areas within the same national boundary that were considered culturally distinct. The countries included Belgium (Flemish), Belgium (French), British Columbia, Ontario,
England, Finland, France, Hong Kong, Hungary, Israel, Japan, Luxembourg, the Netherlands, New Zealand, Nigeria, Scotland, Swaziland, Sweden, Thailand, and the United States. The subjects included a stratified random sample of over 37,000 boys and over 37,000 girls. Students were administered a 180-item test at the end of the 1981-82 school year. The specific content categories measured were arithmetic, algebra, geometry, statistics and measurement.

Hanna found that sex differences in mathematics performance were not found in some countries, that girls performed better in some countries and boys performed better in others, and that any sex differences observed were generally small. The finding that the male advantage was non-existent in many countries and that when one was observed, it was in the mathematics topics least taught in class, such as certain elements of geometry and measurement, led Hanna to conclude that females and males assimilate material taught in the classroom equally well. Schildkamp-Kundiger (1982) found a similar lack of consistent male superiority in mathematics in her study of children from 10 countries.

Since it is unlikely that biological differences between the sexes vary from one country to another, it is plausible that these results reflect differences in boys' and girls' experiences in different countries. Therefore,
findings such as these challenge the view that males' superiority in mathematics achievement, when it is observed, is the result of innate factors.

**Long-Term Trends in Male-Female Achievement Differences**

Additional evidence bringing into question the conclusion that males are biologically destined to have an advantage in mathematics has been provided by researchers utilizing the technique of meta-analysis. In addition to revealing further documentation that male-female performance differences are not uniform within and between categories of mathematics tasks, investigators conducting meta-analyses have observed changes in the mathematics gender gap over time.

Meta-analysis has been defined as the application of "quantitative methods to combining evidence from different studies" (Hedges & Olkin, 1985, p.13). Current meta-analyses use the statistic "d", which is computed as the difference between the female mean and the male mean, divided by the pooled within-group standard deviation. The measure "d" is often referred to as the "effect size" and indicates how far apart the group means are in standard deviation units. This allows studies to be compared because they are measured in the same metric, rather than the traditional method of narrative reviews, which have been criticized because they are unsystematic and overly
subjective (Hyde et al., 1990). Usually, the practical significance of effect sizes is measured using Cohen's (1969) distinction of .20 as a small effect size, .50 as medium, and .80 as large.

Hyde, Fennema & Lamon (1990) conducted a meta-analysis in which they compared studies of sex differences in mathematics performance which were published before 1973 with studies published since then. Over 100 studies which included over three million subjects were analyzed. They found that males' advantage in mathematics performance has declined over the past three decades and is small at this time (.20 standard deviations). In fact, if SAT-M scores are excluded, the gender gap declines to .15; and if one excludes selective samples (such as Benbow and Stanley's studies of precocious youth), there is actually a female advantage of .05. However, broad conclusions are less meaningful than descriptions of gender differences when age, selectivity of the sample, and cognitive level of the test are considered. Hyde et al. found that, on computational tasks, females consistently perform as well or better than males at all ages. The gender difference was essentially zero for understanding of mathematical concepts in all age groups. Females had a slight advantage on problem-solving tasks during the elementary and junior high school years. The largest gender differences favored males and occurred in advanced mathematics tasks,
particularly on problem-solving problems which require complex applications of mathematical knowledge. They point out, however, that these differences parallel males' higher enrollment in courses such as chemistry and physics, which teach complex problem solving. Hyde et al. concluded that there is little support for global conclusions that "boys excel in mathematical ability" (Maccoby & Jacklin, 1974, p. 352) or the interpretation that there exist biological differences in this domain.

Feingold (1988) analyzed data from the four standardizations of the Differential Aptitude Test (DAT) which took place in 1947, 1962, 1972 and 1980. A total of 193,844 students in grades eight through twelve were examined in the four standardizations. On sections of the DAT pertaining to math, there were no cognitive differences favoring girls in any grade or year. Boys scored higher than their females peers in all grades and years on mechanical reasoning and space relations, although the gap decreased by 43% and 59%, respectively, between the 1947 and 1980 standardizations. Males outscored females on abstract reasoning and numerical ability in the earlier assessments, but by 1980, the differences were no longer significant. Linn and Hyde (1989) suggested that the narrowing of a gender gap in spatial relations skills may be the result of females' increasing participation and success in athletics in recent years.
Feingold also conducted a meta-analysis of scores from the standardization samples of the Preliminary Scholastic Aptitude Test (P-SAT) and Scholastic Aptitude Test (SAT) between 1960 and 1983. Both of these instruments contain approximately equal numbers of arithmetic, elementary algebra, and plane geometry problems -- all emphasizing quantitative reasoning. The types of items on each test have remained largely unchanged since the first norming in 1960. Significantly, however, although the differences in the standardization data do not involve test content (which is identical on the two instruments), the characteristics of the two groups from which the norms were obtained are different. The PSAT standardizations were all conducted with representative nationwide samples of high school juniors and seniors, whereas the SAT data are available only for self-selected high school juniors and seniors who completed that examination, usually as a requirement for college admission. Feingold's analysis revealed that although males consistently outperformed their female peers on the PSAT-Mathematical test, the gender gap decreased by 63% between 1960 and 1983. Feingold notes, however, that the gender gap on this test was never very large, changing from an effect size of .34 in 1960 to .12 in 1983. In line with other studies, however, a disproportionate number of males earned scores in the upper end of the distribution on both the SAT-M and the PSAT-M. Nonetheless, in view of
these observed changes over time, gender differences in the performance of mathematical tasks do not appear to be invariable. The findings from these meta-analyses that gender differences in mathematics performance are declining and in some cases have been eliminated during the past thirty years appear to be incompatible with the conclusion that gender differences in mathematics performance are due to biological differences between the sexes.

Cognitive and Affective Variables

In the absence of convincing evidence that gender differences in mathematics behavior is solely a reflection of males' innately superior mathematics ability, researchers have investigated a number of cognitive and affective variables which may account for the gender gap in high-level mathematics problem solving and females' tendency to enroll in fewer upper level high school mathematics courses than boys.

Mathematics Anxiety

Mathematics anxiety has been investigated with respect to its relationship to mathematics achievement and participation. Although mathematics anxiety was once considered to be a powerful influence on mathematics performance and enrollment (Tobias, 1976) recent studies have led to the conclusion that the relationships among
these variables is not always clear. The term "math anxiety" is used generally to refer to "feelings of nervousness, dread, and associated bodily symptoms related to doing mathematics" (Fennema & Sherman, 1976, p.4).

According to Wigfield and Meece (1988), these negative emotional states are thought to interfere with attentional and learning processes so that test or task performance is impaired. Thus, if females have higher math-related anxiety, it may account for the gender differences in achievement which are sometimes found, and this disadvantage in achievement could lead to subsequent avoidance of math-related courses and tasks.

Wigfield and Meece (1988) investigated the existence of gender differences in mathematics anxiety among 6th through 12th grade students (N=564) in a white, middle class school district. Students were administered an 11-item questionnaire which the authors designed for the study in order to measure students' negative affective reactions to doing mathematics and their concerns about their performance in math. These researchers found that even though the boys and girls in their study appeared to be equally concerned about doing well in math, girls reported experiencing more negative affective reactions to mathematics than did boys. Wigfield and Meece also observed a significant negative correlation between
mathematics anxiety and mathematics performance, indicating that mathematics anxiety and poor mathematics performance tend to go together.

In another study, Gilner (1987) administered the Mathematics Anxiety Rating Scale (MARS) (Suinn, 1972) to 50 boys and 45 girls in grades 9-12 at a suburban high school. This extensive, 98-item questionnaire is a measure of students' perceptions of their anxiety in different situations related to mathematics. Achievement was assessed with the California Test of Basic Skills. Grade point average and number of mathematics courses were included in the multiple regression analysis. Gilner found that neither mathematics achievement nor sex were significant variables in predicting mathematics anxiety scores, but students with high mathematics anxiety took fewer mathematics courses than did students with low to moderate mathematics anxiety.

Englehard (1990) examined the relationship between mathematics anxiety, mathematics performance and gender in 4,091 13-year-olds in the United States and 3,613 in Thailand. A 40-item mathematics test was used to measure mathematics performance. In both countries, after controlling for previous achievement, mathematics anxiety had a significant inverse relationship to performance on the mathematics test. However, no relationship between mathematics anxiety and gender was found in either country.
In Eccles’ and Jacobs’ (1986) two-year longitudinal study of 250 average and above-average 7th through 9th graders, they found that mathematics anxiety was an important predictor of subsequent mathematics grades and course-taking plans. Furthermore, in that sample of mathematically competent students, mathematics anxiety was only weakly related to students’ previous performance in mathematics (r=-.17) and females reported more mathematics anxiety than males (r=-.19).

Hembree (1990) conducted a meta-analysis of 151 studies of mathematics anxiety. The studies used in the study were found through computer and manual searches of Dissertation Abstracts, Psychological Abstracts, and the Educational Resources Information Center (ERIC). His analysis indicated that students reporting high levels of mathematics anxiety took fewer mathematics courses and planned to take less mathematics courses in the future than students with low mathematics anxiety. This trend appeared to be stronger for males than females. Beginning in junior high school and continuing in high school and college, females reported more mathematics anxiety than males. For both sexes, mathematics anxiety appeared to peak in grades 9 and 10, and decline slowly thereafter. Furthermore, low-anxious students were found to score about one-half of a standard deviation higher than high-anxious students. Hembree concluded that mathematics anxiety depresses
mathematics performance. He based his conclusion on the findings that intervention studies have shown that when mathematics anxiety is reduced, achievement increases. He concluded that there is no compelling evidence that poor performance causes mathematics anxiety, since the construct's relation with IQ is small, and special efforts to increase students' competence usually do not lead to reductions in their anxiety. Although females at all grades reported higher mathematics anxiety levels than males in the studies he analyzed, males appear to be more strongly affected by mathematics anxiety than females. That is, males' mathematics anxiety is more likely to lead to depressed performance and enrollment than occurs in females with similar levels of reported anxiety.

Hyde, Fennema, Ryan, Frost and Hopp (1990) also performed a meta-analysis of previous research pertaining to mathematics anxiety. They found 70 studies of over 63,000 subjects, approximately 50% of each sex, in which the same measure of mathematics anxiety was used, the Fennema-Sherman Mathematics Anxiety Scale (Fennema & Sherman, 1976). Their analysis indicated that males reported experiencing less mathematics anxiety than females, but the effect size was small (.16).

It is clear, even when using the technique of meta analysis, inquiries into this topic do not always yield consistent patterns of findings. Not all studies indicate
gender differences in mathematics anxiety, and many do not
reveal that mathematics anxiety is related to lower
mathematics performance. On the other hand, most studies
reflect a tendency for students high in mathematics anxiety
to enroll in fewer mathematics courses than their less
mathematics anxious peers. Earlier studies led to similar
conclusions that the higher an individual's level of
mathematics anxiety, the less likely it is that he or she
will choose to take elective high school mathematics
courses (Betz 1978; Fennema and Sherman, 1976; Sherman,
1983) or elect a math-related college major (Hackett, 1985;
Shanklin, 1978). Interestingly, researchers frequently
find also that the level of individuals' mathematics
anxiety is not related strongly to previous mathematics
achievement. Nonetheless, it is clear that females have no
monopoly on mathematics anxiety and that the gender
differences, when found, are not large. Thus, it would be
inaccurate to conclude that any observed gender differences
in mathematics achievement and enrollment are due
necessarily to effects of mathematics anxiety.

Mathematics Confidence

Confidence in one's ability to learn and perform well
in mathematics has been found to be related significantly
to students' decisions to enroll in upper level high school
mathematics courses. Armstrong and Price (1982) found that
for the 1,788 high school seniors in the Women In Mathematics Survey, confidence in mathematics ability was strongly correlated with course enrollment for both boys and girls.

Gender differences in mathematics confidence have been found in most investigations into this topic. Dossey et al. (1988) discovered that during all three National Assessments of Educational Progress from which data about this topic is available (1978, 1982, 1986), the percentage of females in the 13-year-old and 17-year-old groups who believed they were good in mathematics was from 7 to 11 percentage points below that of males. Fennema and Sherman (1977) also found that boys reported significantly more confidence in their mathematics ability than girls in three of the four high schools in their study. This pattern was observed also by Jones and Jones (1989) in their study of 160 high school students in England.

In addition to their inquiry into mathematics anxiety, mentioned above, Hyde et al. (1990) performed a meta-analysis of previous research pertaining to mathematics confidence. They found that when the results of the 70 studies in their analysis were analyzed, males reported greater mathematics confidence than females. Even though the gender differences were statistically significant, however, the effect size of .19 was not considered large.
There is an interesting relationship between confidence and achievement. In both the Fennema and Sherman (1977) and the Dossey et al. (1988) studies mentioned above, researchers found that males reported greater confidence even when males and females performed at the same level. Fennema and Sherman found also that mathematics confidence was a reliable predictor of subsequent mathematics achievement in females. Fennema (1980) found that boys tend to overestimate their ability in mathematics, and that girls, at least high ability girls, have a tendency to underestimate their mathematics ability. Jones and Jones (1989) also observed that girls in their study who had higher quantitative scores were far more negative in their views of their mathematics ability than were girls with lower quantitative scores. In view of the apparent link between confidence and enrollment, this may explain at least some of the differences between males' and females' participation in mathematics courses.

**Autonomous Learning Behavior**

Fennema and Peterson (1985) and Linn and Hyde (1989) suggest that those with high confidence and low anxiety in mathematics will be more likely than those with low confidence to persist in their efforts to solve tough mathematics problems, to try alternative approaches to solving problems, and to experiment with new approaches not
taught in class. Conversely, it seems plausible that a lack of confidence might detract from students' performance.

Fennema and Peterson (1985) have proposed a theoretical model to account for sex differences which have been observed in the performance of mathematics tasks of high cognitive complexity, such as multi-step problem-solving activities. They posit that in order to complete such complex tasks, one must be able to work independently, persist, choose, and succeed at such tasks. They call these behaviors "autonomous learning behaviors" (ALB) and hypothesize that they act as mediators between ability and performance in tasks of high cognitive complexity where sex-related differences are found. The awareness of one's problem-solving approach, the ability to think about thinking, is considered an important element of ALB. According to this model, internal influences such as one's confidence regarding math, and external influences including parental and teacher expectations, plus societal stereotypes about women and mathematics, all influence participation in autonomous learning activities. Fennema and Peterson add that participation in ALB's leads to greater development of ALB's which in turn leads to better performance on higher level tasks. Thus, specific problem-solving behaviors are viewed as important explanations of gender differences in mathematics achievement.
Capporimo (1990) investigated the relationship between gender, confidence and the use of specific problem-solving strategies of 122 8th-grade male and female students who represented all levels of mathematics achievement. Students were administered six routine and six non-routine word problem solving questions from the Iowa Test of Basic Skills. Each student also answered a forty-four item questionnaire designed to assess his or her problem-solving approach when solving non-routine word problems in mathematics class, and their awareness of those behaviors. Subjects also completed the Confidence in Learning Mathematics Scale, a subscale of the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). Although a significant relationship was found between problem-solving strategies and scores on the standardized test, males did not score higher on the problem-solving strategies measure, as had been expected. Nonetheless, these results support the connection between autonomous learning behavior and success in solving mathematics reasoning tasks. The failure to find significant gender differences is not incompatible with findings by most researchers that sex differences in mathematics achievement are minimal or nonexistent among 8th graders. Further research is needed to assess the relationships among these variables in age groups where achievement differences are found more frequently. Although Fennema states that
empirical evidence to support this model is as yet unavailable, data cited in this review regarding girls' attitudes and affect regarding mathematics, and social influences on their formation (described below), offer support for this model as a plausible explanation for some of the variance in performance of higher-level mathematical problem-solving tasks which are found often.

Perceived Usefulness of Mathematics

One variable which has been found to be related significantly to students' decisions to enroll in upper level high school mathematics courses is the perceived usefulness of mathematics. Armstrong and Price (1982) found that the belief that mathematics will be useful in one's future educational or career pursuits was the best predictor of subsequent enrollment in mathematics courses for male as well as female high school seniors. Meece et al. (1982) also found a strong relationship between perceived value of mathematics and course enrollment intentions among high school students of both sexes. Furthermore, he also observed a tendency for males to rate mathematics as more valuable and useful than females did. Pedersen, Elmore and Blyer (1985) found that by junior high school, students in their study had already started to exhibit traditional sex-defined career interests, with males showing significantly higher interest in science and
technology, and girls choosing careers in creative and applied arts, and social, health and personnel services. Other studies have revealed also that perceived usefulness of mathematics is correlated significantly with enrollment and that high school boys tend to perceive mathematics as being more useful than girls do (e.g., Sherman, 1982a; Dossey et al., 1988; Hyde, Fennema, Ryan, Frost & Hopp, 1990).

In their meta-analysis of 70 studies, Hyde et al. (1990) found a significant gender gap in favor of males regarding the perceived usefulness of mathematics as measured by the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). Although the overall difference between males and females was small (effect size: .07), Hyde et al. suggest that the cumulative effect of even small gender differences in mathematics-related attitudes over years may contribute to gender differences in mathematics learning, especially in higher-level courses, where considerable effort and motivation are often necessary to excel.

Eccles, Adler, Futterman, Goff, Kaczala, Meece and Midgley (1983) have proposed a model of achievement which states that persistence, choice and performance are determined primarily by two central constructs: expectations for success and the subjective value of the task. The effects of past achievement and socialization
experiences, plus the individual's interpretation of those events, are seen as important influences on the development of those beliefs.

Ethington (1991) analyzed data from the Second International Mathematics Study in order to test this model. She found that for males, the value of mathematics and expectations for success had a significant influence on intentions to take more mathematics courses. For females, the value of mathematics was related significantly to intentions, but expectations for success were not. It may be that the importance of these beliefs in influencing future study of mathematics differs for females and males. Nonetheless, models such as this offer direct evidence of the influence of subjective cognitive variables in decisions pertaining to mathematics participation.

Social Factors in Schools Which Affect Mathematics Performance

Teachers

In addition to cognitive and affective variables, social factors in school settings have been examined with respect to their relationship with mathematics achievement and enrollment. There is evidence that in many cases teachers treat boys and girls differently in mathematics classes and that certain types of teacher behaviors have a significant effect on mathematics achievement as well as
students' decisions to enroll in mathematics courses in the future. Numerous studies have revealed that regardless of teacher gender, boys receive a greater amount of teacher time, attention, and encouragement in mixed-sex mathematics classes than girls. Spender (1982) estimated that boys received two thirds of mathematics teachers' attention. McDermott (1983) found that females in eighth through tenth grade mathematics classes received more work praise from teachers than their male counterparts, and that teachers provided boys with more criticism, sustaining questions and feedback. In other words, teachers engaged in more interactions with boys which pertained to mathematical processes; whereas more interactions with girls were related to the quality of their answers. McDermott observed also that boys initiated more contacts with teachers than girls did, and, therefore, may have influenced the nature of the teacher-student interaction. Sadker and Sadker (1985) also found that the boys in the 4th-, 6th- and 8th- grade mathematics classrooms they observed consistently received more precise and constructive teacher attention than girls did. Becker (1981) found that teachers initiated more contacts with males than with females, and that boys had an advantage regarding response opportunities, cognitive level of questions, encouragement, individual help, and length of interactions with teachers. Becker too found that boys
volunteered to participate in class more often than girls did. Other researchers have found differential treatment by teachers favoring males in mixed-sex mathematics classes (Brophy & Good, 1970; Croll, 1985; Leder, 1986; Baker, 1986).

In 1992, a report was published by the American Association of University Women (AAUW) in which a synthesis of all research available on the subject of girls in school was presented. The AAUW report offered compelling evidence that girls are not receiving the quantity and quality of mathematics education that boys are (American Association of University Women, 1992).

These findings are noteworthy with regard to the present examination of females' participation in mathematics studies and careers. A consistent finding in the research literature is that teacher encouragement and engagement of students in classroom activities are positively correlated with achievement in mathematics (Petersen and Fennema, 1985; Midgely, Feldlaufer and Eccles, 1988; Brophy, 1983; Casserly & Rock, 1985) and decisions to take additional mathematics courses (McDermott, 1983; Fennema and Sherman, 1976; Armstrong & Price, 1982; Casserly & Rock, 1985).
Sex Composition of Mathematics Classes and Schools

The sex composition of individual class populations has been studied with respect to mathematics attitudes and behaviors. Rowe (1988) found that in an Australian junior high school there was no significant difference in achievement by boys and girls in the single- versus mixed-sex classes, but that males and to a greater extent, females in single-sex classes had significantly more confidence in their ability to learn mathematics and also had a significantly greater tendency to enroll in more difficult mathematics courses for the following year.

Advantages of single-sex mathematics classes for women were observed by Brunson (1983) at the university level. Those women who chose to participate in an all-female basic college mathematics course had significantly higher achievement levels and significantly lower withdrawal rates than women who were in mixed-sex classes. However, Macfarlane and Crawford (1985) found no such advantages for single-sex classes among high school students in Ontario during the 1984-85 school year.

With regard to the sex composition of the student population in schools, there is evidence that single-sex schools may provide certain advantages. Trickett, Trickett, Castro and Schaffner (1982) surveyed students at fifteen single-sex and coeducational independent schools in the United States and found that students perceived single-
sex schools as having more academic orientation, student involvement, student affiliation, teacher support, and task orientation than coeducational schools. Riordan (1985) analyzed data from the National Longitudinal Study of the Class of 1972 in the United States and concluded that males and females from single-sex Catholic schools outperform their peers in mixed-sexed Catholic and mixed-sexed public schools in mathematics as well as other subjects. Lee and Bryk (1986) examined data pertaining to students who attended Catholic high schools between 1980 and 1982. They found that males and females in the single-sex schools had significantly more positive attitudes about mathematics and enrolled in more mathematics courses than their age-mates in coeducational Catholic schools. As noted above, positive attitudes regarding mathematics frequently predict subsequent enrollment in mathematics courses. Few differences in achievement were observed, but when they were, they favored students in the single-sex schools. These findings are in contrast with an early study by Dale (1974), who found modest advantages for boys but not girls in coeducational schools in Britain.

In some cases, the faculty in single-sex schools may provide another advantage to students. Tidball and Kistiakowsky (1976) found that single-sex schools usually have a high percentage of faculty members of the same sex as the students, thus providing important role models. In
subjects which are traditionally not viewed as sex-appropriate, the presence of same-sex role models may act as a buffer against other social influences which undermine confidence and interest in that area.

Peers

The behavior of peers may provide an explanation for advantages of single-sex schools and classes which are sometimes found. Nix (1986) observed that boys tend to dominate student interaction with teachers in mixed-sex classes but that females are more likely to participate in class discussions in single-sex classes. Thus, engaged time with teachers would likely be higher for girls in single-sex classes. Jungwirth (1991) also found that boys interacted more with teachers than girls did in her study, and offered interesting observations about teacher-student exchanges. She found that boys had a much greater tendency than girls to conceal failure when discussing mathematics problems with teachers, and that they also demonstrated an argumentative insistence that their response had some logical basis more often than girls did. Females, in contrast, tended to become silent or give in and admit failure more often than males did, even in cases where females' answers were partially correct. Jungwirth suggested that acting this way is consistent with gender-role stereotypes, and she drew upon the work of Maltz and...
Borker (1982) as a possible explanation for boys’ superiority in managing teacher-student interactions. Maltz and Borker argued that in girls’ peer associations, learning to establish and maintain relationships of equality and closeness is emphasized. For boys, on the other hand, peer group activities often include posturing and counterposturing, and learning to negotiate a series of challenges. Thus, differential experiences in peer interactions encountered by males and females as they grow up may influence their success in classroom participation. Other researchers have documented males’ tendency to initiate more contacts with teachers than females do (Becker, 1981; McDermott, 1983; Sadker & Sadker, 1985). Further research is needed to explore the nature, impact and relative contributions of students and teachers in classroom interactions.

A potential advantage for students of both sexes in single-sex classes pertains to Nelson-LeGall and DeCooke’s (1987) finding that both boys and girls typically seek help more frequently from classmates of the same than the opposite sex. Given that the availability of such help is reduced in mixed-sex classes, this may account for a portion of the greater achievement which is sometimes found in single-sex academic environments.

The influence of peers on enrollment in mathematics courses has also been documented. Armstrong and Price
(1982), found that the approval, support and encouragement of peers had a low but significant correlation with taking high school mathematics. If students receive more support from same-sexed peers than those of the opposite sex, single-sex environments would be likely to provide students with more opportunities to obtain such support.

Coleman's (1961) notion of adolescent subculture may explain another part of the observed differences in cognitive and affective outcomes in single-versus mixed-sex academic environments which are observed at times. Coleman stated that in the adolescent subculture, individuals tend to place more importance on physical attractiveness and heterosexual popularity than on academic achievement. Schneider and Coutts (1982) found that an adolescent subculture was more likely to be present in mixed-sex than in single-sex schools, with the result that there was less emphasis on scholarship and achievement and more emphasis on affiliation and nonacademic activities. This pattern may account for Horner's (1972) fear of success found among many adolescent girls who were afraid that academic success might appear unfeminine to boys and experienced internal conflict over their desire for achievement and their desire for relationships with boys. The finding by Pederson et al. (1985) of a shift toward traditional sex-defined career interests and an increased sex-stereotyping of mathematics during junior high school
may account for the gender differences in achievement and interest in mathematics which some studies have shown begin to emerge at that grade level.

**Summary**

Despite the popular notion that males have greater mathematics ability than females, this review has shown that there is insufficient evidence to support such a broad conclusion. In all samples studied, the distributions of males' and females' scores overlapped substantially. There is considerable evidence that the existence and even the direction of gender differences in mathematics performance can vary depending upon a number of variables, including the measure used to assess mathematics skills, the age and selectivity of the sample, and the type of mathematics operations required to perform the tasks presented. The one area of mathematics achievement in which male superiority is found with consistency is in mastering higher-level problem-solving tasks.

Evidence has also been presented which challenges biological explanations for any observed sex differences in mathematics achievement or participation. Support for this conclusion comes from studies which reveal that the gender gap in mathematics achievement has decreased substantially during recent decades, that gender differences in
mathematics skills vary from country to country, that the gender gap can be reduced or eliminated when out-of-class mathematics-related experiences are taken into account, and that in some cases the gender gap can be closed when females are given training to develop the types of mathematics skills in which male superiority was once considered inevitable (e.g., visual-spatial skills).

Furthermore, a number of cognitive and affective variables have been described which are related to both achievement and enrollment in mathematics. Studies have been described which support the general conclusions that gender differences exist among these variables and that these factors may provide at least partial explanations for the differences in males' and females' mathematics achievement and participation which are sometimes observed. A number of social factors in schools appear to exert an influence on the development of these personal variables.

Overall, support for the role of experiential, personal and social influences on mathematics achievement and enrollment appears to have more empirical support than the view that any observed gender differences pertaining to mathematics are due to gender-related biological differences.
Significance of This Study

The unique features of this study include the following:

Although the effects of coeducational verses single-sex schooling on males' and females' mathematics-related attitudes, affect and enrollment have been examined in previous studies, a unique feature of the present investigation is that the effects of the sex of the school population on these variables will be studied using the same subjects on two occasions. That is, it will be possible to examine the effects of changing from one type of environment to another on the same children during the course of one school year.

Another unique feature of this study is that it will provide an opportunity to examine how this experience affects students from two developmental levels (pre-adolescence and adolescence).

Also, unlike previous studies, the present investigation will explore how changing from a single-sex to coeducational school environment effects high ability students in a high-achieving, high socioeconomic student population.
Hypotheses

The following hypotheses are examined in the present study.

1. There will be a significant decrease in perceived usefulness of mathematics for female middle and upper school students but not male middle and upper school students from the September, 1991 compared to the April, 1992 testing as measured by a self-report questionnaire.

2. Female upper school students will report significantly less perceived usefulness of mathematics than female middle school students on the April, 1992 testing as measured by a self-report questionnaire.

3. Female upper school students will report significantly less perceived usefulness of mathematics than male upper school students on the April, 1992 testing as measured by a self-report questionnaire.

4. Female middle school students will report significantly less perceived usefulness of mathematics than male middle school students on the April, 1992 testing as measured by a self-report questionnaire.

5. There will be a significant increase in mathematics anxiety among female upper and middle school students but not male upper and middle
school students from the September, 1991 compared to the April, 1992 testing as measured by a self-report questionnaire.

6. Female upper school students will report significantly more mathematics anxiety than female middle school students on the April, 1992 testing as measured by a self-report questionnaire.

7. Female upper school students will report significantly more mathematics anxiety than male upper school students on the April, 1992 testing as measured by a self-report questionnaire.

8. Female middle school students will report significantly more mathematics anxiety than male middle school students on the April, 1992 testing as measured by a self-report questionnaire.

9. There will be a significant decrease in mathematics self-concept among female middle and upper school students but not male middle and upper school students from the September, 1991 testing compared to the April, 1992 testing as measured by a self-report questionnaire.

10. Female upper school students will report significantly lower mathematics self-concept than female middle school students on the April, 1992 testing as measured by a self-report questionnaire.
11. Female upper school students will report significantly lower mathematics self-concept than male upper school students on the April, 1992 testing as measured by a self-report questionnaire.

12. Female middle school students will report significantly lower mathematics self-concept than male middle school students on the April, 1992 testing as measured by a self-report questionnaire.

13. Significantly more males than females who are in grades 9, 10 and 11 at the end of the 1991-92 school year will enroll in the next most difficult mathematics course available for the 1992-93 school year. That is, more males than females will choose a mathematics course for the next school year which represents the next step in the sequence of mathematics study in which they are presently engaged.
CHAPTER III

METHODOLOGY

This study was part of a larger study conducted by five doctoral candidates and one master's-level student who attended The Ohio State University. In addition to the areas of interest in the study described in this dissertation, variables examined by the other graduate students included gender role perceptions, career plans, achievement motivation, academic self-concepts, attitudes toward success, and self-perceptions of cognitive and physical competence, parent and peer relationships, and emotional well-being. In this particular study, the central focus was to examine the relationship between mathematics-related attitudes, affect and behavior and the transition from single-sex schooling to coeducation.

Subjects

The subjects who participated in this study were part of a total population of approximately 650 males and females in a private, independent day school in a metropolitan area in the midwest. Students in grades
kindergarten through 12 attended the school during the time of the study, the 1991-92 school year.

Although pupils in all grades in the school were involved in the overall study conducted by the six graduate students, the number of subjects who participated in the study described in this document was approximately 325. There were two criteria for including students in the sample. Since one of the goals of this study was to compare students from two developmental levels, adolescence and pre-adolescence, students in grades below pre-adolescence were not included in this particular study. Also, in order to examine students' reactions to coeducation, only students in grades where both males and females attended were part of the sample. Grades 7, 8 and 12 had no females in them, and pre-adolescence was defined for the purpose of this study as beginning in the 5th grade. Therefore, students from grades 5 and 6 formed the middle school (pre-adolescent) group, and students in grades 9, 10 and 11 constituted the upper school (adolescent) group.

The year of the study was the first year that this school admitted females, after 75 years as an all-male institution. Females represented a small minority of the student population. Approximately 20-25% of the students of each grade level in the study were female. Seventy-five percent of the students in the study attended single-sex
schools during the previous (1990-91) academic year. The faculty of the school was 55% female.

The students in this school are predominantly (>90%) from families of high socioeconomic standing, as defined using Hollingshead's (1958) Four-factor Index of Social Class. Also, these students are generally highly successful academically. One reflection of this is that the young men in the graduating class of 1991 obtained a group average score of 689 on the mathematics portion of the Scholastic Aptitude Test (SAT-M) and 563 on the verbal section (SAT-V). Although standardized test scores are not available for the group of students who attended the school during the 1991-92 academic year, the director of admissions has made it clear that the admissions standards were not changed for the students who started attending there in the fall of 1991 and that they are generally as capable as the students who preceded them (L. Schultz, personal communication, July 1, 1992).

The ethnic composition of the middle school was 76% white, 9% Asian, 9% African-American, and 6% from other ethnic categories (e.g., Middle Eastern). In the upper school, 75% of the students were white, 13% Asian, 4% African-American, and 3% in the "other" classification.
Procedures

Prior to conducting the present study, the headmaster, the executive committee, and teachers in each department were given presentations pertaining to the study. The head teachers in each academic department received questionnaires beforehand, and consent for each step of the study was obtained from school administrators.

The students were tested during two three-day periods. The first assessment date was early in the school year (September, 1991) and is considered the pre-test in this study. The post-test was conducted near the end of the school year, in April, 1992. Approximately thirty students who missed one or more sessions of the pre-test were administered questionnaires during a make-up session in one group during October, 1991. Testing sessions lasted from one-half hour to one hour for each of the three days during both the pre- and post-test assessments. The size of the groups of students ranged from single classrooms to larger groups of up to seventy-five. The instruments and procedures for the pre-test and post-test were identical. During both testing periods, two versions of the questionnaires were used in order to counterbalance the order of presentation of the items within each group each day.

The questionnaires were administered by graduate students in school psychology and counselor education, and
faculty members in education. The majority of the individuals who administered the instruments were the candidates or members of their advisory committees, and were, therefore, highly familiar with the instruments and procedures required to administer them. Graduate students who were not familiar with the instruments were trained in their administration and were supervised by candidates or university faculty members during the testing procedures.

Instructions were read to the students for each measure and were printed at the top of each page along with a description of the choices for answers (e.g., a=always agree, b=sometimes agree, etc.). Students' responses were recorded on answer sheets for eventual computer scoring. Adequate time was allowed for students to complete all instruments presented to them. The graduate students and university faculty members who administered the instruments remained in the rooms with students in order to answer any questions and to make certain that students entered their answers in the correct spaces on the answer sheets.

Classroom-like conditions were maintained throughout the assessment procedures. Adequate lighting and uncrowded seating and rooms were provided. Students remained seated until finished, and no talking was permitted by students unless they had questions about the items on the questionnaires.
Outcome Measures

Perceived Usefulness of Mathematics

Students' perception of the usefulness of mathematics was assessed with the Usefulness of Mathematics Scale, one of the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). This is a self-report questionnaire which requires students to rate their agreement or disagreement with 12 statements, using a Lickert-type scale with a range of 0 to 4. Six items are worded negatively and six positively. The statements in this scale pertain to the perceived usefulness of mathematics in every day circumstances and in relation to one's future educational, financial and career success. The authors reported a split-half reliability of .88 for this scale.

A copy of this instrument is in Appendix A.

Mathematics Anxiety

The Emotional Arousal Scale pertaining to mathematics, developed by Matsui, Matsui and Ohnishi (1990), was used to assess mathematics anxiety. This is a self-report questionnaire with five items containing statements about negative affective, attitudinal or physical reactions to mathematics. Students were instructed to respond to each statement by indicating that they agreed or disagreed
("yes" or "no"). The authors reported a reliability (alpha) coefficient of .84 for this instrument. A copy of this instrument is in Appendix B.

Mathematics Self-Concept

Mathematics self-concept was measured using one of the 11 scales which make up the The Self-Description Questionnaire for early- to mid-adolescents (SDQ-II) (Marsh, 1990). The SDQ-II is a self-report questionnaire with 102 statements to which students respond by rating their degree of agreement or disagreement, using a Lickert-type scale with a range of 0 to 4. The instrument has 11 scales, three of which measure academic self-concept and eight which address the examinee's perceptions about personal matters (e.g., physical appearance, parent relations, etc.). The Mathematics Self-Concept scale contains 10 items, with 4 stated positively, and 6 stated negatively. Six of the 10 items pertain directly to the examinee's perceived ability to master successfully the subject of mathematics (i.e., mathematics confidence), and the remaining items address students' perceptions of their enjoyment and interest in mathematics. The normative sample consisted of 5,494 male and female students in grades 7 through 12 (approximately 50% of each sex) from schools in Sydney, Australia. The
students were from a variety of socioeconomic backgrounds, and attended public and private as well as single-sex and coeducational schools.

The reliability of the SDQ-II was established using the normative sample (Marsh, 1990). Internal consistency for the total self-concept questionnaire was a coefficient alpha estimate of .94. The construct validity of the SDQ-II has been supported also in studies comparing the results from the SDQ-II with related constructs and trends in the general self-concept research literature (Marsh, 1990; Marsh, Parker & Barnes, 1985; Marsh & Pearl, 1988).

A copy of this questionnaire is in Appendix C.

Mathematics Enrollment

Data pertaining to mathematics enrollment were gathered by examining the school records of all of the students who were in grades 9, 10 and 11 during the 1991-92 school year; the students who will be sophomores, juniors and seniors during the 1992-93 academic year. In June, 1992, students' year-end report cards were examined in order to determine which mathematics courses they completed during the 1991-92 academic year. To ascertain which mathematics courses they were scheduled to take for the 1992-93 school year, registration forms indicating students' choices and administrators' approval of those selections were used.
Only enrollment data pertaining to upper school students were utilized because school officials indicated that it is rare for middle school students to deviate from the predetermined mathematics curriculum at that level. Therefore, practically speaking, students in middle school have little or no real choice regarding what mathematics course they take. Course choices for students currently ending 8th grade were not collected because no females were in that class during the present school year, and thus, are not of interest in the present study.

Students’ choices for mathematics coursework for the next academic year were categorized as either Progressive or Regressive. A member of the high school mathematics teaching staff was consulted at length in order to determine which choices represented advancement or abandonment of challenging mathematics training (J. Wuorinen, July 10, 1992). In determining the classification of course choices, consideration was given to not only the course the student chose to take during the upcoming school year, but also the nature of the course he or she had just completed. Choices were defined as Progressive if the student chose a course which was regarded by the mathematics faculty member as a continuation of the student’s advancement in mathematics training and represented a reasonable challenge. Regressive choices included not signing up for any course
offered by the mathematics department at all, enrolling in a computer science course instead of a mathematics course, or planning to take one of the less advanced, slower-paced mathematics courses (such as Business Calculus) after completing a more challenging course in which some of that material was already covered (such as going from Algebra III/Trigonometry to Business Calculus).

Data Analysis

All hypotheses were analyzed using a three-way (2 x 2 x 2) repeated measures analysis of variance, with two between-group factors (gender and grade) and one within-group factor (time of year). Mathematics anxiety, mathematics confidence, perceived usefulness of mathematics and mathematics enrollment were the dependent variables; and gender, grade level, and time were the independent variables. When three-way interactions were found, group comparisons within each level of the two remaining independent variables were conducted. Significant two-way interactions were followed with an analysis of the simple effects corresponding to that interaction. Main effect questions were addressed only in the absence of two- and three-way interactions.

In view of the fact that each of the analyses of variance dealt with separate sets of data, the level of significance was set at .05 for each of the three analyses.
With regard to the follow-up tests which were conducted as indicated in each analysis, the level of significance was adjusted in order to compensate for type I error inflation which could be expected due to the number of analyses being conducted. This significance level was determined using the Bonferroni method, wherein the overall significance level was divided by the number of post hoc tests (.05/p, where p=number of post hoc tests). Due to the fact that all of the independent variables were dichotomous, t-tests were used for these follow-up comparisons. The smallest cell size for each analysis was 19, the number of females in middle school. Thus, using Cohen's (1988) criteria for a "very large" effect size (f=.60), a cell of this size yields a power of .86.

For the purposes of this study, the dependent variable "grade" had two levels: lower school (5th and 6th graders) and middle school (9th, 10th and 11th graders). In the remainder of this document, discussion of students in different grades refers to pupils in these categories and is not used to describe children in single grades (e.g., 6th).

A total of 110 middle school students and 215 upper school pupils met the selection criteria and were eligible to participate in this study. However, due to a number of unusable answer sheets, the responses of many subjects could not be used in the analysis of data. Answer sheets
were classified as unusable if students omitted more than one answer per questionnaire or left out information needed to determine their grade or sex. Marsh (1990) stated that using data from subjects who had omitted one response was acceptable and would not influence significantly the results of the Mathematics Self-Concept Scale (p. 13). This procedure was adopted for use with the Perceived Usefulness of Mathematics Scale and the Emotional Arousal (mathematics anxiety) Scale also. In cases where pre- and post-test scores were compared to assess change over time, only the responses of students who were present for both assessments could be used. The number of subjects included in the analyses described in this report is approximately 60 males and 20 females in the middle school and 160 males and 40 females from the upper school, depending on the questionnaire under consideration. The exact number of subjects in each analysis is provided in Chapter IV.
CHAPTER IV

RESULTS

In this chapter, the results of the analyses of data pertaining to each of the dependent variables are described separately. For each of the first three variables addressed (Perceived Usefulness of Mathematics, Mathematics Anxiety, and Mathematics Self-concept), a 2 x 2 x 2 repeated measures analysis of variance (ANOVA) with two between factors (Grade Level and Sex) and one within factor (Time of Test) was performed to test the hypotheses pertaining to the variable under consideration. In the final section of this chapter, data pertaining to the variable Mathematics Enrollment are presented. A chi square was used to make comparisons between males' and females' mathematics course choices for the 1992-93 school year.

Perceived Usefulness of Mathematics

The results of the analysis of variance regarding this dependent variable indicated that a significant three-way interaction (Grade x Sex x Time) was present. The results of this analysis are presented in Table 1.
### Table 1

**Results of Three-way Repeated Measures Analysis of Variance for Perceived Usefulness of Mathematics**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>MS</th>
<th>F Value</th>
<th>Prob&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>8.97</td>
<td>0.11</td>
<td>0.73</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>8152.25</td>
<td>101.60</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>2993.98</td>
<td>59.41</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Sex x Grade</td>
<td>1</td>
<td>157.49</td>
<td>1.96</td>
<td>0.16</td>
</tr>
<tr>
<td>Time x Sex</td>
<td>1</td>
<td>5.91</td>
<td>0.12</td>
<td>0.73</td>
</tr>
<tr>
<td>Time x Grade</td>
<td>1</td>
<td>2631.76</td>
<td>52.22</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Time x Sex x Grade</td>
<td>1</td>
<td>362.14</td>
<td>7.19</td>
<td>0.007*</td>
</tr>
<tr>
<td>Error (between)</td>
<td>237</td>
<td>80.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error (within)</td>
<td>237</td>
<td>50.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant at .01 level.
**significant at .001 level.

The group means for the pre-test and post-test scores of males and females in middle and upper school are provided in Table 2 and are presented graphically in Figure 1 (next page). The magnitude of change in the perceived usefulness of mathematics was different for males and females at different grade levels, resulting in the three-way interaction.
Figure 1  Mean Scores for Perceived Usefulness of Mathematics
Table 2
Mean Fall and Spring Scores for Perceived Usefulness of Mathematics

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th></th>
<th>Males</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall</td>
<td>Spring</td>
<td>Fall</td>
<td>Spring</td>
</tr>
<tr>
<td>Middle School</td>
<td>37.94</td>
<td>40.94</td>
<td>40.64</td>
<td>37.78</td>
</tr>
<tr>
<td></td>
<td>(19)</td>
<td>(18)</td>
<td>(85)</td>
<td>(82)</td>
</tr>
<tr>
<td>Upper School</td>
<td>23.52</td>
<td>33.65</td>
<td>22.87</td>
<td>37.55</td>
</tr>
<tr>
<td></td>
<td>(42)</td>
<td>(35)</td>
<td>(121)</td>
<td>(131)</td>
</tr>
</tbody>
</table>

Note. Number of subjects appears in parentheses.

As a follow-up to this interaction, simple effects were analyzed in order to make comparisons of findings with regard to the differences in levels of the independent variables; time, grade and sex. A total of seven comparisons were required in order to test the four applicable research hypotheses. Therefore, the alpha level for these analyses was set at .007 (.05/7) using the Bonferroni correction in order to compensate for the possibility of type I error due to multiple comparisons.

The first of these post hoc analyses was performed to determine the simple effect of time. Changes in the perceived usefulness of mathematics from fall to spring were analyzed separately for males and females in the middle school and in the upper school. Results of those t-tests are presented in Table 3.
Table 3
*T-tests for Differences Between Fall and Spring Scores for Perceived Usefulness of Mathematics*

<table>
<thead>
<tr>
<th></th>
<th>Fall Mean</th>
<th>Fall SD</th>
<th>Spring Mean</th>
<th>Spring SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td>40.64</td>
<td>7.35</td>
<td>37.78</td>
<td>9.97</td>
<td>1.72</td>
</tr>
<tr>
<td>Upper School</td>
<td>22.87</td>
<td>4.26</td>
<td>37.54</td>
<td>10.12</td>
<td>-16.20*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Fall Mean</th>
<th>Fall SD</th>
<th>Spring Mean</th>
<th>Spring SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td>37.94</td>
<td>8.17</td>
<td>40.94</td>
<td>7.55</td>
<td>-1.88</td>
</tr>
<tr>
<td>Upper School</td>
<td>23.52</td>
<td>4.04</td>
<td>33.65</td>
<td>10.27</td>
<td>-5.37*</td>
</tr>
</tbody>
</table>

*significant at .007 level.

At the middle school level, there were no statistically significant changes in the perception of the usefulness of mathematics from fall to spring for males or females. In contrast, for both sexes in upper school, there was a significant increase in the perceived usefulness of mathematics over time.

Another analysis was performed in order to compare female students' scores at different grade levels at the time of the post-test. As shown in Table 4, the analysis
of group means indicated that upper school females held significantly lower perceptions of the usefulness of mathematics in the spring than middle school females.

Table 4
T-test for Differences Between Females’ Spring Scores for Perceived Usefulness of Mathematics

<table>
<thead>
<tr>
<th>Middle School</th>
<th>Upper School</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Score</td>
<td>Mean Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.94</td>
<td>33.65</td>
<td>44.5</td>
<td>2.92</td>
<td>.005*</td>
</tr>
</tbody>
</table>

*significant at .007 level.

In order to test the hypotheses regarding the expected male advantage in the perceived usefulness of mathematics at the time of the post-test (spring), additional post hoc comparisons were performed. As can be seen in Table 5 (below), no statistically significant differences were observed in the reported levels of the perceived usefulness of mathematics at the time of the post-test between male and female students in the middle or upper school levels.
Table 5

T-test for Differences in Males’ and Females’ Spring Scores for Perceived Usefulness of Mathematics

<table>
<thead>
<tr>
<th></th>
<th>Male Mean</th>
<th>Female Mean</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>37.78</td>
<td>40.94</td>
<td>32.3</td>
<td>1.49</td>
<td>0.14</td>
</tr>
<tr>
<td>Upper School</td>
<td>37.54</td>
<td>33.65</td>
<td>53.0</td>
<td>-1.99</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*significant at .007 level.

Mathematics Anxiety

The analysis of variance pertaining to students’ responses to the Mathematics Anxiety questionnaire indicated that no statistically significant three-way interaction existed among the independent variables. A statistically significant interaction for Sex x Grade and a statistically significant interaction for Time x Grade were found. The results of this analysis are in Table 6.
Table 6
Results of the Three-way Repeated Measures Analysis of Variance for Mathematics Anxiety

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>MS</th>
<th>F Value</th>
<th>Prob&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>3.585</td>
<td>2.08</td>
<td>0.15</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>0.20</td>
<td>0.12</td>
<td>0.733</td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>1.025</td>
<td>1.08</td>
<td>0.298</td>
</tr>
<tr>
<td>Sex x Grade</td>
<td>1</td>
<td>26.91</td>
<td>15.59</td>
<td>0.0001**</td>
</tr>
<tr>
<td>Time x Grade</td>
<td>1</td>
<td>8.746</td>
<td>9.25</td>
<td>0.002*</td>
</tr>
<tr>
<td>Time x Sex x Grade</td>
<td>1</td>
<td>0.078</td>
<td>0.08</td>
<td>0.773</td>
</tr>
<tr>
<td>Error (between)</td>
<td>242</td>
<td>1.725</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error (within)</td>
<td>242</td>
<td>0.945</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant at .01 level.
**significant at .001 level.

The means for each group are presented in Table 7 (page 85) and are shown graphically in Figure 2 (page 84). The reported level of mathematics anxiety increased over time for middle school males and females, but decreased from fall to spring among upper school students of both sexes.
Figure 2  Mean Scores for Mathematics Anxiety
Table 7
Mean Fall and Spring Scores for Mathematics Anxiety

<table>
<thead>
<tr>
<th></th>
<th>Females Fall</th>
<th>Females Spring</th>
<th>Males Fall</th>
<th>Males Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>0.68</td>
<td>1.21</td>
<td>1.04</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>(19)</td>
<td>(19)</td>
<td>(64)</td>
<td>(78)</td>
</tr>
<tr>
<td>Upper School</td>
<td>1.71</td>
<td>1.38</td>
<td>0.89</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>(42)</td>
<td>(36)</td>
<td>(163)</td>
<td>(161)</td>
</tr>
</tbody>
</table>

Note. Number of subjects appears in parentheses.

In order to identify specific changes within the levels of these variables, tests of simple effects were conducted. Again, an alpha level of .007 was set, following the Bonferroni correction procedure.

As in the previous section, the effect of Time was examined first. The first simple effects analysis compared pre-test and post-test scores among males and females separately in the middle school and the upper school. The results of those analysis are presented in Table 8.
Table 8
T-tests for Differences Between Fall and Spring Scores for Mathematics Anxiety

<table>
<thead>
<tr>
<th></th>
<th>Fall Mean</th>
<th>Fall SD</th>
<th>Spring Mean</th>
<th>Spring SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td>1.04</td>
<td>0.89</td>
<td>1.51</td>
<td>1.36</td>
<td>-2.88*</td>
</tr>
<tr>
<td>Upper School</td>
<td>0.89</td>
<td>1.19</td>
<td>0.64</td>
<td>0.99</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Males

<table>
<thead>
<tr>
<th></th>
<th>Fall Mean</th>
<th>Fall SD</th>
<th>Spring Mean</th>
<th>Spring SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td>0.68</td>
<td>0.82</td>
<td>1.12</td>
<td>0.85</td>
<td>-1.81</td>
</tr>
<tr>
<td>Upper School</td>
<td>1.71</td>
<td>1.58</td>
<td>1.38</td>
<td>1.60</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Females

*significant at .007 level.

With regard to middle school students, females’ mean mathematics anxiety score increased by an amount that was not statistically significant from fall to spring. In contrast, a statistically significant increase was observed among middle school males over time. For upper school students, comparisons of group means revealed that no significant changes occurred from fall to spring for either males or females at this grade level.

In the next analysis, females’ post-test scores were analyzed to determine whether upper school females reported
more mathematics anxiety than female middle school students in the spring. As seen in Table 9, there was no statistically significant difference between ratings of mathematics anxiety by these two groups of female students.

Table 9
T-test for Differences Between Females' Spring Scores for Mathematics Anxiety

<table>
<thead>
<tr>
<th></th>
<th>Middle School</th>
<th>Upper School</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Score</td>
<td>1.21</td>
<td>1.38</td>
<td>57.8</td>
<td>-3.34</td>
<td>0.59</td>
</tr>
</tbody>
</table>

*significant at .007 level.

The final analyses of data pertaining to mathematics anxiety were conducted to examine sex differences at the time of the post-test. Separate comparisons were performed between males' and females' scores in the middle school and males' and females' scores in the upper school. The results of the analyses are presented in Table 10.

Table 10
T-test for Differences in Males' and Females' Spring Scores for Mathematics Anxiety

<table>
<thead>
<tr>
<th></th>
<th>Male Mean</th>
<th>Female Mean</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>1.51</td>
<td>1.21</td>
<td>43.4</td>
<td>-1.21</td>
<td>0.23</td>
</tr>
<tr>
<td>Upper School</td>
<td>0.64</td>
<td>1.38</td>
<td>42.6</td>
<td>2.62</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*significant at .007 level.
As shown above, among the younger students, males’ mean mathematics anxiety post-test score was moderately higher than that of females, but the difference was not statistically significant. For the upper school students, although females obtained a higher mean mathematics anxiety score, this did not represent a statistically significant difference at the .007 level.

Mathematics Self-Concept

The analysis of variance of students’ ratings of their mathematics self-concept indicates the presence of a significant Time x Grade interaction plus a significant effect of Sex. The results are described in Table 11.
Table 11

Results of the Three-way Repeated Measures Analysis of Variance for Mathematics Self-Concept

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>prob&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>24.734</td>
<td>12.77</td>
<td>0.0004**</td>
</tr>
<tr>
<td>Grade</td>
<td>1</td>
<td>6.410</td>
<td>3.31</td>
<td>0.07</td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>3.220</td>
<td>6.49</td>
<td>0.0115*</td>
</tr>
<tr>
<td>Sex x Grade</td>
<td>1</td>
<td>3.619</td>
<td>1.87</td>
<td>0.172</td>
</tr>
<tr>
<td>Time x Sex</td>
<td>1</td>
<td>0.139</td>
<td>0.28</td>
<td>0.5968</td>
</tr>
<tr>
<td>Time x Grade</td>
<td>1</td>
<td>3.043</td>
<td>6.13</td>
<td>0.0139*</td>
</tr>
<tr>
<td>Time x Sex x Grade</td>
<td>1</td>
<td>0.274</td>
<td>0.55</td>
<td>0.458</td>
</tr>
<tr>
<td>Error (between)</td>
<td>254</td>
<td>1.937</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error (within)</td>
<td>254</td>
<td>0.496</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant at .01 level.
**significant at .001 level.

The meaning of the significant Grade x Time effect is understood by examining the group means presented in Table 12 (next page). When both sexes of students are grouped together, students in the upper school demonstrated a modest increase in mathematics self-concept from fall to spring. In contrast, middle school students reported lower ratings for this attitude from fall to spring.
Table 12
Mean Fall and Spring Scores for Middle School and Upper School Students’ Mathematics Self-Concept

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle</td>
<td>4.72</td>
<td>4.21</td>
</tr>
<tr>
<td>School</td>
<td>(105)</td>
<td>(101)</td>
</tr>
<tr>
<td>Upper</td>
<td>4.27</td>
<td>4.32</td>
</tr>
<tr>
<td>School</td>
<td>(185)</td>
<td>(179)</td>
</tr>
</tbody>
</table>

Note. Number of subjects appears in parentheses.

The main effect of sex was the result of females in both the middle and upper schools obtaining lower scores than males on both testing dates. When the pre-test and post-test scores for students at both grade levels are combined, the mean score for all females is 3.88 and for males it is 4.48.

Following the results of the analysis of variance, tests of simple effects were conducted in order to make specific comparisons of group means among the relevant levels of these variables. In line with previous analyses in this study, the Bonferroni correction was used to adjust the alpha level for these comparisons in order to compensate for type I error. Therefore, since seven comparisons were made, an alpha level of .007 was used. The means for the groups in this analysis are presented graphically in Figure 3 and numerically in Table 13.
Figure 3 Mean Scores for Mathematics Self-Concept
Table 13
Mean Fall and Spring Scores for Mathematics Self-Concept

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th></th>
<th>Males</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall</td>
<td>Spring</td>
<td>Fall</td>
<td>Spring</td>
</tr>
<tr>
<td>Middle School</td>
<td>4.33 (20)</td>
<td>4.06 (19)</td>
<td>4.82 (85)</td>
<td>4.25 (82)</td>
</tr>
<tr>
<td>Upper School</td>
<td>3.75 (41)</td>
<td>3.70 (36)</td>
<td>4.42 (144)</td>
<td>4.48 (143)</td>
</tr>
</tbody>
</table>

Note. Number of subjects appears in parentheses.

The first simple effects analysis pertaining to mathematics self-concept compared pre-test and post-test scores among males and females separately in the middle school and the upper school in order to examine changes over time. The results of those analyses are presented in Table 14.
Table 14
T-tests for Differences between Fall and Spring Scores
for Mathematics Self-Concept

<table>
<thead>
<tr>
<th></th>
<th>Fall Mean</th>
<th>Fall SD</th>
<th>Spring Mean</th>
<th>Spring SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>4.82</td>
<td>0.86</td>
<td>4.25</td>
<td>1.25</td>
<td>3.75*</td>
</tr>
<tr>
<td>Upper School</td>
<td>4.42</td>
<td>1.09</td>
<td>4.48</td>
<td>0.99</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Fall Mean</th>
<th>Fall SD</th>
<th>Spring Mean</th>
<th>Spring SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>4.33</td>
<td>1.20</td>
<td>4.06</td>
<td>1.13</td>
<td>1.21</td>
</tr>
<tr>
<td>Upper School</td>
<td>3.75</td>
<td>1.22</td>
<td>3.70</td>
<td>1.36</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*significant at .007 level.

Males in the middle school reported levels of mathematics self-concept which decreased significantly from the time of the pre-test to the post-test. For males in the upper school, however, there was no significant change over time. Females in both the middle school and the upper school demonstrated no significant change in their mathematics self-concept from the fall to the spring.

The next analysis involved comparing the mathematics self-concept of females from each grade level at the time of the post-test. The results of that t-test are found in
Table 15. Although the group mean for upper school females was lower than that of middle school females in April, 1992, the difference was not statistically significant.

Table 15
T-Test for Differences between Females’ Spring Scores for Mathematics Self-Concept

<table>
<thead>
<tr>
<th></th>
<th>Middle School</th>
<th>Upper School</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Score</td>
<td>4.06</td>
<td>3.70</td>
<td>43.1</td>
<td>1.04</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*significant at .007 level.

The mathematics self-concept post-test scores of males and females at each grade level were compared in the remaining analyses of data pertaining this variable. As indicated in Table 16 (next page), an examination of middle school students’ scores reveals that although males had a somewhat higher mean than females, this did not represent a significant difference. For upper school students, however, males did have a significantly higher group mean than females.
Table 16
T-test for Differences in Males’ and Females’ Spring Scores for Mathematics Self-Concept

<table>
<thead>
<tr>
<th></th>
<th>Male Mean</th>
<th>Female Mean</th>
<th>df</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle School</td>
<td>4.25</td>
<td>4.06</td>
<td>29</td>
<td>-0.64</td>
<td>0.52</td>
</tr>
<tr>
<td>Upper School</td>
<td>4.48</td>
<td>3.70</td>
<td>44</td>
<td>-3.23</td>
<td>0.002*</td>
</tr>
</tbody>
</table>

*significant at .007 level.

Mathematics Enrollment

The final variable investigated was Mathematics Enrollment. The mathematics course choices for the 1992-93 school year made by students who were in the 9th, 10th, and 11th grades during the 1991-92 academic year were examined. A chi square test was conducted to compare the proportion of male and female students who enrolled in challenging (Progressive) or non-challenging (Regressive) courses. Table 17 contains the frequencies of students’ enrollment decisions for the next academic year. Course choices are presented graphically for each grade level in Figure 4 (page 97).
Table 17
Observed Frequencies of Mathematics Enrollment Choices by Upper School Students for the 1992-93 School Year

<table>
<thead>
<tr>
<th></th>
<th>Progressive</th>
<th>Regressive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>143</td>
<td>10</td>
<td>153</td>
</tr>
<tr>
<td>Females</td>
<td>38</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Total</td>
<td>181</td>
<td>13</td>
<td>194</td>
</tr>
</tbody>
</table>

Only 7.3% of females and 6.5% of males chose non-challenging mathematics courses for the upcoming academic year. Based on this sample, $X^2 = 0.032$, $p < 0.859$. This indicates that there is no statistically significant association between sex and the difficulty of mathematics courses chosen. The vast majority of students of both sexes in this school enrolled in difficult mathematics courses for the 1992-93 school year.
Figure 4  Mathematics Enrollment of Upper School Students
CHAPTER V
DISCUSSION

The purpose of this study was to investigate the effects of changing from single-sex schooling to coeducation on students' mathematics-related attitudes, affect and enrollment. Previous investigators have described certain advantages in single-sex environments, especially for females (Trickett, Trickett & Castro, 1982; Rowe, 1988; Brunson, 1983; Lee & Bryk, 1982). Therefore, as described in Chapter III, the research hypotheses generally predicted that the experiences encountered by students in the present study would have a detrimental effect on females with regard to the variables under consideration, but not on males.

This chapter begins with a discussion of the results of this study in relation to the research hypotheses pertaining to the four independent variables (i.e., Perceived Usefulness of Mathematics, Mathematics Anxiety, Mathematics Self-Concept, and Mathematics Enrollment). Next, any departures from the expected outcomes are addressed. The chapter ends with a discussion of the limitations of this study and suggestions for future research.
Regarding the perceived usefulness of mathematics, it was hypothesized that females at both age levels (i.e., middle school and upper school) would develop a more negative attitude than males over the course of the school year and that by the time of the April, 1992 testing, males would perceive mathematics as more useful than females would. These negative outcomes were not observed. In fact, the perceived usefulness of mathematics increased among females at both grade levels from September, 1991 to April, 1992, although only to a statistically significant extent for those in the upper school. This pattern is a departure from the decline in the perceived usefulness of mathematics reported in previous studies (e.g., Dossey et al, 1988; Hyde et al, 1990) and indicates that the transition to a coeducational school did not have the negative impact that was anticipated, at least not in this respect.

For males in both the middle and upper schools, perceptions of the usefulness of mathematics did not change significantly during the course of the school year. This was in line with the hypothesized results and adheres to the pattern reported in previous studies describing males' tendency to maintain the view that mathematics is important for personal, academic and career pursuits.

In view of previous research which has reported a tendency for females' attitudes toward mathematics to
decline during high school, developmental differences were examined among females. Female upper school students reported significantly lower perceptions of the usefulness of mathematics than female middle school students on the April, 1992 testing. This was in agreement with the hypothesized outcome.

In the final set of hypotheses related to this variable, it was predicted that female upper and middle school students would report significantly less perceived usefulness of mathematics than male upper and middle school students on the April, 1992 testing. This was not found, as there were no significant differences between males' and females' group means at either grade level.

Comparing these findings to the group of students who participated in the norming of the Perceived Usefulness of Mathematics Scale is useful. The norm group included 589 females and 644 males from four middle class, suburban/rural high schools in Wisconsin. The mean for females was 33.46 and for males it was 34.91. The post-test group means of students in the present study were 40.94 for middle school females, 33.65 for upper school females, 37.78 for middle school males and 37.54 for upper school males. Thus, all of the groups of students who participated in this study obtained mean scores which were at or above the level of the norm group.
Overall, then, the expected developmental differences favoring middle school females and the lack of decreases in males' attitude were observed. However, decreases over time in females' perceptions of the usefulness of mathematics, and sex differences favoring males students were not found.

The hypotheses pertaining to mathematics anxiety predicted the same pattern of outcomes as those concerning the perceived usefulness of mathematics. That is, changes over time, plus sex differences in students' reported levels of mathematics anxiety, were expected to favor males. In general, these hypotheses were not supported. Females in both the middle and upper schools reported no significant increase in math anxiety from September, 1991 to April, 1992. Also unexpected was the finding that middle school males reported an increase in math anxiety from fall to spring. Upper school males' consistently low mathematics anxiety scores were in line with the hypothesized results, however.

Regarding the expected sex differences in math anxiety at the time of the post-test, the group means for male and female students in both the middle and upper schools were not statistically significant. Thus, the hypothesized male advantage was not found.

The hypothesis related to developmental differences in math anxiety among females was not supported also. Upper
school females did not report significantly higher math anxiety than middle school females. In general, the young women in the school under study did not appear to experience a negative impact on their mathematics-related affect during the course of the school year.

The hypotheses regarding mathematics self-concept were similar to those for the previous two variables described above. In general, it was anticipated that changes over time would show a negative trend for females but not for males, and comparisons between sexes were expected to favor males. Once again, these hypotheses were not supported in most cases.

Contrary to the expected outcome, females of both age levels reported no significant decrease in their mathematics self-concept from September, 1991 to April, 1992. However, males in the middle school reported levels of mathematics self-concept which were not expected. Their mathematics self-concept scores decreased significantly from the fall to the spring. For males in the upper school, however, there was no significant change over time, as was predicted.

The next hypotheses to be tested involved comparing the mathematics self-concept levels of males and females at each grade level at the time of the post-test. For middle school students, there was no statistically significant difference between the group means of males and females.
Thus, the expected disadvantage for females at that age was not observed. For upper school students, however, males’ post-test scores were significantly higher than females’, thereby confirming the expected gender gap in mathematics self-concept at that grade level. Yet, this difference was not due to a decrease in females’ scores during the school year. Females began the year with significantly lower mathematics self-concept scores than males, and the size of the gender gap between scores remained approximately the same at the time of the post-test. Moreover, the lower scores for females do not indicate necessarily that these students reported exceptionally low mathematics self-concepts. The group of female students in grades 9 through 11 who participated in the norming of the questionnaire used in this study, the Student Description Questionnaire (Marsh, 1990), obtained mean scores between 3.3 and 3.7 in their mathematics self-concept ratings, with higher mean scores at each grade level. The group mean scores of the young women in grades 9 through 11 in the present study were at or above those of the norm group in the fall (3.75) and in the spring (3.70).

The mathematics self-concept scores of females from each grade level at the time of the post-test were compared in order to test the hypotheses pertaining to developmental differences. Although the group mean for upper school females was lower than that of middle school females in
April, 1992, the difference was not statistically significant. Therefore, the hypothesized outcome did not occur.

The final hypothesis to be tested in the present study concerned mathematics enrollment. It was expected that significantly more males than females who were in grades 9, 10 and 11 at the end of the 1991-92 school year would enroll in the next most difficult mathematics course available for the 1992-93 school year. In other words, more males than females were expected to choose a highly challenging mathematics course for the next school year. This did not happen. No significant sex differences were found in the difficulty of mathematics courses chosen for the 1992-93 school year. Nearly all of the males and females at all three grade levels enrolled in challenging math courses for the next school year. Given the generally positive self-reports by all groups of students regarding mathematics, this is not surprising.

Thus we see that almost all of the hypothesized gender differences favoring males, and the negative changes which were expected to develop from fall to spring for females, did not occur. Moreover, some of the male students demonstrated unfavorable changes over time which were unanticipated. Middle school males' self-reports regarding mathematics anxiety were more negative in the spring than in the fall. Males at that grade level also reported
significantly lower mathematics self-concepts at the time of the post-test than they did on the pre-test. The only area in which females demonstrated a more negative mathematics-related attitude than males was the mathematics self-concept of upper school females at the time of the post-test. However, it is unlikely that this gender difference is the result of the experiences these young women encountered during the school year, since their group mean score was nearly the same in the spring as it was in the fall.

A number of factors may have inclined the students in this study to demonstrate mathematics-related attitudes, affect and behavior which are unlike those found in the majority of previous studies of these topics. First of all, the school in which the study was conducted is not an ordinary teaching institution. It has a seventy-five year history of excellence and is considered one of the finest academic institutions in the midwest region. Each year, nearly all of the graduating students go on to college. All of the students in the class of 1991 were accepted into colleges, according to an upper school guidance counselor (G. Williams, personal communication, July 9, 1992). In addition, the exceptionally high average score of 689 obtained on the mathematics portion of the Scholastic Aptitude Test (SAT-M) by members of the most recent graduating class provides persuasive evidence that
mathematics instructors are highly skilled at teaching and motivating their students. There is no reason to expect that the apparent skill and dedication of those teachers were reduced by the introduction of female students into the school.

Members of the administration of the school in this study demonstrated their commitment to making a successful transition from a single-sex to a coeducational school by the steps they took to prepare the teachers for the change in the student population. A Transition Coordinator was hired to design and implement a training program to educate teachers about sex equity issues in classroom processes, the importance of giving female students as much attention and encouragement as males experience, and other strategies aimed at ensuring that the new students received the high quality of education as males. According to the American Association of University Women (1992), teacher training can reduce significantly the gender gap in the nature of the treatment male and female students receive in mathematics classrooms. Therefore, it is quite possible that teachers devoted the same quantity and quality of attention to females as they did to males in this school. Anecdotal support for this notion was provided at the end of the 1991-92 school year by a mathematics teacher who informed this writer that he had encouraged two upper school female students to enroll in more challenging
mathematics courses for the 1992-93 school year than they had initially registered to take (J. Wuorinen, personal communication, July 10, 1992). Positive teacher attitudes and behavior toward female students in mathematics may have accounted for the significant increase in the perceived usefulness of mathematics from fall to spring which was found among upper school female students in this study.

Another factor which may account for the surprisingly positive adjustment among female students with respect to the mathematics-related variables examined in the present inquiry is the nature of the young women themselves. As described in Chapter III, these females had to meet the school's stringent standards in order to be admitted. The majority of them came from a private all-girls school and were accustomed to succeeding academically in a competitive environment. Therefore, they may have possessed such high academic ability and motivation that they were not daunted by the change of schools or by being outnumbered by males in their classes.

In an interview with this writer, the director of admissions stated that he viewed the female students as a rather "adventurous" group, due to the fact that they were more active in sports and other school activities than had been anticipated (L. Schultz, personal communication, July 1, 1992). Thus, it is possible that the females who were inclined to be members of the first coeducational
class in the school’s history possessed more confidence, independence or other characteristics which caused them to respond to that experience in non-traditional ways, at least with respect to their mathematics-related attitudes, affect and enrollment.

It is also conceivable that the family backgrounds of these young women contributed to their positive adjustment in this school. As noted in Chapter III, over 90% of the students have parents who meet the criteria for Hollingshead’s (1958) highest socioeconomic level (professional and managerial). Therefore, their children have role models who are achievement-oriented and successful. In addition, it is possible that by sending their daughters to an independent school which is known for academic excellence, these parents demonstrated that they placed great importance on education and that they wanted and expected their children to excel academically. Previous studies have documented repeatedly that parental encouragement is highly correlated with positive attitudes and participation in mathematics for high school students, particularly females (e.g., Eccles & Jacobs, 1986; Armstrong & Price, 1982). Furthermore, it is reasonable to expect that parents who place a high degree of importance on education and are willing to have their daughters participate in the inaugural coeducational class in this institution would be highly involved with the school. They
may have monitored closely their children’s progress in order to ensure that their adjustment to this new environment was successful. Thus, parental influence would be maximized.

Overall, then, it appears likely that the unexpectedly positive adjustment by females to the transition to a coeducational environment is at least partly accounted for by the exceptional characteristics of the students, their parents and the school personnel who participated in the present study. It is less apparent why the male students at the middle school level demonstrated less positive attitudes and anxiety toward mathematics toward the end of the school year than at the beginning. All of the beneficial conditions which may have helped female students adjust favorably were available also to males.

One possible explanation for the negative self-reports of middle school males pertains to their stage of psychosocial development (Erikson, 1963). The middle school students in this study were in the 5th and 6th grades and approximately 10 to 13 years of age. According to Erikson’s classification of developmental stages, they are in the "Industry verses Inferiority" stage. During this period, children normally are busy comparing themselves to their peers and defining themselves according to what they can do or produce. Youths at this stage can be extremely sensitive to their own imperfections and may
feel inferior if they are in any way less capable than their peers. It is possible that the boys at that grade level expected to outperform the girls in their math classes, either because they believed that they were more competent than females in general or because they viewed males as more able in mathematics in particular. When the group of high-ability females joined their school, these boys may have had their illusions of superiority shaken. This could lead them to develop doubts about their own mathematics aptitude and experience considerable anxiety toward the subject. This is in line with declines in academic self-concept during the middle school years which have been reported in previous studies (e.g., Soares & Soares, 1977; Marsh, 1989).

The lack of a negative reaction among upper school males, who also encountered mathematically bright females in their classes, may be related also to their developmental level. Students in grades 9 through 11 are at Erikson's "Identity verses Role Diffusion" stage. Individuals at this phase of adolescence often focus more on themselves and less on the opinions of others than in the previous stage of development. They are likely to be more established along the path toward their future goals than are middle school-aged children, and may be less
inclined to have their confidence diminished or experience major disruptions in their view of how they will fit into the world (Erikson, 1963).

The difference in the self-reports of the male students at the two grade levels studied may be the result of a number of other factors as well, including differential experiences with teachers or peers, or dissimilar personal or background characteristics. These variables were not explored in this study.

Although this was an exploratory study, this research may offer a useful contribution to the literature pertaining to women in mathematics. The findings reported here support the view that, given certain conditions, females may be integrated successfully into an educational setting which was previously attended only by males with generally high scholastic aptitude. Very few young women have the high level of academic aptitude and the type of family background that these subjects possessed. Therefore, conclusions based on the present study should be generalized only to a select portion of the general population. Nonetheless, it is clear that highly able females from predominantly upper-level socioeconomic families can be involved in very challenging mathematics coursework and still maintain positive mathematics-related attitudes, affect and enrollment. It is possible to sustain and even increase females' motivation and
willingness to participate in mathematics in a coeducational setting, and thereby allow them to maximize their career options in technological fields. These findings add weight to the growing body of evidence supporting the conclusion that gender differences in mathematics affect and attitudes are small and declining, and that they are not inevitable. Under certain circumstances, some of which appear to be under societal control, young women can continue to view mathematics as important and remain motivated to develop their mastery of this subject.

Limitations of the Study

Perhaps the most significant limitation of the present study is the lack of a control or comparison group. This made it impossible to rule out the potential influence of other factors which may have contributed to the results which were obtained, such as a testing effect or the influence of other personal or environmental characteristics. Although the use of repeated measures in this study allowed each subject to serve as his or her own control, thus reducing overall variance and internal threats to validity, external threats remained and thus placed severe restrictions on the generalizability of the findings reported in this study.
The size and sex composition of the sample of subjects in the study posed another limitation. Although the overall group size appeared substantial (approximately 300), the ratio of males to females was unequal. This confounded the interpretation of the results, because one cannot be certain the same outcome would be observed if females were not a clear minority. In addition, the actual number of females for whom useable data was available was rather small, particularly in the middle school, where the scores of only 19 females could be used. These factors combined to increase the risk of error.

The instruments utilized in the study had certain characteristics which placed limitations of the usefulness of the findings. The questionnaire used to assess mathematics anxiety had only five items which required either a "yes" or "no" answer and yielded a range of only five points per student. This limited the amount of variability which could occur between and within subjects over time. An instrument with more items and more response choices such as is available through a Lickert-type scale, might have increased the instruments' sensitivity to subtle but real differences between and within subjects. Also with respect to measurement, the use of instruments with more information regarding the psychometric properties of the measure (e.g., validity and reliability descriptions, plus normative data) may have made it
possible to have greater understanding regarding the practical meaning of the results which were obtained. Few instruments are available for assessing mathematics-related affect and attitude which have been studied extensively regarding their psychometric qualities, however.

The addition of procedures designed to gather qualitative data would have facilitated greater understanding of the factors which may have influenced the results of the present study. Such information may have been particularly useful in the interpretation of unexpected findings, such as why boys in the middle school developed more negative feelings about mathematics during the year and how the females perceived their interaction with teachers.

**Directions for Future Research**

Additional research is needed to answer a number of remaining questions related to this study. First of all, it is unclear whether or not this pattern of results will continue in the years ahead. It is possible that the first female students in the history of this school were different than their successors will be. Perhaps they were more adventurous or otherwise different in their nature or motivation than most female students, even those who are high achievers from high socioeconomic families. Also, the teachers and other personnel in the school may have been
more motivated to make this a successful experience for the new students than they will be when the novelty of having young women there subsides. A study which measures mathematics-related variables such as these over a time span of several years is needed to sort out the impact of these factors.

Future research should examine also the relative effect of other variables in bringing about outcomes such as those described here. For example, follow-up studies comparing these findings with those obtained from other groups should explore the influence of factors such as family background, students’ ability level, and sex ratios of students in the classrooms. The relationship between the sex of the teacher and student outcomes needs additional study also.
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APPENDIX A

Perceived Usefulness of Mathematics Scale

Presented below are the instructions and items students received in order to assess their perception of the usefulness of mathematics.

DIRECTIONS: Tell how much you agree or disagree with each of the following statements by darkening the space on your answer sheet. Use the following key.

A B C D E
Strongly Slightly Neither agree Slightly Strongly
disagree disagree nor disagree agree agree

1. I'll need mathematics for my future work.
2. I study mathematics because I know how useful it is.
3. Knowing mathematics will help me earn a living.
4. Mathematics is a worthwhile and necessary subject.
5. I'll need a firm mastery of mathematics for my future work.
6. I will use mathematics in many ways as an adult.
7. Mathematics is of no relevance to my life.
8. Mathematics will not be important to me in my life's work.
9. I see mathematics as a subject I will rarely use in my daily life as an adult.
10. Taking mathematics is a waste of time.
11. In terms of my adult life it is not important for me to do well in mathematics in high school.

12. I expect to have little use for mathematics when I get out of school.
APPENDIX B

Emotional Arousal Scale

Presented below are the instructions and items students received in order to assess their mathematics anxiety.

DIRECTIONS: Indicate whether you agree or disagree with the statements below by using the following key.

\[ a = \text{no} \quad b = \text{yes} \]

1. I really hate math.
2. I am always anxious about math.
3. I often feel blue when I think of math.
4. I often have stomach aches in math class.
5. I often have dreams of failing in math class.)
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