1996

Effects of mathematics and science student performance in a single-sex learning environment

Teri Jean Wilson
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Effects of mathematics and science student performance
in a single-sex learning environment

by

Teri Jean Wilson

A Dissertation Submitted to the
Graduate Faculty in Partial fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Department: Professional Studies in Education
Major: Education (Educational Administration)

Approved:
Signature was redacted for privacy.

In Charge of Major Work
Signature was redacted for privacy.

For the Major/Department
Signature was redacted for privacy.

For the Graduates College

Iowa State University
Ames, Iowa
1996
TABLE OF CONTENTS

CHAPTER I. INTRODUCTION 1
   Overall Trends in Mathematics and Science Achievement and Participation 2
   Evidence of Gender Differences in Mathematics and Science Achievement and Participation 3
   Gender Equity and Implications for Single-sex Schooling 5
   Statement of the Problem 9
   Hypotheses 11
   Delimitations of the Study 12
   Definition of Terms 14

CHAPTER II. REVIEW OF LITERATURE 16
   Explanation Efforts for Gender Performance Differences 16
   Differences in Mathematical Ability and Problem Solving 20
   Self-concept, Causal Attributions, and Achievement 23
   Sex Differences in Test Performance 27
   Spatial Skills and Mathematical Ability 31
   Single-sex Schooling 34
   Summary 37

CHAPTER III. METHODOLOGY 53
   The Design 54
   The Sample 55
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumentation</td>
<td>56</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>60</td>
</tr>
<tr>
<td>Human Subjects Release</td>
<td>62</td>
</tr>
<tr>
<td>CHAPTER IV. FINDINGS</td>
<td>63</td>
</tr>
<tr>
<td>Analysis of Academic Performance and Academic Achievement in a Single-sex Mathematics and Science Class</td>
<td>64</td>
</tr>
<tr>
<td>Analysis of Academic Growth in a Single-sex Mathematics and Science Class: Pre/Posttest Treatment Comparisons</td>
<td>68</td>
</tr>
<tr>
<td>Analysis of Academic Growth in a Single-sex Mathematics and Science Class: Statistically Controlling for Previous Academic Achievement</td>
<td>73</td>
</tr>
<tr>
<td>Examination of Attribution Variables Which May Influence the Learning of Mathematics and Science</td>
<td>79</td>
</tr>
<tr>
<td>CHAPTER V. SUMMARY, CONCLUSIONS, LIMITATIONS, DISCUSSION, AND RECOMMENDATIONS</td>
<td>88</td>
</tr>
<tr>
<td>Summary</td>
<td>88</td>
</tr>
<tr>
<td>Conclusions</td>
<td>91</td>
</tr>
<tr>
<td>Limitations</td>
<td>94</td>
</tr>
<tr>
<td>Discussion</td>
<td>95</td>
</tr>
<tr>
<td>Recommendations for Practice</td>
<td>98</td>
</tr>
<tr>
<td>Recommendations for Further Research</td>
<td>101</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>103</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>112</td>
</tr>
<tr>
<td>APPENDIX A. CUSHMAN SCHOOL INTRODUCTION LETTER</td>
<td>114</td>
</tr>
<tr>
<td>APPENDIX B. RESPONSE LETTER TO CUSHMAN SCHOOL</td>
<td>116</td>
</tr>
<tr>
<td>Appendix</td>
<td>Title</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>C.</td>
<td>Cushman School Parent Letter</td>
</tr>
<tr>
<td>D.</td>
<td>Cushman School Authorization Letter</td>
</tr>
<tr>
<td>E.</td>
<td>Cushman School Parental Permission Letter</td>
</tr>
<tr>
<td>F.</td>
<td>Human Subjects Release Form</td>
</tr>
<tr>
<td>G.</td>
<td>Strands for Mathematics Program (Monroe County, Florida)</td>
</tr>
<tr>
<td>H.</td>
<td>Strands for Science Program (Monroe County, Florida)</td>
</tr>
<tr>
<td>I.</td>
<td>Student Response Inventory</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A synthesis of the research literature for differences in mathematical ability and problem solving</td>
<td>39</td>
</tr>
<tr>
<td>2.</td>
<td>A synthesis of the research literature for self-concept, causal attributions, and achievement</td>
<td>41</td>
</tr>
<tr>
<td>3.</td>
<td>A synthesis of the research literature for sex differences in test performance</td>
<td>47</td>
</tr>
<tr>
<td>4.</td>
<td>A synthesis of the research literature for spatial skills and mathematical ability</td>
<td>49</td>
</tr>
<tr>
<td>5.</td>
<td>A synthesis of the research literature for single-sex schooling</td>
<td>51</td>
</tr>
<tr>
<td>6.</td>
<td>Analysis of academic performance on year-end mathematics and science report card grades (GPA) by gender</td>
<td>65</td>
</tr>
<tr>
<td>7.</td>
<td>Analysis of academic achievement on mathematics and science standardized achievement tests (SAT) using grade level equivalent scores by gender</td>
<td>66</td>
</tr>
<tr>
<td>8.</td>
<td>Analysis of academic growth on mathematics and science criterion-referenced examinations by girls</td>
<td>69</td>
</tr>
<tr>
<td>9.</td>
<td>Analysis of academic growth on mathematics and science criterion-referenced examinations by boys</td>
<td>70</td>
</tr>
<tr>
<td>10.</td>
<td>Analysis of academic growth on criterion-referenced mathematics and science examinations by gender</td>
<td>72</td>
</tr>
<tr>
<td>11.</td>
<td>Analysis of covariance of mathematics achievement on mathematics performance (GPA) by gender</td>
<td>74</td>
</tr>
<tr>
<td>12.</td>
<td>Analysis of covariance of science achievement on science performance (GPA) by gender</td>
<td>75</td>
</tr>
<tr>
<td>13.</td>
<td>Adjusted means for mathematics and science achievement (SAT) on mathematics and science performance (GPA) by gender</td>
<td>76</td>
</tr>
</tbody>
</table>
Table 14. Analysis of covariance of mathematics achievement on mathematics gain scores by gender  

Table 15. Analysis of covariance of science achievement on science gain scores by gender  

Table 16. Frequencies of student opinion data for Attribution Variable I: Knowledge, use, value of mathematics and science for future work  

Table 17. Frequencies of student opinion data for Attribution Variable II: Parental attitude toward pursuit of mathematics and science  

Table 18. Frequencies of student opinion data for Attribution Variable III: Academic self-concept and interest  

Table 19. Frequencies of student opinion data for Attribution Variable IV: Teacher expectation of student’s gender  

Table 20. Frequencies of student opinion data for Attribution Variable V: Teacher’s gender influences learning
CHAPTER I. INTRODUCTION

America is facing a significant challenge in mathematics and science education as evidenced by the following:

• Declines in American student performance relative to international peers.

• Inadequate preparation and lack of current scientific knowledge among many American teachers.

• Insufficient numbers of students pursuing education and training to fill critical scientific, mathematical, and technical jobs.

• Underrepresentation of women, minorities, and persons with disabilities in mathematics and science courses and related careers.

• Low levels of scientific literacy among the American public (U.S. Department of Health and Human Services, 1991, p. 1).

Many of the state education policy reforms in the 1980s were aimed at improving the quality of mathematics and science education in elementary and secondary schools. States have raised standards for teacher certification, increased course requirements for graduation, revised state curriculum frameworks, and established new and innovative statewide student assessments (CCSSO, 1995). The National Education Goals of the President and Governors, set in 1989, state that mathematics and science achievement of American high school graduates will be first in the world by the year 2000 (National Education Goals Panel, 1994).

Educators at local, state, and national levels are working to implement national professional standards for mathematics education. The new national standards for science education will further advance science education reform (National Council of Teachers of
Mathematics, 1989; National Goals Panel, 1994; National Research Council, 1994; National Science Foundation, 1994). Efforts to reform and restructure mathematics and science education need to be based on sound assessment practices of the current conditions, the rate of improvement, and problems in the system (CCSSO, 1995). Furthermore, educators and policymakers need reliable measures of the quality of mathematics and science education to enhance present programs and recommend new initiatives.

Overall Trends in Mathematics and Science
Achievement and Participation

In general, the trends in mathematics and science show noteworthy improvements during the past decade since the 1983 publication of A Nation at Risk.

National assessment of educational progress

At all three ages, science performance declined significantly in the 1970s, but improved significantly during the 1980s. Compared to 1969–70, average achievement in 1992 was higher at age 9, essentially the same at age 13, and lower at age 17. Average mathematics proficiency improved between 1973 and 1992 at ages 9 and 13. The data at age 17 parallel the science trends, with declines in performance between 1973 and 1982 followed by recovery. In mathematics, at age 17, however, performance in 1992 had returned to the initial 1973 level (U.S. Department of Education, 1992).

Elementary level participation

Elementary class time spent on mathematics in grades 4–6 varies by state from over four to five hours per week (CCSSO, 1995). Projected to a school year, the states with highest class
time provide 36 hours, or seven weeks, more mathematics instruction than states with low average time.

In science, average class time in grades 4–6 varies by state from 2.3 hours to four hours per week (CCSSO, 1995). Projected to a school year, students in states with the highest science class time provide 45 hours, or 11 weeks, more science instruction for students than in states with the lowest class times.

Enrollment in higher-level courses

As of 1994, 60 percent of high school students reach the third year of high school mathematics by graduation, as indicated by student enrollments in algebra 2 or integrated mathematics 3 (CCSSO, 1995). State enrollments differ significantly—from 1990 to 1994, eight states’ enrollment in algebra 2/integrated mathematics 3 increased 10 or more percentage points, and nationally the percentage went up 11 points.

Fifty-one percent of high school students now progress to a third year of high school science by graduation, as indicated by enrollments in chemistry as of 1994 (CCSSO, 1995). Six states increased their chemistry enrollments by 10 percentage points from 1990 to 1994, and nationally the percentage taking chemistry went up six points.

Evidence of Gender Differences in Mathematics and Science

Since the publication in 1974 of Maccoby and Jacklin’s volume on gender differences, considerable attention has been accorded gender differences in performance. The past 15 years have seen an explosion of research on the relationship between gender and mathematics
(AAUW, 1995). While there has been less study in the linkage of gender and science, there is still sufficient information to draw preliminary conclusions.

Despite a narrowing of the "gender gap" in mathematics performance, girls are not doing as well as boys in science. The 1992 NAEP Mathematics Assessment showed no gender differences in scores of students at ages 9 or 13, and slightly higher scores for males at age 17 (U.S. Department of Education, 1993). But the NAEP Science Assessment showed that females continue to score lower than males at ages 9, 13, and 17 (U.S. Department of Education, 1992). The difference in NAEP science scores between 17-year-old males and females (grade twelve) is 10 scale points, or the equivalent of about one year of high school (CCSSO, 1995).

Gender trends in enrollment data show increased female enrollments in higher level mathematics and science courses (CCSSO, 1995). In 1994, 17 states (of only 19 reporting data by gender) had more females than males taking algebra 2/integrated mathematics 3, and 9 of the 19 states had more females than males taking trigonometry or precalculus; 16 (of 19) states had more females taking chemistry than males.

Regardless of data reflecting only minimal differences in courses taken between males and females, there are still significant discrepancies in the scores of males and females in mathematics and science assessments at the secondary level for college bound populations (Mid-Atlantic Equity Consortium, 1993). For example:

- In 1992, males outperformed females by 44 points in the mathematics portion of the Scholastic Aptitude Test (SAT) and by 9 points on the verbal section (U.S. Department of Education, 1992). This performance pattern has been consistent over the last 20 years (Educational Testing Service, 1992).
• On College Board Achievement tests, males consistently average higher scores in all mathematics and science related subject areas (Educational Testing Service, 1992).

• On the 1991 Advanced Placement Examinations, the mean scores of males exceeded those of females in calculus, biology, chemistry, physics, and computer science (Educational Testing Service, 1992).

Whether these differences in test scores reflect the number of classes taken, actual achievement in mathematics and science, bias in the tests themselves, or additional factors is not clear. Whatever the reason, by the end of high school, girls express more negative attitudes toward both mathematics and science than do boys (Dossey, Mullis, Lindquist, & Chambers, 1988).

Regardless of the contributing factors, the fact is that decisions are made on the basis of these test scores that may negatively impact female students. The impact goes beyond college acceptances and scholarships—repercussions may include barriers to career choice and possibly to opportunities to succeed in the work place.

Gender Equity and Implications for Single-sex Schooling

“Attaining gender equity in and through education means achieving equitable outcomes for females and males in all that is of value to individuals and society” (Klein & Ortman, 1994, p. 13). Klein and Ortman (1994) adapted their definition of gender equity from the sex equity process and outcome goals identified in the American Educational Research Association (AERA)-sponsored Handbook for Achieving Sex Equity Through Education (Klein, Russo, Campbell, & Harvey, 1985). The four basic sex equity goals discussed in the handbook represent a prescriptive dimension of the conceptual framework for achieving educational
equity. The goals address factors such as learner attributes and outcomes, external influences, and educational access and treatment. The following outline reveals that the goals are not entirely definitive or mutually exclusive:

**Sex Equity Goals**

1. **Process goals: eliminate sex discrimination by**
   - Providing the same access and treatment to female and male learners
     —within the same context
     —possibly in a separate (sex-segregated) but equal context

2. **Outcome goals: the elimination of sex discrimination when**
   - Both females and males acquire the most valued characteristics and skills, whether or not they are generally attributed to the opposite sex or to their own sex
   - Both sexes achieve at least minimum levels of competency in the desired outcomes
   - Members of the less dominant sex achieve parity with members of the dominant sex group
   - The range of desirable outcomes is extended beyond those formerly restricted on the basis of sex
   - There is a trend toward less sex differentiation in achievements

3. **Process goals: decrease sex stereotyping and sex segregation in education by**
   - Decreasing sex-role expectations and behavior that limit the opportunities of members of either sex to maximize their individual talents
   - Increasing knowledge and use of sex equitable (sex fair and sex affirmative) processes by examining and counteracting sex stereotyping in society
4. Outcome goals: the reduction of sex stereotyping and sex segregation in education and society when

- Fewer jobs, roles, activities, and expectations are differentiated by sex
- There is decreased use of sex stereotypes in decision making by and about individuals
- Sex segregation in education and society caused by sex stereotyping is reduced.

(Klein, Russo, Campbell, & Harvey, 1985, pp. 7-8)

Klein (Klein, Russo, Campbell, & Harvey, 1985) acknowledges that the goals are multifaceted and likely to differ according to the particular learner(s) and educational context. If these gender equity experts were certain that sex integrated environments were best for reaching the same goals for females and males in all circumstances, there would have been no need to select separate but equal process goals. However, since such causal evidence to support mixed-sex classes in all of the curriculum areas is not consistent, it appears that special kinds of sex-differential treatment in the short term may be needed to reach longer-term goals.

Single-sex schooling

Many years ago, the single-sex public schools were common, especially in big cities. But in recent decades, such schools have almost disappeared. Today, only one percent of American students attend single-sex schools, and all but a handful of those youngsters are in Catholic or independent schools (Ravitch, 1995).

Researchers are beginning to consistently document the positive effects of single-sex schooling. However, considering single-sex strategies as the preferred option for improving schooling for girls have evoked fierce advocates as well as critics (Leder & Forgasz, 1994). In
recent studies containing a large randomly selected sample of high school students, females and minorities in single-sex schools outperformed their mixed-sex counterparts on academic achievement and affective measures after initial ability and home background were statistically controlled (Lee & Bryk, 1986; Riordan, 1990). Ravitch (1995) reports that students in these schools are more likely to enroll in courses that are popular with the other sex, and girls in girls' schools are far more likely to perform well in mathematics and science.

Despite these findings that demonstrate the potential benefits of single-sex schooling, returning to this form of education would have enormous implications. Students, parents, educators, and government officials would likely have questions and concerns about the impact of such a decision without more consistent empirical evidence. For example, researchers do not know why students in single-sex schools outperform students in mixed-sex schools. The critical attributes of the single-sex environment that contribute to the positive achievement and attitude outcomes have yet to be investigated (Gierl, 1994). In light of the need for additional empirical evidence to support single-sex classes, the undertaking of this study is to examine the benefits of single-sex instruction and its relationship to gender achievement in mathematics and science.

As controversial as it may be, gender separate instruction in mathematics and science is receiving a significant amount of national attention and debate. Single-sex instructional strategies deserve consideration as a vehicle to address specific needs or remedy existing inequities. Researchers point out that the issue is not whether single-sex education is preferable to coeducation, but how learning variables in different settings influence achievement (AAUW, 1995).
Statement of the Problem

The high school years are a critical filter that can block or foster advanced study in the sciences and mathematics. Although college women who end up in these fields are better prepared by their high school courses than women who go into other fields, they are less prepared than the males who go into mathematics and science (Frazier-Kouassi, 1992). One of the continuing and serious problems is that although female students are enrolling in more higher-level science and mathematics courses, they still demonstrate a lower level of proficiency in both areas on assessment measures at the secondary level for college bound populations (Frazier-Kouassi, 1992; Mid-Atlantic Equity Consortium, 1993).

Although women compose half of the college population, they represent only 16 percent of the quarter million scientists and engineers in the United States (Wollman, 1990). The underrepresentation of women and minorities in science, mathematics, and engineering has implications for education policy formation at all levels. Unless programs are developed to attract and retain more females and minorities into science, mathematics, and engineering (an estimated 35 percent will have to come from these groups), the nation will not be able to meet its technical personnel needs into the next century (U.S. Department of Health and Human Sciences, 1991).

This underrepresentation of young women in science, mathematics, and engineering has been addressed by researchers who propose 1) increasing student awareness of career opportunities; 2) providing more hands-on experiences for developing skills; and 3) building enthusiasm in pre-adolescence for mathematics and science inquiry before negative attitudes towards these fields appear (AAUW, 1995). After ninth grade, the number of students considering careers in technical fields remains relatively fixed (Dunham, 1990). Hence, the
need to continue investigating intervention strategies during early adolescence, designed to increase the participation and achievement of girls in mathematics and science, is a schooling practice which warrants further study.

This study will be undertaken in response to a specific request from an elementary, coeducational independent day school. The school has requested assistance with statistical analysis to measure the effects of fifth grade student mathematics and science performance in a single-sex learning environment. Sensitized by the heightened national consciousness of gender differences in mathematics and science achievement and its relationship to self-concept, the school more specifically requested valid means of assessing student performance, as well as measuring various affective factors which appear to influence student learning in mathematics and science.

This study will examine student performance data from standardized achievement tests in mathematics and science, year-end school report card grades in mathematics and science, and criterion-referenced mathematics and science examinations. The study will also examine data measuring students’ opinions of perceptual indicators, grouped by five attribution variables, which may influence their learning in mathematics and science.

In order to address the school’s request and guide its research endeavors to reflect critical attributes discussed in the literature, this investigator suggests the study be guided by the following research questions:

1. Will girls and boys demonstrate similar academic performance when assigned to a single-sex mathematics and science class, as measured by year-end report grades?
2. Will girls and boys demonstrate similar academic achievement when assigned to a single-sex mathematics and science class, as measured by standardized achievement tests?

3. Will girls and boys demonstrate similar academic growth when assigned to a single-sex mathematics and science class, as measured by criterion-referenced examinations (aligned with the respective state’s grade level curriculum)?

4. If statistically controlling for gender differences in previous academic achievement, will girls and boys demonstrate similar academic performance when assigned to a single-sex mathematics and science class as measured by year-end report grades?

5. If statistically controlling for gender difference in previous academic achievement, will girls and boys demonstrate similar academic growth when assigned to a single-sex mathematics and science class as measured by criterion-referenced examinations (aligned with the respective state’s grade level curriculum)?

6. Will girls and boys have similar perceptual opinions regarding five categories of achievement-related beliefs (attribution variables), which may influence the learning of mathematics and science, after one year of instruction in a single-sex mathematics and science class?

Hypotheses

This study will compare gender difference among fifth grade students in relationship to academic performance, achievement, and perceptual influences in the learning of mathematics and science. The study is more specifically defined by the following hypotheses:
1. There will be no significant difference in academic performance between girls and boys assigned to a single-sex mathematics and science class, as measured by year-end report card grades.

2. There will be no significant difference in academic achievement between girls and boys assigned to a single-sex mathematics and science class, as measured by standardized achievement tests.

3. There will be no significant difference in academic growth between girls and boys when assigned to a single-sex mathematics and science class, as measured by criterion-referenced examinations (aligned with the respective state’s grade level curriculum).

4. There will be no significant difference in academic performance between girls and boys, statistically controlling for gender differences in previous academic achievement, when assigned to a single-sex mathematics and science class measured by year-end report card grades.

5. There will be no significant difference in academic growth between girls and boys, statistically controlling for gender differences in previous achievement, when assigned to a single-sex mathematics and science class measured by criterion-referenced examinations (aligned with the state’s grade level curriculum).

Delimitations of the Study
The delimitations of the study will be as follows:

1. This investigation will be delimited to Cushman School (an elementary, independent coeducational day school in Miami, Florida) during the 1994–95 school year.
2. This investigation will be delimited to the collection of data for only fifth grade mathematics and science.

3. This investigation will be delimited to the use of the following data sets to measure student performance:
   a. Fifth Grade Mathematics Examination (Monroe County Public School District, Monroe County, Florida: Examination Content Aligned with Florida’s Public Schools, Grade Five Mathematics Curriculum);
   b. Fifth Grade Science Examination (Monroe County Public School District, Monroe County, Florida: Examination Content Aligned with Florida’s Public Schools, Grade Five Science Curriculum);
   c. Stanford Achievement Tests (Eighth Edition, Grade Five: Total Mathematics Battery, Science Battery);
   d. Cushman School Report Card (Year-end Mathematics Grade);
   e. Cushman School Report Card (Year-end Science Grade).

4. This investigation will accept the findings of previous research conducted by the School Improvement Model (SIM, 1994) as to the content validity and reliability of the Monroe County Fifth Grade Mathematics and Science Examinations.

5. This investigation will be delimited to the use of one Student Response Inventory.

6. This investigation will be delimited to the collection of student opinion data for examining only the following five attribution variables:
   a. Knowledge, use, and value of mathematics and science for future work;
   b. Parental attitude toward pursuit of mathematics and science;
   c. Academic self-concept and interest in mathematics and science;
d. Teacher expectation of gender performance in mathematics and science;

e. Relationship of teacher gender to student performance in mathematics and science.

Definition of Terms

Key definitions for conceptual clarity of the study will be as follows:

**Attribution Variable:** Important characteristics and/or perceptions in beliefs children hold which may influence subsequent academic efforts and performance.

**Educational Equity:** A learning process which results in proportional educational outcomes for all socioeconomic groups attending school.

**Equity:** A fair share of the advantages of society.

**Gender Bias:** Conditions in content, procedures, or interpretation of assessment information that favors one gender over the other.

**Gender Equity:** The state or quality of being fair, just, and equally appropriate for all students.

**Mixed-sex Classes:** Instructional setting comprised of students of both genders.

**Outcome Goal:** A goal which represents the elimination of sex discrimination.

**Perceptual Indicator:** Insight, intuition, or knowledge gained by perceiving conditions and situations.

**Process Goal:** A goal to bring about the elimination of sex discrimination.

**Self-esteem:** The overall evaluation an individual makes of self and customarily maintains with regard to self; it is expressed through an attitude of approval or disapproval and indicates the degree to which the individual believes the self to be capable, significant, successful, and worthy.
SIM: The acronym for Iowa State University College of Education School Improvement Model. The model was developed by a team of researchers headed by Richard Manatt and Shirley Stow working under the auspices of the Research Institute for Studies in Education (RISE).

Single-sex Classes: Instructional setting comprised of like-gender students.

Student Response Inventory: Inventory which collects information to assess student perceptions relating to his or her academic performance.
CHAPTER II. REVIEW OF LITERATURE

Mathematics is the key to opportunity. No longer just the language of science, mathematics now contributes in direct and fundamental ways to business, finance, health, and defense. For students, it opens doors to careers. For citizens, it enables informed decisions. For nations, it provides knowledge to compete in a technological community. To participate fully in the world of the future, America must tap the power of mathematics. (MSEB, 1993, p. 15)

Explanation Efforts for Gender Performance Differences

Overall sex differences in achievement and attainment appear to be diminishing, but there is considerable controversy concerning the degree to which differences in specific domains such as mathematics may be due to biological differences as contrasted with socialization and sex-role stereotyping.

Biological factors

Sex differences in mathematical ability have been attributed to genetic differences, differences in brain organization, and hormonal factors (Meece, 1982; McGlone, 1980). Other popular biological explanations include the hypothesis that innate spatial visualization abilities—abilities more pronounced in men—mediate mathematical achievement. Several studies have demonstrated a strong correlation between mathematical achievement test scores and spatial skills (Meece, 1982; Fennema & Sherman, 1977, 1978; Sherman, 1980). Other studies, however, show an equally strong correlation between math performance and verbal
skills—traditionally an area of strength for women (Fennema & Sherman, 1977, 1978; Sherman, 1980). Taken together, the literature supporting the theory of biological determinants is, at best, inconclusive.

Socialization factors

The research on socialization factors is more compelling. Socializers (parents, teachers, and counselors in particular) have been shown to contribute to math attitudes in a number of ways: 1) as role models, 2) by setting different expectations for males and females, and 3) by providing and encouraging different activities for male and female children. A range of persuasive studies exists in this area. Research by Ernest (1976), for example, supports theories concerning role model influence. Fathers, he reports, help their children more often than mothers with math homework after the sixth grade. Other studies (Meece & Parsons, 1982) have reported a disproportionate number of male math teachers in advanced math courses. Past research on teacher attitudes has also tended to show negative bias against females. Surveys of elementary and high school teachers have shown that a substantial percentage expected boys to excel in math. No teachers studied expected girls to outperform boy students (Ernest, 1976). Abel (1983) has reported that parents are more likely to offer rewards to male rather than female children for excelling in math.

Achievement–self-image relationship

Research on the achievement–self-image relationship among children and adolescents has suggested that the relationship develops differently for boys and girls over time. Among children the achievement/self-image relationship is generally positive for both boys and girls
with some evidence of a stronger relationship among girls (Roberts, 1987). However, during early adolescence the achievement–self-image relationship is strong and positive for boys, but not girls. Moreover, for girls there is evidence of a negative relationship between self-image and mathematics achievement (Roberts, 1987).

Findings in the much acclaimed report, How Schools Shortchange Girls (AAUW, 1992), document evidence of declining self-esteem in adolescent girls. The report highlights the following:

- As girls grow older, their self-esteem decreases considerably—much more so than boys’—with the severest drop taking place between elementary and middle school years.

- Adolescent girls are more likely to let low self-esteem impair their ambitions than are adolescent boys. Girls are more likely to perceive that they’re neither “smart enough” nor “good enough” to attain their career aspirations.

- Academic confidence strongly influences girls’ self-esteem—more so than peer acceptance does. Yet only 12 percent of high school girls report that they are proud of their schoolwork.

- Perceived math and science ability strongly relates to all adolescents’ self-esteem, but only 15 percent of high school girls say they’re “good at math.” Moreover, girls interpret their poor math abilities as personal failures, while boys blame inability on the subject itself.

- Low self-esteem, meager career aspirations, and poor math and science ability are related. Adolescent girls who enjoy math have confidence in their academic ability and, correspondingly, have higher self-esteem and career aspirations.
According to the study (AAUW, 1992), family and school rather than peers have the greatest impact on the self-esteem and aspirations of young people.

This study will investigate the effects of mathematics and science student performance in a single-sex learning environment. This review of literature will 1) discuss the literature relating to gender differences in mathematical ability and its relationship to problem solving and mathematical reasoning; 2) review the research describing children's achievement related beliefs (academic self-concept and causal attributions) and the influence these beliefs can have on children's subsequent efforts and performance; 3) discuss the literature describing how males and females approach learning differently, resulting in males outperforming females on standardized tests; 4) review the research on gender differences on mathematics performance and the cognitively based explanation supporting a lack of development of spatial ability in females; 5) summarize the research comparing the effects of single-sex and mixed-sex schooling practices and their relationship to student achievement.

Research efforts for this study utilized sources such as Dissertation Abstracts, Educational Resources Information System (ERIC), Review of Research in Education, and Scholar. A vast number of research studies, reference books, organization reports, commissioned projects, and U.S. government publications were critically analyzed for applicability of research to the present study.

The review process pointed to the fact that there is an overwhelming amount of literature related to gender differences in mathematical achievement and numerous controversial findings to support the many theoretical explanations. Several limitations of the search procedure should be noted:

1. No systematic studies of sources outside of the United States were included;
2. Most of the studies were from published sources, which tended to report only those articles or findings with significant results;
3. The majority of the studies reflect sample population of students from elementary school age through seniors in high school;
4. Other contributions to the existing body of literature may have been excluded from the present study due to time constraints.

Differences in Mathematical Ability and Problem Solving

There is considerable interest within the education community concerning gender-related differences in mathematical ability. Although the topic has been highly researched, attempts to determine the nature of gender-related differences in mathematical ability have obtained mixed results (Zambo & Follman, 1993). However, several tendencies are apparent.

In a review, Aiken (1971) found that females tended to be superior in computational, algorithmic activities while males were somewhat superior in arithmetic reasoning and application and that the gender-related difference in arithmetic reasoning tended to increase with age. Fennema (1974) concluded that gender-related differences tended to favor females on lower level mathematical skills and males on higher level mathematical skills including problem solving, and that the proportion of researchers reporting significant differences increased with the age and grade level of the students. Maccoby and Jacklin (1974) found that in studies involving elementary students, males exhibited some superiority in arithmetic reasoning, and that in studies with high school students, males were more consistently superior to females in arithmetic reasoning.
In a meta-analysis, Linn and Hyde (1989) found that gender-related differences in mathematics ability were narrowing over time, a conclusion also reached by the National Assessment of Educational Progress (U.S. Department of Education, 1994), and that no gender-related differences in overall mathematical ability existed when all levels of skills were considered simultaneously. Again, however, females were found to be superior at computational skills at all age levels and males were found to be superior in problem solving ability at the high school level.

Hyde, Fennema, and Lamon (1990) and Hyde and Fennema (1990) reported that females were superior to males in computational skills in both elementary and middle schools. There were no gender differences in the understanding of concepts at any age level. Males surpassed females at the high school level in problem solving. No differences in problem solving were found at either the elementary school or the middle school levels.

In summary, the literature reviews and meta-analyses indicate that females tend to excel at algorithmic tasks such as computation at all levels and that males tend to excel at application and problem solving. Male superiority in problem solving first appears in the upper elementary grades and increases with grade level.

Individual studies concerned specifically with word problem solving offer similar conclusions. Marshall (1984) compared the scores of 286,767 sixth graders on computational items and also on story problem items from the California Assessment Program's Survey of Basic Skills. The females tended to score higher than the males on computation items, while the males tended to score higher than the females on word problem items. Armstrong (1981) reported results of the Women in Mathematics Project, a national survey conducted by the Education Commission of the States in 1978. Based on items from standardized tests, females
aged 13 (approximately eighth grade) scored significantly higher than males on both computational skills and also on spatial abilities. Males significantly outperformed females in solving one- and two-step routine story problems.

Moore and Smith (1987) analyzed data for gender-related differences collected in the National Longitudinal Study of Youth Labor Force Behavior. The data were obtained from both the Mathematics Knowledge and the Arithmetic Reasoning subtests of the Armed Services Vocational Aptitude Battery. No significant differences were found on scores on Mathematics Knowledge, but an ANOVA did indicate significant main effects for gender in ninth grade and beyond for scores on the Arithmetic Reasoning Subtest. The Arithmetic Reasoning Subtest was comprised of multiple choice arithmetic word problems. The authors concluded that the ability to solve arithmetic word problems increased with age for both sexes, and also that the magnitude of the gender-related difference in word problem solving ability increased with educational level.

Male superiority in word problem solving is not only apparent in general mathematical tasks, but also in algebraic tasks. Phillips, Uprichard, and Blair (1983) measured the ability of 320 high school students to solve algebraic word problems. On a measure of eight types of algebraic word problems commonly found in algebra textbooks, the males overall averaged 5.16 points, of a possible 72, higher than the females.

Swafford (1980) also tested high school algebra students using consumer word problems. These consumer problems were described as word problems dealing with buying, selling, interest rates, and other topics concerning the uses of money. Boys did better than girls at the beginning of the course in algebra and boys improved even more than girls by the end of the course in algebra. These results are consistent with the research, which indicates that gender-
related differences exist in word problem solving ability and that these differences increase in magnitude over time.

The research studies consistently indicated significant gender-related differences in mathematical word problem solving ability beginning at the upper elementary level and continuing into high school. This gender-related difference in verbal problem solving ability in favor of males first appears in the sixth grade (Marshall, 1984). The superiority of males in word problem solving ability seems to persist through the middle grades (Armstrong, 1981) and into high school and college (Moore & Smith, 1987).

Self-concept, Causal Attributions, and Achievement

Understanding children's achievement-related beliefs (academic self-concept and causal attributions) is important because of the influence these beliefs can have on children's subsequent efforts and performance (Dweck & Elliot, 1983; Felson, 1984). These beliefs vary as a joint function of sex, achievement level, and academic area (Light, Stadler, & Swenson, 1989).

Researchers have reported sex differences in achievement-related beliefs. For example, girls often enter intellectual achievement situations with lower expectations of success than do boys; and girls' lower expectations are unrealistic in light of children's actual performances (Crandall, 1969; Dweck, Goetz, & Strauss, 1980; Parsons & Ruble, 1977). Sex differences also are found in children's causal attributions. Girls are more likely than boys to attribute their failures to insufficient ability (Dweck et al., 1980; Frey & Ruble, 1987; Nicholls, 1979; Phillips, 1984) and are less likely than boys to attribute their successes to high ability (Nicholls, 1980; Wollet, Pedro, Backer, & Fennema, 1980). Meece, Parsons, Kaczala, Goff, and
Futterman (1982) also found sex differences on some self-concept of ability measures, with girls reporting lower self-concepts.

Although sex differences in achievement-related beliefs are reported frequently, they do not emerge in all intellectual achievement situations. Girls' lower confidence emerges primarily when there is uncertainty of success, for example, when tasks are unfamiliar or difficult, and when past performance feedback has been infrequent or ambiguous (Crandall, 1969; Fennema & Meyer, 1989; Parsons, Meece, Adler, & Kaczala, 1982; Miller, 1986). In general, girls express as much confidence as boys when tasks are familiar and when they have received clear feedback about their previous performances.

Consistent with this analysis, Dweck and Licht (1980) have suggested that girls will show less confidence than boys primarily in those academic areas where success seems most uncertain. Dweck and Licht (1980) argued that, by adolescence, success should be more uncertain in math than in verbal areas. For example, junior high and high school math is likely to introduce many new mathematical concepts and require solving simultaneous equations that are difficult to relate to existing knowledge. These new concepts should increase children's uncertainty of success. In contrast, the verbal lessons presented to students of this age are more likely to be gradual extensions of existing knowledge, such as using more difficult vocabulary involves applying the same rules that were used previously.

The implication of this analysis is that by adolescence, girls should show less confidence than boys in their math abilities, but not in their verbal abilities. Other theories also exist that lead to the same prediction: for example, society views math as a "male domain." This pattern of sex differences has been found by Daly, Bell, and Korinek (1987); Marsh, Smith, and Barnes (1985); Ryckman and Peckman (1987); and Stipek (1984).
Although sex differences in math confidence have been reported among children as young as fifth and sixth graders (Marsh, Smith, & Barnes, 1985), these sex differences do not emerge reliably until seventh grade or later (Meece et al., 1982; Stevenson & Newman, 1986). The plausibility exists that the conditions likely to lower girls’ confidence (difficult tasks and infrequent feedback) do not emerge reliably in math classes until after seventh grade. From junior high on, girls express more negative attitudes toward math and rate their math ability lower than do boys even though objective indices suggest they are performing at comparable levels; furthermore, girls rate math as less important and less interesting than do boys (Eccles, Adler, & Meece, 1984; Fennema, 1974; Fennema & Sherman, 1977; Hilton & Berglund, 1974). Females are also less likely than males to elect optimal advanced level math courses in both high school and colleges (Eccles et al., 1984; Ernest, 1976; Fennema & Sherman, 1977). A wide variety of hypotheses has been generated and tested to explain these sex differences in math-related attitudes and behaviors (Yee & Eccles, 1988).

Several studies suggest that parents may contribute to these sex differences. For example, junior high school students rate their parents as the most influential people in their course enrollment decisions (Eccles, Adler, Futterman, Goff, Kaczala, Meece, & Midgley, 1983); these students also rank parents second only to the usefulness of math in influencing their decision to take more math (Armstrong, 1980). Further, children’s self-concept of ability and their confidence in math are more directly related to their parents’ beliefs about their math aptitude and potential than to their past achievement in math (Eccles-Parsons, Adler, & Kaczala, 1982). Finally, parents, to a much greater extent than teachers, hold sex-differentiated beliefs about their sons’ and daughters’ math achievement (Eccles-Parsons et al., 1982); in particular, while the parents in the Eccles-Parsons et al. (1982) study did not rate their
daughters' math ability significantly lower than that of their sons, they did think that math was more difficult for their daughters, that their daughters had to work harder in order to do well in math, and that enrollment in advanced level math courses was less important for daughters than for sons. These sex-differentiated perceptions existed even though boys and girls in this study had performed similarly on standardized math achievement tests and math grades. To the extent that parents convey the expectations inherent in these beliefs to their children, parents may help socialize the sex differences in students' attitudes toward mathematics (Yee & Eccles, 1988).

The literature supports the importance of examining children's achievement-related beliefs in different academic areas, as opposed to measuring only their generalized achievement-related beliefs. This study will examine the gender difference in student opinion data relating to five categories of attribution variables which may influence their learning in mathematics and science. The five categories are 1) knowledge, use, and value of mathematics and science for future work; 2) parental attitude toward the pursuit of mathematics and science; 3) academic self-concept and interest in mathematics and science; 4) teacher expectation of gender performance in mathematics and science; and 5) relationship of teacher gender to student performance in mathematics and science.

Attribution theorists (Eccles et al., 1983; Frieze, Fisher, Hanusa, McHugh, & Valle, 1978; Weiner, Nirenberg, & Goldstein, 1976; Weiner, Frieze, Kukla, Reed, Rest, & Rosenbaum, 1971) argue that people's causal expectations for success and failure affect their self-concept of ability, future expectancies, and subsequent achievement behaviors. In particular, these theorists suggest that attributing success to stable factors such as ability should facilitate the acquisition of a positive self-concept to a greater extent than attributing success to
unstable factors such as effort or luck. Conversely, attributing failure to stable, controllable factors such as insufficient effort should support a positive self-concept to a greater extent than attributing failure to stable, uncontrollable factors such as lack of ability. If parents make different attributions for their sons’ and daughters’ performance in math, then the inferential process suggested by attribution theory could account for these sex-differentiated parental beliefs. In particular, if parents are more likely to attribute their sons’ success in math to ability and to attribute their daughters’ success in math to effort, then they should conclude that math is easier for their sons than for their daughters even though their performances are equivalent.

Sex Differences in Test Performance

There is much controversy over why males outperform females on standardized tests, with some believing that the reason lies in the fact that males and females approach learning differently and therefore analyze and solve problems differently (Mid Atlantic Equity Consortium, 1993). Particular tests may be designed in a manner more conclusive to one gender. The context of the questions is important, with both girls and boys doing better on questions with content familiar to them, and if more items favor boys they have the advantage. References to males on standardized test items consistently outnumber those to females (AAUW, 1992). Finally, girls complete fewer items and are more likely than boys to check an “I don’t know” option and fail to complete the test (Becker, 1990).

Because of their potential impact on decisions about admission, placement, and scholarship awards, sex differences in admission tests are particularly vexing to those concerned with educational equity. And because of its prominence and visibility as an admission criterion,
the SAT has received the lion’s share of critical attention where sex differences and trends in these have been concerned (Wilder & Powell, 1989). The American College Testing (ACT) Program Examination is also taken each year by large numbers of high school students seeking admission to college (Wilder & Powell, 1989). While girls are more apt than boys to go to college and to get higher grades in both high school and college, scholarships based on test scores, such as the SAT, are twice as likely to go to boys (Rosser, 1989). Some would like to conclude that the gender difference in performance on these “gate keeper” tests are the results of sex bias and should not be tolerated in the educational community (AAUW, 1992).

The SAT is described as “a measure of developed abilities” and produces separate scores for verbal (SAT verbal) and mathematical (SAT mathematical) subsections and the Test of Standard Written English (TSWE). In the SAT population, the average mathematical score difference has been about half of a standard deviation in favor of males for most of the years since the SAT was introduced (Wilder & Powell, 1989). By way of contrast, and consistent with the findings of Maccoby and Jacklin (1974), women’s average SAT verbal scores tended to be slightly higher than men’s until the late 1960s. At that point a downward trend in women’s scores began. By 1980 women’s average verbal score was 12 points below men’s, a difference of about .11 standard deviation.

Four subsections make up the ACT: English usage, mathematics usage, social studies reading, and natural science reading. The last two subsections combine items that measure reading comprehension and items based solely on prior knowledge of subject matter (Burton, 1987). Dauber (1987) examined gender differences in performance on the various subsections of these two tests among students who took the tests in 1984–85 and 1985–86, and computed the significance of the effects they document to assess the magnitude of the observed
differences. The largest effect sizes were found for the SAT mathematical scores (.41 standard deviation), ACT natural science reading (.40), ACT mathematics usage (.34), and ACT social studies reading (.23), all favoring males. Cohen (1977) labels these effect sizes small, although Dauber underscores the practical significance of the differences by calling attention to the fact that, for example, the ratio of males to females who scored at the 90th percentile for SAT mathematical sections was 2.6:1.

A great deal of attention has been devoted to understanding these differences. Part of the explanation relates to the fact that the SAT-taking population is a self-selected group and that the backgrounds of the females, who chose to take the SAT are, on average, different from the backgrounds of the men taking the test (Wilder & Powell, 1989). Perhaps the most obvious difference is sheer numbers; there are now considerably more women than men taking the SAT. In addition, the women taking the test are less likely than men to have completed as many advanced college preparatory courses, particularly in mathematics and science. There are also differences in other background characteristics, such as the fact that women are much more likely to come from families where neither parent attended college (Wilder & Powell, 1989).

Critics of the SAT have asserted that the tests themselves contribute to gender differences in performance. At least one study prior to the current flurry of activity in the area of test and item bias found that females performed less well on items with "male" content and better on items with "female" content (Donlon, Ekstrom, & Lockheed, 1979). A recent study by a group concerned with fairness in testing (Loewen, Rosser, & Katzman, 1988) examined the performance of 1,112 students in a coaching class on one mock form of the SAT. They identified 17 items—7 verbal, 10 math—that favored one sex or the other and concluded from
simply examining the items that male-oriented vocabulary in both the verbal and math items may have adversely affected female performance.

The relative emphasis placed on different skill areas within a content area determines if a test will help minimize or maximize sex differences. While much of the work in this area has been related to mathematics, the conclusions may impact other areas. In mathematics, girls outperform the boys in computation, while boys outperform girls in some problem solving (Hyde, Fennema, & Lamon, 1990). Even when girls and boys were matched on overall skill areas, girls performed significantly better on mathematics test items that required arithmetic algebra than they did on items requiring arithmetic geometry. Girls' performance was also higher in areas of logic (Harns & Carlton, 1990) for the 1987 SAT. Where boys outperformed girls on almost all items, the differences were smaller in arithmetic and algebra questions than in geometry questions (Rosser, 1989).

In general, if a mathematics test emphasizes computation, logic, and combined arithmetic and algebra skills, girls will do better. If the test emphasizes word problems and combined arithmetic and geometry skills, boys will do better. All of these areas are integral parts of mathematical knowledge, but the emphasis test developers place on one area or another can increase or decrease gender differences.

The impact of affective factors is mixed. While girls report being more anxious about tests than do boys, girls' increased anxiety does not correlate with poorer test performance (Harris & Carlton, 1990). Attitudes toward math do not appear to have an impact on the SAT math gender gap. Sex differences in SAT math scores were found even among students who chose math as their favorite subject or who chose science first and math second (Chipman, 1988).
Perhaps most important, SAT scores, which are designed to predict college success as defined by first-year grades, underpredict women's grades and overpredict men's. Young women tend to receive higher college grades than young men with the same SAT scores (Rosser, 1989).

The issues relating to the question of sex bias in the design, construction, and administration of standardized tests are complex. Perfectly good tests can be designed in subjects on which girls will tend to score higher. Other equally good tests can be developed on which boys will tend to score higher, and still other tests can be developed on which there will be no sex differences (AAUW, 1992).

Spatial Skills and Mathematical Ability

Research on gender differences in mathematics has often focused on a cognitively based explanation for them proposed by Sherman in 1967. Sherman conjectured that lack of development of spatial ability in women caused commensurate lacks in other cognitive areas, including mathematical ability (Friedman, 1995). Sherman suggested that social socialization might be the problem, that the encouragement of females towards verbal activities and away from spatial and mechanical ones might be at fault. Other researchers believe it possible that innate genetic structure produces greater spatial skill in males (Sherman, 1967).

The role of spatial skill in mathematical prowess has become a key issue for researchers of gender differences in mathematics. While gender differences in mathematics are small and apparently decreasing over time, they still exist, particularly on some college entrance examinations (Friedman, 1989; Hyde, Fennema, & Lamon, 1990). Gender differences in
spatial skills have long been documented, though they also are, apparently, decreasing (Hilton, 1985; Linn & Petersen, 1985).

The relationship of mathematical and spatial reasoning had intrigued researchers before Sherman. In the 1960s many psychometricians believed that one mode of thought underlies both mathematical and spatial reasoning; some proposed that spatial ability, or even a more fundamental trait producing it, enables those who possess it to reason differently and more effectively, in all disciplines (Smith, 1964; Witkin, Dyk, Faterson, Goodenough, & Karp, 1962). Today, some researchers are supportive of these same views (Battista, 1994). However, not all. Gardner's (1983) portrayal of mathematical logical intelligence as the ability to create long chains of reasoning about mathematical objects provides a sharp contrast to the characterization of mathematics as essential.

Researchers at the Wisconsin Research and Development Center for Cognitive Learning have produced a significant amount of mathematical gender difference research (Friedman, 1995). Much of the research, some of it done by Fennema and Sherman, has considered possible effects of spatial ability on mathematical achievement (Fennema & Sherman, 1977). They did not find overall evidence for a relationship. Fennema and Tartre (1985) pursued Sherman's (1967) conjecture by comparing students who were high in spatial ability and low in verbal with those who were low in spatial ability and high in verbal. Junior high school males who were high in verbal but low in spatial abilities solved more mathematical problems than those in other categories. In a study of high school students, Tartre (1984) found that both high and low spatial males excelled on problem solving tasks, but females with low spatial skills were significantly less capable than the other groups. Tartre (1990) has concluded that higher
Spatial ability itself is defined and studied in a variety of ways. In their meta-analysis of spatial differences reported after Maccoby and Jacklin's (1974) review, Linn and Peterson (1986) identified four different perspectives that distinguish research on spatial ability: the differential, concerned with performance differences among different populations; the psychometric, concerned with identifying the "structure" of the spatial domain; the cognitive, concerned with identifying the processes used to solve spatial tasks; and the strategic, concerned with identifying strategies used by test-takers attempting to solve spatial tasks.

Linn and Peterson (1986) divided the spatial domain into three broad categories which they labeled "spatial perception," "mental rotation," and "spatial visualization" (Linn & Peterson, 1986, p. 70). Spatial perception tasks require the individuals to locate true horizontal or vertical in the presence of distracting information. Mental rotation requires the ability to rotate a two- or three-dimensional figure in the individual's mind. And spatial visualization refers to tasks that require analytic processing of spatially presented information, for example, locating embedded figures, block design, and paper folding.

In a review of the statistical procedures used by Linn and Peterson (1986), Wilder & Powell (1989) summarized the procedures and findings of their investigation. Wilder reported that Linn and Peterson computed and tested over 150 effect sizes and, finding a lack of homogeneity, they partitioned the effect sizes into not only the three categories previously described, but also into three age groups (under 12, 12 to 17, and 18 or older) within each category. For tasks involving spatial perception, they found differences favoring males among individuals as young as 7 or 8. These differences increased with age. Likewise, gender
difference on mental rotation tasks were found throughout the life span, although because of
difficulties involved in testing younger individuals for mental rotation, the domain has not been
measured with children younger than 10. Gender differences favoring males in spatial
visualization were found to be so small as to be considered neither significant nor meaningful,
and consistently so across three age groups.

Speculation about the role of spatial skill in cognitive processes has generated attempts to
train spatial skills (Battista, Wheatley, & Talsma, 1982; Connor, Schackman & Serbin, 1978).
Early attempts indicated that females gained more from the training than males; however, such
results were not replicated (Connor & Serbin, 1985). Furthermore, those who have trained
spatial skills with success and then gone on to measure the effect of that training on
mathematical achievement have not found significant results (Baldwin, 1985; Tillotson, 1985).

Single-sex Schooling

Research comparing the effects of single- and mixed-sex schooling at the secondary level
began to emerge in the late 1960s (Lee & Bryk, 1986). The early studies were designed to
identify social and psychological variables that distinguished single- and mixed-sex schools.
Researchers found that mixed-sex schools tended to have friendlier and more relaxed social
climates (Dale, 1969, 1971; Feather, 1974; Jones, Shallcross, & Dennis, 1972) and were
described by some as affiliative and pleasure-oriented (Schneider & Coutts, 1982). Conversely,
single-sex schools, particularly those for females, were considered to emphasize control and
discipline (Jones et al., 1972; Trickett, Castro, Trickett, & Schaffner, 1982). The research was
equivocal as to whether single-sex schools were more academically oriented than coeducational
schools (Dale & Miller, 1972; Feather, 1974; Jones et al., 1972; Trickett et al., 1982).
Psychological variables were also reported to be different in single- and mixed-sex schools. For example, Trickett et al. (1982) found that girls in single-sex high schools showed a significantly higher level of interest in the feminist movement than girls in coeducational schools. Lockheed (1976) reported that adolescent females participated in more activities when in a single-sex context.

In the late 1980s, a second wave of research comparing single- and mixed-sex schools at the secondary level emerged. Researchers were sensitive to the limitations of the early studies in this area and adopted a more rigorous approach in two respects (Gierl, 1994). First, confounding variables, such as initial ability and home background, were statistically controlled using such techniques as covariance adjustment (Anderson, Auquier, Hauch, Oakes, Vandaele, & Weisberg, 1980). Second, researchers began to focus on how achievement and attitudinal variables were related to academic performance. This study will also examine gender differences in mathematics and science performance, using covariance adjustments, to control for previous mathematics and science achievement. By focusing on a broader range of outcome measures, researchers were able to investigate a variety of variables believed to differ across the two environments (Gierl, 1994).

Two studies that exemplify this more rigorous contemporary approach were conducted by Lee and Bryk (1986) and Riordan (1990). Both studies are based on a sample of students obtained from High School and Beyond (HSB), a national survey of American high school students. According to Riordan (1990), the HSB data set contains the highest quality survey data available because respondents were randomly selected from a representative sample of single- and mixed-sex American high schools. Students were tested in grade 10 and again in
grade 12 on a variety of measures, some of which could be used to statistically control for the effects of confounding variables.

Lee and Bryk (1986) compared students in single- and mixed-sex schools using student background, curriculum track, and school social composition as the adjustment variables. Compared with females in mixed-sex schools, females in single-sex schools were more interested in math and English, associated with more academically oriented friends, spent more time on homework, and enrolled in more mathematics classes. On gain scores comparing test results from grades 10 to 12, females in single-sex classes had higher scores on reading and science tests, higher educational aspirations, and lower sex-role stereotyping than their same sex coeducational peers. Gain scores for all achievement measures favored the single-sex context, indicating a trend in the data existed, although no comparisons were statistically significant.

For the males, students in the single-sex schools had a more positive attitude toward socially active peers and student athletes, did more homework, and enrolled in more mathematics and physical sciences classes than mixed-sex males. On gain score measures comparing test results from grades 10 to 12, males in the single- and mixed-sex classes did not perform significantly different on the achievement or attitude measures. Gain scores for one achievement test (writing) favored the mixed-sex content, although it was not statistically significant. Lee and Bryk (1986) concluded: “In our view, the observational evidence that we assembled provides strong support for concluding that there are positive effects associated with attendance at girls’ schools. The picture is more ambiguous with regard to the effects of the boys’ school” (p. 392).

The findings reported by Lee and Bryk (1986) and Riordan (1990) indicate that single-sex schooling tends to benefit students, especially females. However, little is known about what
critical attributes of the single-sex context contribute to the positive achievement and attitude outcomes consistently observed.

Summary

Gender differences in mathematics achievement are small and continue to decline. Gender differences in mathematics do exist but are related to the age of the sample, how academically selective it is, and which cognitive level the test is tapping. However, females more than males have been found to doubt their confidence in mathematics. Researchers have found a strong correlation between mathematics achievement and confidence. Studies indicate this drop in mathematics confidence and achievement for females appears in their middle school years.

Males and females may be affected differently by their success (or lack of success) as that success is reflected in mathematics performance. Lesser performance on measures of mathematical skill, whatever its origin, may cause females to lower their aspirations, take courses in areas other than the quantitative ones, and/or conclude that certain domains are the province of males. The most visible form of the concern is the attention given to relative shortages of women in mathematics, science, and engineering. One product of this concern is a search for intervention strategies that can break into the cycle to increase the choices for females.

Among the intervention strategies designed to increase the participation and achievement of girls in mathematics, is the establishment of single-sex classes. As the previously cited studies suggest, interest in the gender separate intervention approach is growing; however, substantial evidence to justify the approach must keep pace with its efforts to measure
implementation effectiveness. Whether concerning academic achievement, achievement
gains, educational aspirations, sex role stereotyping, or attitudes and behaviors related to
academics, results are indicating that single-sex schools deliver specific advantages to their
students, especially female students. The overarching importance to advance research for
measuring student mathematics and science performance in single-sex environments, is the
underlying aspect that mathematics and science concepts permeate a variety of academic fields.
(Tables 1–5 summarize the research literature reviewed for this study.)
Table 1. A synthesis of the research literature for differences in mathematical ability and problem solving

<table>
<thead>
<tr>
<th>Research study</th>
<th>Finding</th>
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<tbody>
<tr>
<td>Zambo &amp; Follman (1993)</td>
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<tr>
<td>Linn &amp; Hyde (1989)</td>
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<td>U.S. Department of Education (1994)</td>
<td>No gender-related differences in overall mathematical ability existed when all levels of skills were considered simultaneously.</td>
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<td>Females were superior to males in computational skills in both elementary and middle school.</td>
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</tr>
<tr>
<td>Marshall (1984)</td>
<td>Sixth grade females scored higher than males on computation items, while males scored higher than females on word problem items.</td>
</tr>
<tr>
<td>Armstrong (1981)</td>
<td>Eighth grade females scored higher than males on both computational skills and spatial abilities. Males outperformed females in solving one- and two-step routine story problems.</td>
</tr>
<tr>
<td>Moore &amp; Smith (1987)</td>
<td>Ability to solve arithmetic word problems increased with age for both sexes, and the magnitude of the gender-related difference in word problem-solving ability increased with educational level.</td>
</tr>
<tr>
<td>Phillips, Uprichard, &amp; Blair (1983)</td>
<td>Males tended to average higher than females, overall, on a measure of eight types of algebraic word problems commonly found in high school algebra textbooks.</td>
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<tr>
<td>Research study</td>
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</tr>
<tr>
<td>Armstrong (1981)</td>
<td>The superiority of males in word problem-solving ability seemed to persist through the middle grades.</td>
</tr>
<tr>
<td>Moore &amp; Smith (1987)</td>
<td>The superiority of males in word problem-solving ability seemed to persist through the middle grades and into high school and college.</td>
</tr>
</tbody>
</table>
Table 2. A synthesis of the research literature for self-concept, causal attributions, and achievement

<table>
<thead>
<tr>
<th>Research study</th>
<th>Finding</th>
<th>Attribution variable examined in Student Response Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dweck &amp; Elliot (1983)</td>
<td>Understanding children's achievement related beliefs (academic self-concept and causal attributions) is important because of the influences these beliefs can have on children's subsequent effort and performance.</td>
<td></td>
</tr>
<tr>
<td>Felson (1984)</td>
<td>Understanding children's achievement related beliefs (academic self-concept and causal attributions) is important because of the influences these beliefs can have on children's subsequent effort and performance.</td>
<td></td>
</tr>
<tr>
<td>Licht, Stader, &amp; Swenson (1989)</td>
<td>These beliefs vary as a joint function of sex, achievement level, and academic area.</td>
<td>X</td>
</tr>
<tr>
<td>Crandall (1969)</td>
<td>Females often enter intellectual achievement situations with lower expectations of success than males; and females' lower expectations are unrealistic in light of children's actual performances.</td>
<td></td>
</tr>
<tr>
<td>Dweck et al. (1980)</td>
<td>Females often enter intellectual achievement situations with lower expectations of success than males; and females' lower expectations are unrealistic in light of children's actual performances.</td>
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<tr>
<td>Parsons &amp; Ruble (1977)</td>
<td>Females often enter intellectual achievement situations with lower expectations of success than males; and females' lower expectations are unrealistic in light of children's actual performances.</td>
<td></td>
</tr>
<tr>
<td>Dweck et al. (1980)</td>
<td>Females are more likely than males to attribute their failures to insufficient ability.</td>
<td></td>
</tr>
<tr>
<td>Frey &amp; Ruble (1987)</td>
<td>Females are more likely than males to attribute their failures to insufficient ability.</td>
<td></td>
</tr>
<tr>
<td>Nicholls (1979)</td>
<td>Females are more likely than males to attribute their failures to insufficient ability.</td>
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</tr>
<tr>
<td>Phillips (1984)</td>
<td>Females are more likely than males to attribute their failures to insufficient ability.</td>
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<td>Research study</td>
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<td>--------------------------------</td>
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</tr>
<tr>
<td>Nicholls (1980)</td>
<td>Females are less likely than males to attribute their successes to high ability.</td>
<td></td>
</tr>
<tr>
<td>Wolleet al. (1980)</td>
<td>Females are less likely than males to attribute their successes to high ability.</td>
<td></td>
</tr>
<tr>
<td>Meece et al. (1982)</td>
<td>Gender differences exist on some self-concept of ability measures, with females reporting lower self-concepts.</td>
<td>X</td>
</tr>
<tr>
<td>Crandall (1969)</td>
<td>Females' lower confidence emerges primarily when there is uncertainty of success, when tasks are unfamiliar or difficult, and when past performance feedback has been infrequent or ambiguous. Females express as much confidence as boys when tasks are familiar and when they receive clear feedback about their previous performance.</td>
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</tr>
<tr>
<td>Fennema &amp; Meyer (1989)</td>
<td>Females' lower confidence emerges primarily when there is uncertainty of success, when tasks are unfamiliar or difficult, and when past performance feedback has been infrequent or ambiguous. Females express as much confidence as boys when tasks are familiar and when they receive clear feedback about their previous performance.</td>
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<td>Miller (1986)</td>
<td>Females' lower confidence emerges primarily when there is uncertainty of success, when tasks are unfamiliar or difficult, and when past performance feedback has been infrequent or ambiguous. Females express as much confidence as boys when tasks are familiar and when they receive clear feedback about their previous performance.</td>
<td></td>
</tr>
<tr>
<td>Dweck &amp; Licht (1980)</td>
<td>Junior high mathematics is likely to introduce many new mathematical concepts. These concepts should increase children's uncertainty of success. Verbal lessons at this age are more likely to be gradual extensions of existing knowledge. Females should show less confidence than</td>
<td></td>
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<th>Research study</th>
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<tr>
<td>Daly, Bell, &amp; Korinek (1987)</td>
<td>A variety of theories exist that lead to patterns of sex differences, predicting females to show less confidence than males in their mathematical abilities.</td>
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</tr>
<tr>
<td>Marsh, Smith, &amp; Barnes (1985)</td>
<td>A variety of theories exist that lead to patterns of sex differences, predicting females to show less confidence than males in their mathematical abilities.</td>
<td>X</td>
</tr>
<tr>
<td>Ryckman &amp; Peckman (1987)</td>
<td>A variety of theories exist that lead to patterns of sex differences, predicting females to show less confidence than males in their mathematical abilities.</td>
<td>X</td>
</tr>
<tr>
<td>Stipek (1984)</td>
<td>A variety of theories exist that lead to patterns of sex differences, predicting females to show less confidence than males in their mathematical abilities.</td>
<td>X</td>
</tr>
<tr>
<td>Marsh, Smith, &amp; Barnes (1985)</td>
<td>Sex differences in mathematical confidence have been reported among children as young as fifth and sixth graders.</td>
<td>X</td>
</tr>
<tr>
<td>Meece et al. (1982)</td>
<td>Sex differences in mathematical confidence do not emerge reliably until seventh grade or later.</td>
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<tr>
<td>Stevenson &amp; Newman (1986)</td>
<td>Sex differences in mathematical confidence do not emerge reliably until seventh grade or later.</td>
<td></td>
</tr>
<tr>
<td>Eccles, Adler, &amp; Meece (1984)</td>
<td>From junior high on, females express more negative attitudes toward mathematics and rate their mathematical ability lower than do males, even though performing at comparable levels. Females rate mathematics as less important and less interesting than do males.</td>
<td>X</td>
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<tr>
<td>Fennema (1974)</td>
<td>From junior high on, females express more negative attitudes toward mathematics and rate their mathematical ability lower than do males, even though performing at comparable levels. Females rate mathematics as less important and less interesting than do males.</td>
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<td>Fennema &amp; Sherman (1977)</td>
<td>From junior high on, females express more negative attitudes toward mathematics and rate their mathematical ability lower than do males, even though performing at comparable levels. Females rate mathematics as less important and less interesting than do males.</td>
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<tr>
<td>Hilton &amp; Berglund (1974)</td>
<td>From junior high on, females express more negative attitudes toward mathematics and rate their mathematical ability lower than do males, even though performing at comparable levels. Females rate mathematics as less important and less interesting than do males.</td>
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<tr>
<td>Eccles et al. (1984)</td>
<td>Females are less likely than males to elect optional advanced level mathematics courses in both high school and college.</td>
<td></td>
</tr>
<tr>
<td>Ernest (1976)</td>
<td>Females are less likely than males to elect optional advanced level mathematics courses in both high school and college.</td>
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<tr>
<td>Fennema &amp; Sherman (1977)</td>
<td>Females are less likely than males to elect optional advanced level mathematics courses in both high school and college.</td>
<td></td>
</tr>
<tr>
<td>Yee &amp; Eccles (1988)</td>
<td>A variety of hypotheses have been generated and tested to explain these sex differences in mathematics-related attitudes and behaviors.</td>
<td></td>
</tr>
<tr>
<td>Eccles, Adler, Futterman, Goff, Kaczala, Meece, &amp; Midgley (1983)</td>
<td>Junior high students rate their parents as the most influential people in their course enrollment decisions.</td>
<td>X</td>
</tr>
<tr>
<td>Armstrong (1980)</td>
<td>Junior high students rank their parents second only to the usefulness of mathematics in influencing their decision to take more mathematics.</td>
<td>X</td>
</tr>
<tr>
<td>Eccles-Parsons et al. (1982)</td>
<td>Children’s self-concept of ability and their confidence in mathematics are more directly related to their parents’ beliefs about their mathematics aptitude and potential than to their past achievement in mathematics.</td>
<td>X</td>
</tr>
</tbody>
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<tr>
<td>Eccles-Parsons et al. (1982)</td>
<td>Parents, more than teachers, hold sex-differentiated beliefs about their sons’ and daughters’ mathematical achievement.</td>
<td>X</td>
</tr>
<tr>
<td>Eccles-Parsons et al. (1982)</td>
<td>Parents indicated mathematics was more difficult for their daughters, that their daughters had to work harder in order to do well in mathematics, and that enrollment in advanced level mathematics courses was less important for daughters than for sons.</td>
<td>X</td>
</tr>
<tr>
<td>Eccles-Parsons et al. (1982)</td>
<td>Sex-differentiated perceptions existed even though males and females had performed similarly on standardized mathematics achievement tests and mathematics grades.</td>
<td>X</td>
</tr>
<tr>
<td>Yee &amp; Eccles (1988)</td>
<td>To the extent that parents convey the expectations inherent in these beliefs to their children, parents may help socialize the sex differences in students’ attitude toward mathematics.</td>
<td>X</td>
</tr>
<tr>
<td>Eccles et al. (1983)</td>
<td>Attributions theorists argue that people’s causal expectations for success and failure affect their self-concept of ability, future expectancies, and subsequent achievement behaviors. Theorists suggest that attributing success to stable factors such as ability should facilitate the acquisition of a positive self-concept to a greater extent than attributing success to unstable factors such as effort or luck.</td>
<td></td>
</tr>
<tr>
<td>Frieze, Fisher, Hanusa, McHugh, &amp; Valle (1978)</td>
<td>Attributions theorists argue that people’s causal expectations for success and failure affect their self-concept of ability, future expectancies, and subsequent achievement behaviors. Theorists suggest that attributing success to stable factors such as ability should facilitate the acquisition of a positive self-concept to a greater extent than attributing success to unstable factors such as effort or luck.</td>
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<tr>
<td>Weiner, Nirenberg, &amp; Goldstein (1976)</td>
<td>Attributions theorists argue that people’s causal expectations for success and failure affect their self-concept of ability, future expectancies, and subsequent achievement behaviors. Theorists suggest that attributing</td>
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<th>Research study</th>
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<tr>
<td>Weiner, Frieze, Kukla, Reed, Rest, &amp; Rosenbaum (1971)</td>
<td>Attributions theorists argue that people's causal expectations for success and failure affect their self-concept of ability, future expectancies, and subsequent achievement behaviors. Theorists suggest that attributing success to stable factors such as ability should facilitate the acquisition of a positive self-concept to a greater extent than attributing success to unstable factors such as effort or luck.</td>
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Table 3. A synthesis of the research literature for sex differences in test performance

<table>
<thead>
<tr>
<th>Research study</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-Atlantic Equity Consortium (1993)</td>
<td>Equity report addressed the increased amount of controversy over why males outperform females on standardized tests. Some believe males and females approach learning differently and therefore analyze and solve problems differently.</td>
</tr>
<tr>
<td>AAUW (1992)</td>
<td>Contextual content of questions is important, with both females and males doing better on questions with familiar content. References to males on standardized test items consistently outnumber those to females.</td>
</tr>
<tr>
<td>Becker (1990)</td>
<td>Females complete fewer items and are more likely than males to check an “I don’t know” option and fail to complete the test.</td>
</tr>
<tr>
<td>Wilder &amp; Powell (1989)</td>
<td>Sex differences in admissions tests, because of their impact on decisions about admission, placement, and scholarship awards are particularly concerning to those investigating issues of educational equity.</td>
</tr>
<tr>
<td>Wilder &amp; Powell (1989)</td>
<td>Because of its prominence and visibility as an admission criterion, the SAT has received critical attention where sex differences and trends in these differences have been concerned.</td>
</tr>
<tr>
<td>Rosser (1989)</td>
<td>Females are more apt to go on to college and get higher grades in both high school and college than males. Scholarships based on test scores are twice as likely to go to males.</td>
</tr>
<tr>
<td>AAUW (1992)</td>
<td>Gender difference in test performance on these “gatekeeper” tests are seen as the result of sex bias.</td>
</tr>
<tr>
<td>Wilder &amp; Powell (1989)</td>
<td>The average SAT mathematics score has been about half of a standard deviation, in favor of males, most of the years since the test was introduced.</td>
</tr>
<tr>
<td>Maccoby &amp; Jacklin (1974)</td>
<td>Females’ average SAT verbal scores tended to be slightly higher than males’ until the late 1960s. By 1980 females’ average verbal score was 12 points below males’, a difference of about .11 standard deviation.</td>
</tr>
<tr>
<td>Dauber (1987)</td>
<td>Gender differences in performance on the various subsections of the ACT and SAT with the greatest magnitude, all favoring males (indicated by effect size): SAT mathematics scores; ACT natural science reading; ACT mathematics usage; and ACT social studies reading.</td>
</tr>
<tr>
<td>Cohen (1977)</td>
<td>Ratio of males to females who scored at the 90th percentile for SAT mathematics sections was 2.6:1.</td>
</tr>
</tbody>
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### Table 3. Continued

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Wilder &amp; Powell (1989)</td>
<td>Understanding the differences in gender performance relates to the fact that the SAT-taking population is a self-selected group and that the backgrounds of the females who choose to take the SAT are on average different from the backgrounds of the males taking the test. Females have completed less advanced college preparatory classes and are much more likely to come from families where neither parent attended college.</td>
</tr>
<tr>
<td>Donlon, Ekstrom, &amp; Lockheed (1979)</td>
<td>Females performed less well on items with “male” content and better on items with “female” content.</td>
</tr>
<tr>
<td>Loewen, Rosser, &amp; Katzman (1988)</td>
<td>Male-oriented vocabulary, in both the verbal and mathematics practice items, may have adversely affected female performance in SAT coaching sessions.</td>
</tr>
<tr>
<td>Hyde, Fennema, &amp; Lamon (1990)</td>
<td>When females and males were matched on overall skill areas, females outperformed males in computation, while males outperformed females on some problem solving. Females performed better on test items that required arithmetic algebra than on items requiring arithmetic geometry.</td>
</tr>
<tr>
<td>Harris &amp; Carlton (1990)</td>
<td>Females performed higher than males in areas of logic.</td>
</tr>
<tr>
<td>Rosser (1989)</td>
<td>Where males outperformed females on almost all items, the differences were smaller in arithmetic and algebra questions than in geometry questions.</td>
</tr>
<tr>
<td>Harris &amp; Carlton (1990)</td>
<td>Females reported being more anxious about tests than did males; females’ increased anxiety did not correlate with poorer test performance.</td>
</tr>
<tr>
<td>Chipman (1988)</td>
<td>Attitudes toward mathematics did not appear to have an impact on the SAT mathematics gender gap. Sex differences in SAT mathematics scores were found even among students who chose math as their favorite subject.</td>
</tr>
<tr>
<td>Rosser (1989)</td>
<td>SAT scores underpredict females’ first-year college grades and overpredict males’. Females tend to receive higher college grades than males with the same SAT scores.</td>
</tr>
<tr>
<td>AAUW (1992)</td>
<td>Issues relating to gender bias in standardized tests are complex. Good tests can be designed in subjects where one gender will tend to score higher than the other. Tests can be developed where there will be no sex differences.</td>
</tr>
</tbody>
</table>
Table 4. A synthesis of the research literature for spatial skills and mathematical ability

<table>
<thead>
<tr>
<th>Research study</th>
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<tbody>
<tr>
<td>Sherman (1967)</td>
<td>Gender differences in mathematics often focus on a cognitively based explanation.</td>
</tr>
<tr>
<td>Sherman (1967)</td>
<td>Lack of development of spatial ability in females resulted in lack of development in other cognitive areas, including mathematical ability.</td>
</tr>
<tr>
<td>Friedman (1995)</td>
<td>Lack of development of spatial ability in females resulted in lack of development in other cognitive areas, including mathematical ability.</td>
</tr>
<tr>
<td>Sherman (1967)</td>
<td>Innate genetic structure produces greater spatial skills in males.</td>
</tr>
<tr>
<td>Friedman (1989)</td>
<td>Gender differences in mathematics performance are small and decreasing over time; however, they still exist on some college entrance examinations.</td>
</tr>
<tr>
<td>Hyde, Fennema, &amp; Lamon (1990)</td>
<td>Gender differences in mathematics performance are small and decreasing over time; however, they still exist on some college entrance examinations.</td>
</tr>
<tr>
<td>Hilton (1985)</td>
<td>Gender differences in spatial skills have long been documented; however, the evidence shows they are decreasing over time.</td>
</tr>
<tr>
<td>Linn &amp; Peterson (1985)</td>
<td>Gender differences in spatial skills have long been documented; however, the evidence shows they are decreasing over time.</td>
</tr>
<tr>
<td>Smith (1964)</td>
<td>Persons who possess a fundamental trait which underlies both mathematical and spatial reasoning, reason differently and more effectively in all disciplines than those not possessing the trait.</td>
</tr>
<tr>
<td>Witkin, Dyk, Faterson, Goodenough, &amp; Karp (1962)</td>
<td>Persons who possess a fundamental trait which underlies both mathematical and spatial reasoning, reason differently and more effectively in all disciplines than those not possessing the trait.</td>
</tr>
<tr>
<td>Battista (1994)</td>
<td>Author cited that some researchers today are supportive of the “fundamental trait” characteristic for mathematical and spatial reasoning.</td>
</tr>
<tr>
<td>Gardner (1983)</td>
<td>Mathematical logical intelligence is the ability to create long chains of reasoning about mathematical objects.</td>
</tr>
<tr>
<td>Fennema &amp; Sherman (1977)</td>
<td>Authors reported no overall evidence of a relationship between spatial ability and its effect on mathematical achievement.</td>
</tr>
</tbody>
</table>
Table 4. Continued

<table>
<thead>
<tr>
<th>Research study</th>
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</tr>
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<tbody>
<tr>
<td>Fennema &amp; Tartre (1985)</td>
<td>Junior high males, high in verbal skills but low in spatial skills, solved more mathematical problems than those in other categories.</td>
</tr>
<tr>
<td>Tartre (1990)</td>
<td>Higher spatial skills do not contribute to greater mathematical achievement for males, but appear to be a factor for females.</td>
</tr>
<tr>
<td>Linn &amp; Peterson (1986)</td>
<td>Authors identified perspectives that distinguish research on spatial ability: the differential (performance differences among different populations); the psychometric (structure of the spatial domain); the cognitive (processes used to solve spatial tasks); and the strategic (strategies used by test-takers attempting to solve spatial tasks).</td>
</tr>
<tr>
<td>Linn &amp; Peterson (1986)</td>
<td>Differences favoring males, as young as 7 or 8, were found in tasks involving spatial perception. Differences increase with age.</td>
</tr>
<tr>
<td>Battista, Wheatley, &amp; Talsma (1982)</td>
<td>The role of spatial skills in the cognitive processes has generated attempts to train for spatial skills.</td>
</tr>
<tr>
<td>Connor, Schackman, &amp; Serbin (1978)</td>
<td>The role of spatial skills in the cognitive processes has generated attempts to train for spatial skills.</td>
</tr>
<tr>
<td>Connor &amp; Serbin (1985)</td>
<td>Females gained more than males from the training of spatial skills.</td>
</tr>
<tr>
<td>Baldwin (1985)</td>
<td>Those that have trained for spatial skills have not found it significantly affects mathematical achievement.</td>
</tr>
<tr>
<td>Tillotson (1985)</td>
<td>Those that have trained for spatial skills have not found it significantly affects mathematical achievement.</td>
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Table 5. A synthesis of the research literature for single-sex schooling

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<tr>
<td>Dale (1969, 1971)</td>
<td>Mixed-sex schools tended to have friendlier, more relaxed social climates.</td>
</tr>
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<td>Feather (1974)</td>
<td>Mixed-sex schools tended to have friendlier, more relaxed social climates.</td>
</tr>
<tr>
<td>Jones, Shallcross, &amp; Dennis (1972)</td>
<td>Mixed-sex schools tended to have friendlier, more relaxed social climates.</td>
</tr>
<tr>
<td>Schneider &amp; Coutts (1982)</td>
<td>Mixed-sex schools were described as affiliative and pleasure-oriented environments.</td>
</tr>
<tr>
<td>Jones et al. (1972)</td>
<td>Single-sex schools, particularly those for females, were considered to emphasize control and discipline.</td>
</tr>
<tr>
<td>Trickett, Castro, Trickett, &amp; Shaffner (1982)</td>
<td>Single-sex schools, particularly those for females, were considered to emphasize control and discipline.</td>
</tr>
<tr>
<td>Dale &amp; Miller (1972)</td>
<td>Authors reported equivocal findings as to whether single-sex schools were more academically oriented than coeducational schools.</td>
</tr>
<tr>
<td>Feather (1974)</td>
<td>Author reported equivocal findings as to whether single-sex schools were more academically oriented than coeducational schools.</td>
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<tr>
<td>Jones et al. (1972)</td>
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<tr>
<td>Trickett et al. (1982)</td>
<td>Authors report equivocal findings as to whether single-sex schools were more academically oriented than coeducational schools.</td>
</tr>
<tr>
<td>Trickett et al. (1982)</td>
<td>Females in single-sex high schools showed higher level of interest in the feminist movement than girls in coeducational schools.</td>
</tr>
<tr>
<td>Lockheed (1976)</td>
<td>Females participated in more activities when in single-sex school settings.</td>
</tr>
<tr>
<td>Gierl (1994)</td>
<td>Author cited researchers were adopting a more rigorous approach to previous limitations of early single-sex studies. Research began to focus on how achievement and attitudinal variables were related to academic performance.</td>
</tr>
<tr>
<td>Anderson, Auquier, Hauch, Oakes, Vandaele, &amp; Weisberg (1980)</td>
<td>Researchers identified confounding variables, such as initial ability and home background, and began to design research investigations statistically controlling for these types of variables.</td>
</tr>
</tbody>
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<tr>
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<tbody>
<tr>
<td>Lee &amp; Bryk (1986)</td>
<td>Females in single-sex high schools, compared to females in mixed-sex high schools, were more interested in mathematics and enrolled in more mathematics classes, associated with more academically oriented friends, and spent more time on homework.</td>
</tr>
<tr>
<td>Riordan (1990)</td>
<td>Females in single-sex classes, compared to females in mixed-sex classes, had higher gain scores (results from grades 10 to 12) on reading and science tests, higher educational aspirations, and lower sex-role stereotyping than their same-sex coeducational peers. Gain scores for all achievement measures favored the single-sex context.</td>
</tr>
<tr>
<td>Lee &amp; Bryk (1986)</td>
<td>Males in single-sex classes, compared to males in mixed-sex classes, enrolled in more mathematics and physical science classes, had a more positive attitude toward socially active peers and student athletes, and did more homework.</td>
</tr>
<tr>
<td>Riordan (1990)</td>
<td>Males in single-sex classes, compared to males in mixed-sex classes, did not demonstrate significantly higher achievement or attitudes measures (results from grades 10 to 12) than their same-sex coeducational peers. Gain scores in one achievement test (writing) favored the mixed-sex context.</td>
</tr>
</tbody>
</table>
CHAPTER III. METHODOLOGY

This research was designed to study the effects of mathematics and science student performance in a single-sex learning environment. The research was undertaken by the administration and faculty of an elementary, independent coeducational day school in Miami, Florida, as an exploratory study to address the gender differences in the participation and achievement of females in mathematics and science. The administration assigned all fifth grade students enrolled at Cushman School during the 1994–95 school term to participate in the gender separate mathematics and science study. This being Cushman School’s initial efforts in implementing an experimental design and statistical analysis of a research investigation, the administration contacted the leaders of the Iowa State University School Improvement Model (SIM) to assist in evaluation of the study. Cushman administrators became interested in working with the SIM team when they learned of the team’s joint research efforts with the Monroe County Public Schools (Monroe County, Florida) in district-wide curriculum renewal and assessment projects.

During the spring and summer months of 1994, Cushman School’s administration and faculty reviewed current gender equity literature addressing the gender differences in the participation and achievement of mathematics and science. Sensitized by the amount of national attention being given to the topic, school personnel prepared for the implementation of single-sex classes in mathematics and science for one grade level. In the fall of 1994, the fifth graders at Cushman School were separated by gender for their mathematics and science classes. It was decided that the mathematics and science curricula would be delivered through the use of an interdisciplinary approach for approximately 90 minutes daily. The school’s administration
assigned like-gender faculty members to instruct the respective gender treatment groups. The two faculty members were given a common planning period to provide similar instructional experiences for both single-sex classrooms.

The Design

This research study is a quasi-experimental, single-group design. The design was selected by the faculty of the participating school. The faculty realized the experimental rigor of its selected design would limit the feasibility of establishing a control group and randomly assigning students to treatment groups. Upon requesting assistance from this investigator, the decision was reached to propose a one-group pretest-posttest design for the study. According to Borg and Gall (1989), a one-group pretest-posttest design involves three steps: first, the administration of a pretest measuring the dependent variable; second, the application of the experimental treatment (independent variable) to the participants; and third, the administration of a posttest measuring the dependent variable again. In addition to the administration of the pretest and posttest assessments in mathematics and science, standardized achievement test data in mathematics and science and year-end report card grades in mathematics and science were analyzed to measure student performance. The literature has identified numerous attribution variables which influence students' perceptions of their own achievement, benefits, and attitudes toward the study of mathematics and science. A Student Response Inventory was constructed to ascertain student opinion data and measure gender differences in relationship to five categories of attribution variables.

The mathematics curriculum was delivered using the text and supplemental materials entitled Transition Mathematics: University of Chicago School Mathematics Program, by Scott
Foresman, 1995. All fifth graders were presented the following units: decimal notation, large and small numbers, measurement, use of variables, problem solving strategies. The science curriculum as outlined by the text, Science Plus: Technology and Society, by Holt, Rinehart, and Winston, 1993, Level Green, addressed the following units: science and technology, patterns of living things, it's a small world, investigating matter, chemical changes, energy and you, temperature and heat, our changing earth. The third variable was the assigning of like-gender faculty members to instruct the respective female/male sections of the integrated mathematics and science classes. The two faculty members were given a common planning period, as a means to provide similar teaching/learning experiences for both single-sex classrooms.

The Sample

Cushman School is an independent, non-denominational, non-discriminatory elementary school designed for boys and girls of average and above average development and learning ability. The program is offered in a day school model. Traditionally, enrollment is limited to ensure small class size. The 1994–95 enrollment totaled 351 students with class size ranging from 14–21 students per grade. Applications from alumni children and siblings are given priority consideration. The current annual tuition rate is $6,375 for grades 1–6 and $5,575 for preschool students.

The fifth grade class at Cushman was comprised of 28 students: 19 girls and 9 boys. The majority of the students entered the Cushman program as kindergartners. Only one new female student joined the fifth grade in September. The fifth graders were taught coeducationally as in
traditional elementary school settings, except for the single-sex instruction in mathematics and science. Each student’s curriculum consisted of the following:

**Core Academic Divisions:**
1. Language Arts;
2. Mathematics/Science;
3. Reading/Literature;
4. Social Studies.

**Specialty Subjects:**
1. Art;
2. Computers;
3. Library Science;
4. Music;
5. Physical Education;

Although Cushman faculty incorporated all fifth graders into the gender respective treatment groups, parental permission was requested for the use of each student’s individual data in the study. Only those who received parental permission were participants in this study.

**Instrumentation**

**Criterion-referenced examinations**

Approximately three months following the implementation of the gender separate investigation, Cushman faculty selected two criterion-referenced assessment instruments to measure student achievement. The two instruments were to serve as pretest measures. An assessment was administered in both mathematics and science. The faculty selected the Monroe County Fifth Grade Mathematics and Science Examinations (criterion-referenced measures), developed collaboratively by members of the School Improvement Model (SIM) team at Iowa State University and faculty members of the Monroe County Public School District, Monroe
County, Florida. These instruments were selected for use in this study because the content assessed in the examinations is aligned with the state of Florida’s public school curriculum.

The mathematics examination is a 48-item multiple choice test assessing student performance in relationship to the following mathematical content strands: number sense, addition, subtraction, multiplication, division, equations and inequalities, problem solving, money, measurement, time, probability and statistics, geometry, logic.

The science examination is a 50-item multiple choice test assessing student performance on relationship to the following nature of science and science-related content strands: scientific investigation and problem solving, life science, physical science, earth and space science, science for personal development, integration of science and technology and other disciplines.

Both criterion-referenced examinations have been extensively field tested by the Monroe County School District (assisted by the SIM team) for assurances of obtaining the empirical measurements of content validity (Carmines & Zeller, 1979) and internal consistency (Fraenkel & Wallen, 1993). The same instruments, when administered to all fifth graders attending Monroe County Schools in the fall of 1994, reported Kuder-Richardson 20 reliability estimates of .79 for the science examination and .76 for the mathematics examination (SIM, 1994).

Recently, the Monroe County Mathematics Examination was statistically compared to the Achievement Test (Eighth Edition, Mathematics Subtests). The correlation was .76, testing at the .01 level of significance (Putz, in progress). The same two instruments serving as posttests were readministered to Cushman's fifth graders in June 1995.
Norm-referenced tests

In addition to the criterion-referenced Monroe County Examinations, student achievement data from Cushman's annual spring administration of the Stanford Achievement Test (Kramer & Conoley, 1992) were incorporated into the statistical analysis. The data collected consist of performance indicators described in grade level equivalent scores for the Total Mathematics Battery and Science Battery of each student participating in the study.

In a review of the Stanford Achievement Test, Fredrick Brown addresses the issue of gender bias:

A panel of educators from various minority groups reviewed all items for possible ethnic, gender, socioeconomic, cultural, or regional bias. The test authors also attempted to balance the frequency and nature of gender and ethnic references within the test. Rasch model and Angoff delta estimates of item difficulty were computed for two gender and three ethnic groups (African American, Hispanic, White), and items exhibiting large differences were flagged for possible exclusion. No information on the criterion used to flag items, nor on the numbers of items flagged and excluded, was presented in the preliminary technical report (Kramer & Conoley, 1992, p. 862).

The Kuder-Richardson 20 reliability coefficients for most of the tests and subtests are at least .85 and many are over .90 (Krammer & Conoley, 1992). However, Brown cautions educators of a major shortcoming of the series: its lack of convincing arguments and data in support of the validity of the battery.
Report card grades

Each student’s year-end report card grade in mathematics and science, assigned by the respective teachers of the gender separate treatment groups, was collected and incorporated into the statistical analysis. Each student’s year-end report card grades were converted to a numerical score using the standard values assigned for grade point average (GPA) calculations.

Student Response Inventory

Each student was asked to complete a Student Response Inventory at the end of the 1994-95 year. The inventory used in this study was designed collaboratively with Cushman’s administration and this investigator. The instrument consists of 19 questions, grouped by five categories of attribution variables, based on conclusions drawn from the literature.

Two previously administered questionnaires, one used to assess student attitudes and perceptions in a gender equity high school mathematics study (Cohen & Koster, 1991), and the other assessing nationwide attitudes, educational experiences, math and science interest, and career aspirations of girls and boys from 9 to 15 years old (AAUW, 1991), served as models in designing the Student Response Inventory used in this study.

The literature reviewed for this study identified numerous attribution variables which influence students’ perceptions of their own achievement, benefits, and attitudes toward the study of mathematics and science. The five categories of attribution variables incorporated in the Student Response Inventory include the following: knowledge, use, and value of mathematics and science for future work; parental attitude toward pursuit of mathematics and science; academic self-concept and interest in mathematics and science; teacher expectation of
gender performance in mathematics and science; and relationship of teacher gender to student performance in mathematics and science.

The 19-item inventory contained six items pertaining to the knowledge, use, and value of mathematics and science for future work, four items pertaining to parental attitude toward pursuit of mathematics and science, five items pertaining to academic self-concept and interest in mathematics and science, two items pertaining to teacher expectation of gender performance in mathematics and science, and two items pertaining to the relationship of teacher gender to student performance in mathematics and science. Each of the five attribution variables provided students three to five selected response options. No weighted values were assigned to the response options.

Data Analysis

After all of the assessments and the inventory were completed, the data were scanned by the Test and Evaluation Services, Iowa State University Computational Center. Statistical treatment of the data was completed using the Statistical Package for Social Science (SPSS) (Norusis, 1992) and the Iowa State University mainframe, Wylbur. Descriptive statistics providing frequencies, means, and standard deviations were computed to study the relative value of the variables.

Data were collected from the pretest and posttest administration of the Monroe County Fifth Grade Mathematics and Science Examinations of the 26 participants. Four paired t-tests were used to assess the differences between pretest (pre-treatment) and posttest (post-treatment) scores of the participants.
Ten independent t-tests were used to compare female to male student performance of the participants in this study. Independent t-tests analyzed gender differences in student performance utilizing the following data sets: both the pretest and posttest scores from the Monroe County Fifth Grade Mathematics and Science Examinations; the grade equivalent scores, provided by the administration, from the Stanford Achievement Tests (Eighth Edition), Grade Five: Total Mathematics and Science Batteries; and both the mathematics and science year-end grade point averages, provided by the administration, from the individual student report cards.

An analysis of covariance (ANCOVA) was used to test for statistically significant gender differences in both the mathematics and science grade point averages and the individual student gain scores on both the Monroe County Fifth Grade Mathematics and Science Examinations. Individual student grade equivalent scores from the respective subject area tests of the Stanford Achievement Test were used as the covariate. The formula for the analysis of covariance is:

\[
\begin{array}{l}
\text{Source} & \text{SS} & \text{df} & \text{MS} & F & F_{CV} \\
\text{Covariate} & \text{SS}_{COV} & 1 & & & \\
\text{Between} & \text{SS}'_B & K - 1 & \text{MS}'_B & & \\
\text{Within} & \text{SS}'_w & N - K - 1 & \text{MS}'_w & & \\
\text{Total} & \text{SS}'_T & N - 1 & & & \\
\end{array}
\]

\[
F = \frac{\text{MS}'_B}{\text{MS}'_w}
\]
The level of significance was established at .05, and appropriate degrees of freedom were determined for each test. Any test yielding a probability of ≤ .05 resulted in rejection of the null hypothesis and acceptance of the alternative hypothesis.

Student opinion data for the Student Response Inventory were examined for gender differences in response frequencies. The differences in response of frequencies were investigated and categorized by five categories of attribution variables which may influence the learning of mathematics and science.

Human Subjects Release

On March 7, 1995, a letter authorizing this research was written to Professor Manatt by Dr. Joan Lutton, Headmistress, and Cheryl Rogers, Elementary Principal, of Cushman School.

The Iowa State University Committee on the Use of Human Subjects in Research reviewed this project and concluded that the rights and welfare of the human subjects were adequately protected, that risks were outweighed by the potential benefits and expected value of the knowledge sought, that confidentiality of data was assured, and that informed consent was obtained by appropriate procedures.
CHAPTER IV. FINDINGS

The purpose of this chapter is to report the findings of the investigation of the effects of student mathematics and science performance in a single-sex learning environment. This chapter restates each of the research questions presented in Chapter I. A null hypothesis is stated for each statistical test conducted. The results of the statistical tests performed on the data are displayed in table form as well.

The inferential statistical tests of significance used to determine whether the difference between sample means reflect population differences were t-tests for dependent and independent groups. And, to adjust for preexisting differences that may exist among the intact groups prior to the research, an ANCOVA one-way analysis was utilized. ANCOVA can also increase the precision of the statistical analysis by partitioning out the variation attributed to the covariate, which results in a smaller error variance (Hinkle, Wiersma, & Jurs, 1994).

The chapter has been divided into the following four sections: 1) Analysis of academic performance and academic achievement in a single-sex mathematics and science class; 2) analysis of academic growth in a single-sex mathematics and science class: pre/posttest treatment comparisons; 3) analysis of academic growth in a single-sex mathematics and science class: statistically controlling for previous academic achievement; and 4) examination of attribution variables which may influence the learning of mathematics and science.
Analysis of Academic Performance and Academic Achievement in a Single-sex Mathematics and Science Class

**Research Question 1:** Will girls and boys demonstrate similar academic performance when assigned to a single-sex mathematics and science class, as measured by year-end report card grades?

**Research Null Hypothesis 1a:** There will be no significant difference between girls and boys in academic performance, when assigned to a single-sex mathematics and science class, as measured by the mean scores of grade point averages (GPA) from year-end mathematics report card grades.

Academic performance, as measured by year-end report card grades in mathematics, is presented in Table 6. Twenty-five of the 26 participants were issued year-end mathematics report card grades by the school’s administration. The girls’ year-end mean mathematics GPA indicates an overall higher academic performance than that of the boys. The girls’ performance resulted in a mean GPA of 3.40; the boys reported a year-end mathematics GPA of 3.17.

An independent, pooled t-test was utilized to calculate for significant differences between mean GPA scores. The t-test analysis yielded a t-value of .54, indicating a 2-tail probability of .596. Testing at the $p \leq .05$ level, this finding was not significant. Thus, fail to reject Research Null Hypothesis 1a.

**Research Null Hypothesis 1b:** There will be no significant difference between girls and boys in academic performance, when assigned to a single-sex mathematics and science class, as measured by the mean scores of grade point averages (GPA) from year-end science report card grades.
Analysis of Table 6 data also indicates girls demonstrated an overall higher academic performance in science than boys, as measured by year-end science report cards. Twenty-five of 26 participants in the study were issued year-end science report card grades by the school’s administration.

Although the mean GPA score for girls (3.72) appears to be much higher than the boys’ GPA mean score (3.05), it is not statistically significant. Conducting an independent pooled t-test, the t-value was 1.98 with a 2-tail probability of .06. Testing at the p=.05 level, the results are not significant. Therefore, fail to reject Research Null Hypothesis 1b.

Research Question 2: Will girls and boys demonstrate similar academic achievement when assigned to a single-sex mathematics and science class, as measured by standardized achievement tests?

Research Null Hypothesis 2a: There will be no significant difference between girls and boys in academic achievement, when assigned to a single-sex mathematics and science class.

Table 6. Analysis of academic performance on year-end mathematics and science report card grades (GPA) by gender

<table>
<thead>
<tr>
<th>Subject/gender</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>t value</th>
<th>2-tail prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>19</td>
<td>3.4032</td>
<td>.790</td>
<td>.54</td>
<td>.596</td>
</tr>
<tr>
<td>Boys</td>
<td>6</td>
<td>3.1667</td>
<td>1.345</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>18</td>
<td>3.7228</td>
<td>.716</td>
<td>1.98</td>
<td>.060</td>
</tr>
<tr>
<td>Boys</td>
<td>7</td>
<td>3.0486</td>
<td>.891</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
science class, as measured by the mean scores of grade level equivalent scores from the Stanford Achievement Test (SAT), Total Mathematics Battery.

Table 7 shows the statistical analysis of academic achievement on mathematics and science standardized achievement tests (SAT) using grade level equivalent scores. The data indicate that the boys demonstrated slightly higher mathematics achievement than the girls, represented by a mean score of 9.70. The girls’ mean grade level equivalent score in mathematics was 8.26, yielding a mean score difference of 1.44.

A pooled t-test was utilized to determine the significance of the gender differences in achievement scores. The t-test analysis indicates no significant difference at the .05 level. Thus, fail to reject Research Null Hypothesis 2a. This finding, coupled with the gender differences in mathematics performance as measured by GPA (Table 6), parallels one of the controversial concerns related to gender differences in standardized achievement test performance. The literature indicates boys tend to outperform girls on measure of standardized

<table>
<thead>
<tr>
<th>Test battery/gender</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>t value</th>
<th>2-tail prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mathematics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>19</td>
<td>8.2579</td>
<td>2.183</td>
<td>-1.31</td>
<td>.204</td>
</tr>
<tr>
<td>Boys</td>
<td>7</td>
<td>9.6857</td>
<td>3.184</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Science</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>18</td>
<td>8.2944</td>
<td>2.797</td>
<td>-.63</td>
<td>.537</td>
</tr>
<tr>
<td>Boys</td>
<td>7</td>
<td>9.1571</td>
<td>3.791</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
mathematics achievement test data; however, girls tend to receive higher mathematics grades than boys in school (Table 3).

**Research Null Hypothesis 2b:** There will be no significant difference between girls and boys in academic achievement, when assigned to a single-sex mathematics and science class, as measured by the mean scores of grade level equivalent scores from the Stanford Achievement Test (SAT), Science Battery.

Further examination of the data in Table 7 reflects the same trend in gender-related academic achievement performance discrepancies in science (Table 3). The results indicate that the boys outperformed the girls on the standardized science achievement test; however, their academic performance in the classroom resulted in a lower, overall year-end science GPA (Table 6). The boys' mean grade level equivalent score was 9.16 and the girls' mean score was 8.29. These scores indicate a mean difference of .87. The pooled t-test used to determine the significance of the difference in performance indicates a t-value of -.63 and a 2-tail probability of .537. Therefore, at the .05 significance level, fail to reject Research Null Hypothesis 2b.

Although no results in between group comparisons indicate statistically significant gender differences in mathematics or science year-end report card grades or standardized achievement test scores, the findings show contrasting results (Tables 6 and 7). The analysis of achievement test scores indicates a greater mean score difference between girls and boys in mathematics (1.44, favoring boys) than in science (.87, favoring boys). Conversely, the analysis of year-end report card grades (GPA) indicates a greater mean score difference between girls and boys in science (.67, favoring girls) than in mathematics (.23, favoring girls).
Analysis of Academic Growth in a Single-sex Mathematics and Science Class: Pre/Posttest Treatment Comparisons

Research Question 3: Will girls and boys demonstrate similar academic growth when assigned to a single-sex mathematics and science class, as measured by criterion-referenced examinations (aligned with the respective state’s grade level curriculum)?

Research Null Hypothesis 3a: There will be no significant difference in girls’ academic growth, when assigned to a single-sex mathematics and science class, as measured by the mean scores of criterion-referenced mathematics pre/posttests (aligned with the respective state’s grade level curriculum).

A dependent t-test was used to compare the mean scores of the mathematics pretest examination with the mathematics posttest examination to determine if the girls demonstrated a significant increase in mathematics growth. The results of the paired t-test on participants’ scores for the mathematics pretest examination and mathematics posttest examination are reported in Table 8.

The pretest mean was 30.89 and the posttest mean was 32.05. There was a difference of 1.16 between the pretest and posttest means. The analysis of standard deviation scores indicates a greater dispersion of scores between the girls on the posttest. The within group t-value was .84, which was not significant for the 2-tailed test at the p ≤ .05 level. Thus, fail to reject Research Null Hypothesis 3a.

Research Null Hypothesis 3b: There will be no significant difference in girls’ academic growth, when assigned to a single-sex mathematics and science class, as measured by the mean scores of criterion-referenced science pre/posttests (aligned with the respective state’s grade level curriculum).
Table 8. Analysis of academic growth on mathematics and science criterion-referenced examinations by girls

<table>
<thead>
<tr>
<th>Examination scores</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>t value</th>
<th>2-tail prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics (48 items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>19</td>
<td>32.0526</td>
<td>7.427</td>
<td>.84</td>
<td>.414</td>
</tr>
<tr>
<td>Pretest</td>
<td>19</td>
<td>30.8947</td>
<td>4.267</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science (50 items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>18</td>
<td>29.2222</td>
<td>4.037</td>
<td>4.96</td>
<td>.000***</td>
</tr>
<tr>
<td>Pretest</td>
<td>18</td>
<td>24.3889</td>
<td>5.304</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***Significant at the .001 level.

A dependent t-test was used to compare the mean scores of the science pretest examination with the science posttest examination to determine if girls demonstrated a significant increase in science growth. Eighteen of 19 girls in the study participated in both the pre/posttest science assessments.

The results displayed in Table 8 indicate girls did demonstrate a significant increase in academic growth in science. The pretest mean was 24.39 and the posttest mean was 29.22, indicating a mean difference of 4.83. The within group t-value was 4.96, yielding a 2-tail probability of .000 at the p<.05 level. Therefore, Research Null Hypothesis 3b was rejected. The girls were able to demonstrate significant academic growth in science between the pre/posttest treatment examinations.

Research Null Hypothesis 3c: There will be no significant difference in boys’ academic growth, when assigned to a single-sex mathematics and science class, as measured
by the mean scores of criterion-referenced mathematics pre/posttests (aligned with the respective state's grade level curriculum).

To measure the academic growth in mathematics of the boys participating in the study, a paired t-test was conducted. The results displayed in Table 9 indicate no significant growth in mathematics was reported.

The pretest mean was 33.43 and the posttest mean was 34.71, indicating a mean difference of 1.29. Similar to the girls' findings, the boys' posttest standard deviation score in mathematics represents more dispersion within the posttest than pretest scores. Although the boys were able to demonstrate some growth in mathematics, it is not significant. The within group t-value was .73. This t-value is accompanied by a 2-tail probability of .492. Therefore, fail to reject Research Null Hypothesis 3c.

Table 9. Analysis of academic growth on mathematics and science criterion-referenced examinations by boys

<table>
<thead>
<tr>
<th>Examination scores</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>t value</th>
<th>2-tail prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics (48 items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>7</td>
<td>34.7143</td>
<td>8.499</td>
<td>.73</td>
<td>.492</td>
</tr>
<tr>
<td>Pretest</td>
<td>7</td>
<td>33.4286</td>
<td>6.705</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science (50 items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>7</td>
<td>31.2857</td>
<td>8.845</td>
<td>1.19</td>
<td>.280</td>
</tr>
<tr>
<td>Pretest</td>
<td>7</td>
<td>29.1429</td>
<td>10.123</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Research Null Hypothesis 3d: There will be no significant difference in boys' academic growth, when assigned to a single-sex mathematics and science class, as measured by the mean scores of criterion-referenced science pre/posttests (aligned with the respective state's grade level curriculum).

Table 9 also contains the results of the paired t-test used to compare the mean scores of the science pretest examination with the science posttest examination. The paired t-test analysis was done to ascertain if the boys demonstrated significant academic growth in science between the pre/posttest treatment assessments. The pretest mean was 29.14 and the posttest mean was 31.29, indicating a mean difference of 2.14. Although the boys did demonstrate academic growth in science, the t-test conducted yielded a within group t-value of 1.19 and a 2-tail probability of .280. Thus, at the p≤.05 level, fail to reject Research Null Hypothesis 3d.

Research Null Hypothesis 3e: There will be no significant difference between girls and boys in academic growth, when assigned to a single-sex mathematics and science class, as measured by mean scores of mathematics and science pretests, posttests, and gain scores of criterion-referenced examinations aligned with the respective state's grade level curriculum.

Table 10 summarizes gender differences in academic growth between the pre/post-treatment assessments as measured by mean scores of the criterion-referenced mathematics and science examinations. To further investigate the significance of gender differences, a statistical analysis was conducted on the gain scores for both the mathematics and science assessments. After mean scores and standard deviations were calculated for each comparison, six independent t-tests were used to determine the significance of the data.
Table 10. Analysis of academic growth on criterion-referenced mathematics and science examinations by gender

<table>
<thead>
<tr>
<th></th>
<th>Girls</th>
<th></th>
<th>Boys</th>
<th></th>
<th>t value</th>
<th>2-tail prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>N</td>
<td>Mean</td>
<td>S.D.</td>
<td>N</td>
</tr>
<tr>
<td>Mathematics (48 items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>30.89</td>
<td>4.26</td>
<td>19</td>
<td>33.43</td>
<td>6.71</td>
<td>7</td>
</tr>
<tr>
<td>Posttest</td>
<td>32.05</td>
<td>7.43</td>
<td>19</td>
<td>34.71</td>
<td>8.50</td>
<td>7</td>
</tr>
<tr>
<td>Gain score</td>
<td>1.16</td>
<td>6.03</td>
<td>19</td>
<td>1.29</td>
<td>4.65</td>
<td>7</td>
</tr>
<tr>
<td>Science (50 items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>24.39</td>
<td>5.30</td>
<td>18</td>
<td>29.14</td>
<td>10.12</td>
<td>7</td>
</tr>
<tr>
<td>Posttest</td>
<td>29.22</td>
<td>4.04</td>
<td>18</td>
<td>31.29</td>
<td>8.85</td>
<td>7</td>
</tr>
<tr>
<td>Gain score</td>
<td>4.83</td>
<td>4.13</td>
<td>18</td>
<td>2.14</td>
<td>4.78</td>
<td>7</td>
</tr>
</tbody>
</table>

There were no significant differences between girls and boys regarding their academic growth in mathematics or science; however, two comparisons should be noted. First, each gender demonstrated a modest growth in both mathematics and science with the boys experiencing a slightly higher gain score in mathematics (mean gain score difference of .13). Second, the girls demonstrated more growth than did boys in science, represented by a mean gain score difference of 2.70. In overall pre/posttest treatment comparisons between gender, the boys outperformed the girls on all of the criterion-referenced examinations which were administered during the study.

Although none of the data indicate significant results, the variability of the science pretest and posttest scores indicated the need to analyze the data using independent separate t-tests. Independent pooled t-tests were appropriate for the analysis of the remaining data presented in Table 10. Summarizing all between group criterion-referenced data, girls and boys were able
to demonstrate similar academic growth when instructed in single-sex mathematics and science classes. Therefore, fail to reject Research Null Hypothesis 3e.

Analysis of Academic Growth in a Single-sex Mathematics and Science Class: Statistically Controlling for Previous Academic Achievement

Research Question 4: If statistically controlling for gender differences in previous academic achievement, will girls and boys demonstrate similar academic performance, when assigned to a single-sex mathematics and science class, as measured by year-end report card grades?

Research Null Hypothesis 4a: There will be no significant difference in academic performance between girls and boys, statistically controlling for gender differences in previous achievement, when assigned to a single-sex mathematics and science class, as measured by the adjusted mean scores of grade point averages from year-end mathematics report card grades.

Table 11 presents the statistical analysis of mathematics achievement (MSAT) on mathematics performance (GPA). The results indicate two significant findings. First, the F ratio of 17.346, corresponding with a p = .000 at the .05 level, indicates a significant relationship between the students’ MSAT scores and their mathematics GPA. In particular, since this finding is also significant at the .001 level, it demonstrates a fairly strong relationship between the two variables.

Because the ANCOVA reflects a significant relationship between the covariate (MSAT) and the dependent variable (GPA), the analysis of variance results were calculated using adjusted mathematics performance scores (GPA) (Table 13). Testing at the .05 level, the
Table 11. Analysis of covariance of mathematics achievement on mathematics performance (GPA) by gender

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F ratio</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSAT</td>
<td>1</td>
<td>7.860</td>
<td>7.860</td>
<td>17.346</td>
<td>.000***</td>
</tr>
<tr>
<td>Main effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>2.722</td>
<td>2.722</td>
<td>6.007</td>
<td>.023*</td>
</tr>
<tr>
<td>Explained</td>
<td>2</td>
<td>10.582</td>
<td>5.291</td>
<td>11.676</td>
<td>.000</td>
</tr>
<tr>
<td>Residual</td>
<td>22</td>
<td>9.969</td>
<td>.453</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>20.551</td>
<td>.856</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

***Significant at the .001 level.

finding (p=.023) demonstrates that a significant gender difference (after adjusting for the preexisting differences of the students’ MSAT scores) does exist in year-end mathematics report card grades (GPA). Therefore, reject Research Null Hypothesis 4a and accept the alternative hypothesis.

**Research Null Hypothesis 4b:** There will be no significant difference in academic performance between girls and boys, statistically controlling for gender differences in previous achievement, when assigned to a single-sex mathematics and science class, as measured by the adjusted mean scores of grade point averages from year-end science report card grades.
When investigating the difference between gender in academic performance in science (GPA), statistically controlling for gender differences in previous science achievement (SSAT), the results displayed in Table 12 are similar to those in Table 11. Two significant findings are evident. There is a significant relationship between the students' SSAT scores and their science GPA (F ratio of 12.259, p=.002). And the ANOVA, calculated using adjusted science performance scores (GPA), indicates a significant difference between the girls’ and boys’ academic performance in science (F ratio of 8.901, p=.007). Thus, reject Research Null Hypothesis 4b and accept the alternative hypothesis.

The data in Table 13 represent the adjusted means for mathematics and science achievement (MSAT, SSAT) on mathematics and science performance (GPA) by gender. In

Table 12. Analysis of covariance of science achievement on science performance (GPA) by gender

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F ratio</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate SSAT</td>
<td>1</td>
<td>4.479</td>
<td>4.479</td>
<td>12.259</td>
<td>.002**</td>
</tr>
<tr>
<td>Main effect Gender</td>
<td>1</td>
<td>3.252</td>
<td>3.252</td>
<td>8.901</td>
<td>.007**</td>
</tr>
<tr>
<td>Explained</td>
<td>2</td>
<td>7.731</td>
<td>3.865</td>
<td>10.580</td>
<td>.001</td>
</tr>
<tr>
<td>Residual</td>
<td>22</td>
<td>8.038</td>
<td>.365</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>15.769</td>
<td>.657</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at the .01 level.
Table 13. Adjusted means for mathematics and science achievement (SAT) on mathematics and science performance (GPA) by gender

<table>
<thead>
<tr>
<th>Subject/gender</th>
<th>Unadjusted mean</th>
<th>Adjusted mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics (GPA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>3.40</td>
<td>3.55</td>
</tr>
<tr>
<td>Boys</td>
<td>3.17</td>
<td>2.72</td>
</tr>
<tr>
<td>Science (GPA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>3.72</td>
<td>3.76</td>
</tr>
<tr>
<td>Boys</td>
<td>3.05</td>
<td>2.95</td>
</tr>
</tbody>
</table>

*Overall mathematics GPA=3.35; overall science GPA=3.53.

Both subjects, the results of the ANCOVA generated raised GPA means for the girls due to lower SAT scores (mathematics GPA: 3.40 to 3.55; science GPA: 3.72 to 3.76) and lowered GPA means for the boys due to higher SAT scores (mathematics GPA: 3.17 to 2.72; science GPA: 3.05 to 2.95).

Overall, these results indicate, when statistically controlling for gender differences in previous achievement (MSAT, SSAT), gender differences in mathematics and science performance (GPA) do exist between the single-sex treatment groups.

Research Question 5: If statistically controlling for gender difference in previous academic achievement, will girls and boys demonstrate similar academic growth, when assigned to a single-sex mathematics and science class, as measured by criterion-referenced examinations (aligned with the respective state's grade level curriculum)?
Research Null Hypothesis 5a: There will be no significant difference in academic growth between girls and boys, statistically controlling for gender differences in previous achievement, when assigned to a single-sex mathematics and science class, as measured by the adjusted mean gain scores of criterion-referenced mathematics examinations (aligned with the respective state’s grade level curriculum).

Table 14 represents the data of the ANCOVA used to assess the significance of students’ mathematics achievement on their mathematics gain scores by gender. The results indicate no significant relationship between the covariate (MSAT) and the dependent variable (mathematics gain scores). The statistical results yield an F ratio of 1.258 (p = .274) for the linear regression analysis and an F ratio of .061 (p = .808) for the ANOVA analysis. Finding no significant relationship between the covariate (MSAT) and the dependent variable (mathematics gain

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F ratio</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSAT</td>
<td>1</td>
<td>40.548</td>
<td>40.548</td>
<td>1.258</td>
<td>.274</td>
</tr>
<tr>
<td>Main effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>1.958</td>
<td>1.958</td>
<td>.061</td>
<td>.808</td>
</tr>
<tr>
<td>Explained</td>
<td>2</td>
<td>42.506</td>
<td>21.253</td>
<td>.659</td>
<td>.527</td>
</tr>
<tr>
<td>Residual</td>
<td>23</td>
<td>741.532</td>
<td>32.241</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>784.038</td>
<td>31.362</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
scores), no adjustment was made to the students’ mathematics gain scores in the ANOVA analysis. Therefore, when controlling for gender differences in previous mathematics achieved (MSAT), there is no significant difference between the two treatment groups in mathematics growth, as measured by the mean gain scores on the criterion-referenced mathematics examinations. Thus, fail to reject Research Null Hypothesis 5a.

**Research Null Hypothesis 5b:** There will be no significant difference in academic growth between girls and boys, statistically controlling for gender differences in previous achievement, when assigned to a single-sex mathematics and science class, as measured by the adjusted mean gain scores of criterion-referenced science examinations (aligned with the respective state’s grade level curriculum).

The analysis of covariance of science achievement on science gain scores by gender is presented in Table 15. The data reflect no significant relationship between the students’ science achievement (SSAT) and their gain scores on the science criterion-referenced examinations (F ratio of 1.163 and p=.293). Since there is no significant relationship between the covariate (SSAT) and the dependent variable (science gain scores), the statistical procedures did not adjust the science gain scores in the ANOVA.

Testing at the .05 level, the ANOVA data also show nonsignificant results (F ratio of 1.604 and p=.219). Thus, fail to reject Research Null Hypothesis 5b. The findings indicate, when statistically controlling for gender differences in previous science achievement, there is no significant gender difference in academic growth in science, as measured by the mean gain score of criterion-referenced science achievement.
Table 15. Analysis of covariance of science achievement on science gain scores by gender

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F ratio</th>
<th>Significance of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate SSAT</td>
<td>1</td>
<td>21.774</td>
<td>21.774</td>
<td>1.163</td>
<td>.293</td>
</tr>
<tr>
<td>Main effect Gender</td>
<td>1</td>
<td>30.043</td>
<td>30.043</td>
<td>1.604</td>
<td>.219</td>
</tr>
<tr>
<td>Explained</td>
<td>2</td>
<td>51.817</td>
<td>25.908</td>
<td>1.383</td>
<td>.272</td>
</tr>
<tr>
<td>Residual</td>
<td>22</td>
<td>412.023</td>
<td>18.728</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>463.840</td>
<td>19.327</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Examination of Attribution Variables Which May Influence the Learning of Mathematics and Science

Research Question 6: Will girls and boys have similar perceptual opinions regarding five categories of achievement-related beliefs (attribution variables), which may influence the learning of mathematics and science, after one year of instruction in a single-sex mathematics and science class?

Student opinion data for the Student Response Inventory were examined for gender differences in response frequencies, categorized by five attribution variables. The opinion data were not analyzed in depth due to the low number of participants who answered all questions and the variety in their selected response options. School officials administered the inventory during the final month of the study. Seventeen girls and five boys returned completed inventories. The results are displayed in Tables 16–20.
Attribution Variable I: Knowledge, use, and value of mathematics and science for future work.

Attribution theorists argue that people's causal expectations for success and failure affect their self-concept of ability, future expectations, and subsequent achievement behaviors. From junior high on, females express more negative attitudes toward mathematics and rate their mathematical ability lower than do males, even though performing at comparable levels. Females rate mathematics as less important and less interesting than do males (Table 2).

The data in Table 16 indicate 53.33 percent of the boys, as compared to 35.83 percent of the girls, selected "strongly agree" as to importance of knowledge, use, and practical value of mathematics and science in future work. The responses also show that none of the boys marked "moderately or strongly disagree," while 7 percent of girls' responses were in these two categories.

Attribution Variable II: Parental attitude toward pursuit of mathematics and science.

The literature indicates that children's self-concept of ability and their confidence in mathematics are more directly related to their parents' beliefs about their mathematics aptitude and potential than their past achievement in mathematics (Table 2).

Table 17 presents the student opinion responses regarding parental attitudes toward the pursuit of mathematics and science. Although the majority of responses indicate "very supportive" attitudes expressed by both parents, the findings appear to reflect a gender variation in perceptions. The girls perceive their mothers to be more supportive than their fathers in both mathematics and science. Conversely, the boys perceive their fathers to be the most supportive; however, equally as supportive for their pursuit in mathematics as science.
Table 16. Frequencies of student opinion data for Attribution Variable I: Knowledge, use, value of mathematics and science for future work (N=girls [17], boys [5])

<table>
<thead>
<tr>
<th>Perceptual indicator</th>
<th>(A) Strongly agree</th>
<th>(B) Moderately agree</th>
<th>(C) Uncertain</th>
<th>(D) Moderately disagree</th>
<th>(E) Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Knowledge of mathematics will be of some use in everyday life.</td>
<td>Girls</td>
<td>10(59%)</td>
<td>6(35%)</td>
<td>1(6%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>4(80%)</td>
<td>0</td>
<td>1(20%)</td>
<td>0</td>
</tr>
<tr>
<td>2. Knowledge of science will be of some use in everyday life.</td>
<td>Girls</td>
<td>2(12%)</td>
<td>9(53%)</td>
<td>6(35%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>3(60%)</td>
<td>2(40%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Knowledge of mathematics will have practical value for me in earning a living.</td>
<td>Girls</td>
<td>9(56%)</td>
<td>4(25%)</td>
<td>2(13%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>3(60%)</td>
<td>2(40%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Knowledge of science will have practical value for me in earning a living.</td>
<td>Girls</td>
<td>5(29%)</td>
<td>4(24%)</td>
<td>5(29%)</td>
<td>2(12%)</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>1(20%)</td>
<td>4(80%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Mathematics courses are needed for my intended major field or future work.</td>
<td>Girls</td>
<td>7(41%)</td>
<td>5(29%)</td>
<td>4(24%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>3(60%)</td>
<td>0</td>
<td>2(40%)</td>
<td>0</td>
</tr>
<tr>
<td>6. Science courses are needed for my intended major field or future work.</td>
<td>Girls</td>
<td>3(18%)</td>
<td>7(41%)</td>
<td>5(29%)</td>
<td>2(12%)</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>2(40%)</td>
<td>0</td>
<td>3(60%)</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 17. Frequencies of student opinion data for Attribution Variable II: Parental attitude toward pursuit of mathematics and science (N=girls [17], boys [5])

<table>
<thead>
<tr>
<th>Perceptual indicator</th>
<th>(A) Very supportive</th>
<th>(B) Moderately supportive</th>
<th>(C) Neither</th>
<th>(D) Moderately unfavorable</th>
<th>(E) Strongly unfavorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Describe the attitude of your mother toward your pursuit of mathematics.</td>
<td>Girls 11(65%)</td>
<td>6(35%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 3(60%)</td>
<td>2(40%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8. Describe the attitude of your mother toward your pursuit of science.</td>
<td>Girls 10(59%)</td>
<td>3(18%)</td>
<td>4(24%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 2(40%)</td>
<td>2(40%)</td>
<td>1(20%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9. Describe the attitude of your father toward your pursuit of mathematics.</td>
<td>Girls 8(53%)</td>
<td>4(27%)</td>
<td>3(20%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 4(80%)</td>
<td>1(20%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10. Describe the attitude of your father toward your pursuit of science.</td>
<td>Girls 6(40%)</td>
<td>4(27%)</td>
<td>5(33%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 4(80%)</td>
<td>1(20%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Attribution Variable III: Academic self-concept and interest in mathematics and science.

Gender differences exist on some self-concept of ability measures, with females reporting lower self-concepts. A variety of theories exist that led to patterns of sex differences, predicting females to show less confidence than males in their mathematical abilities. Sex differences in mathematical confidence have been reported among children as young as fifth and sixth graders (Table 2).

Overall, the results displayed in Table 18 indicate that the girls and boys in the study have moderately high academic self-concepts and interests in mathematics and science. However, when examining the strongest response option for students ("almost always"), the boys (64%) indicated an overall higher academic self-concept than the girls (44.8%). In particular in both subject areas, girls expressed more interest than confidence. The boys’ confidence level in both mathematics and science equaled or surpassed their interest level.

Attribution Variable IV: Teacher expectation of gender performance in mathematics and science.

Past research on teacher attitudes has also tended to show negative bias against females. Surveys of elementary and high school teachers have shown that a substantial percentage expected boys to excel in mathematics. No teachers studied expected girls to outperform boys (Ernest, 1976). However, parents, more often than teachers, held sex-differentiated beliefs about their sons’ and daughters’ mathematical achievement (Table 2).

The differences in response frequencies regarding teacher expectation of gender performance in mathematics and science represents a substantial difference in gender opinion (Table 19). Each gender selected only two of four response options. Sixty-five percent of the girls perceived their mathematics teacher to have “no difference” in expectations for boys or
Table 18. Frequencies of student opinion data for Attribution Variable III: Academic self-concept and interest (N=girls [17], boys [5])

<table>
<thead>
<tr>
<th>Perceptual indicator</th>
<th>(A) Almost always</th>
<th>(B) Sometimes</th>
<th>(C) Uncertain</th>
<th>(D) Seldom</th>
<th>(E) Almost never</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. I like mathematics.</td>
<td>Girls 9 (53%)</td>
<td>6 (35%)</td>
<td>1 (6%)</td>
<td>0</td>
<td>1 (6%)</td>
</tr>
<tr>
<td></td>
<td>Boys 4 (80%)</td>
<td>1 (20%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12. I think I am good at mathematics.</td>
<td>Girls 7 (41%)</td>
<td>8 (47%)</td>
<td>2 (12%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 4 (80%)</td>
<td>0</td>
<td>1 (20%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13. I like science.</td>
<td>Girls 7 (41%)</td>
<td>7 (41%)</td>
<td>2 (12%)</td>
<td>1 (6%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 2 (40%)</td>
<td>2 (40%)</td>
<td>1 (20%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14. I think I am good at science.</td>
<td>Girls 4 (24%)</td>
<td>11 (65%)</td>
<td>1 (6%)</td>
<td>1 (6%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 3 (60%)</td>
<td>2 (40%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15. I think I'm good at a lot of things.</td>
<td>Girls 11 (65%)</td>
<td>5 (29%)</td>
<td>1 (6%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Boys 3 (60%)</td>
<td>1 (20%)</td>
<td>1 (20%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 19. Frequencies of student opinion data for Attribution Variable IV: Teacher expectation of student’s gender (N=girls [17], boys [5])

<table>
<thead>
<tr>
<th>Perceptual indicator</th>
<th>(A) No difference</th>
<th>(B) Expects girls to do better</th>
<th>(C) Expects boys to do better</th>
<th>(D) Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Do you think your mathematics teacher has different expectations for girls and boys?</td>
<td>Girls 11(65%)</td>
<td>0</td>
<td>0</td>
<td>6(35%)</td>
</tr>
<tr>
<td></td>
<td>Boys 0</td>
<td>0</td>
<td>2(40%)</td>
<td>3(60%)</td>
</tr>
<tr>
<td>17. Do you think your science teacher has different expectations for girls and boys?</td>
<td>Girls 9(53%)</td>
<td>1(6%)</td>
<td>1(6%)</td>
<td>6(35%)</td>
</tr>
<tr>
<td></td>
<td>Boys 0</td>
<td>0</td>
<td>1(20%)</td>
<td>4(80%)</td>
</tr>
</tbody>
</table>
girls, while 35 percent of the girls were uncertain as to how to respond. Sixty percent of the boys also expressed an "uncertainty" as to different teacher expectations in mathematics for either gender. Yet, 40 percent of the boys' responses indicated the perception that their mathematics teacher did "expect boys to do better."

When examining the data for gender opinions relating to teacher expectation of student's gender in science, almost half of the students expressed an "uncertainty" in identifying if this attribution variable was present in their science class during the study. However, slightly more than half of the girls indicated their teacher demonstrated no difference in student expectations. Since the school's administration had assigned like-gender faculty members to instruct the respective gender-separate treatment groups, the attribution variable of gender-different student expectations, if any, may have been difficult for students to determine.

**Attribution Variable V:** Relationship of teacher gender to student performance in mathematics and science.

Socializers (parents, teachers, and counselors in particular) have been shown to contribute to mathematics attitudes in a number of ways: 1) as role models, 2) by setting different expectations for males and females, and 3) by providing and encouraging different activities for female and male children (AAUW, 1992, 1995; Table 2). The results displayed in Table 20 represent strong discrepancies in gender-related responses. Attribution Variable V addresses the factor of the teacher's gender influencing the learning of mathematics and science.

Eighty percent of the boys indicate that the teacher’s gender in both mathematics and science does have an effect on their learning. Conversely, less than 20 percent of the girls indicate a similar response. In both subject areas, more than half of the girls in the study do not think the gender of their teacher influences the learning of mathematics and science.
Table 20. Frequencies of student opinion data for Attribution Variable V: Teacher's gender influences learning (N=girls [17], boys [5])

<table>
<thead>
<tr>
<th>Perceptual indicator</th>
<th>(A) Yes</th>
<th>(B) No</th>
<th>(C) Uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Do you think the gender of your mathematics teacher has an effect on your learning?</td>
<td>Girls 3(18%)</td>
<td>9(53%)</td>
<td>5(29%)</td>
</tr>
<tr>
<td></td>
<td>Boys 4(80%)</td>
<td>1(20%)</td>
<td>0</td>
</tr>
<tr>
<td>19. Do you think the gender of your science teacher has an effect on your learning?</td>
<td>Girls 2(13%)</td>
<td>10(63%)</td>
<td>4(25%)</td>
</tr>
<tr>
<td></td>
<td>Boys 4(80%)</td>
<td>1(20%)</td>
<td>0</td>
</tr>
</tbody>
</table>
CHAPTER V. SUMMARY, CONCLUSIONS, LIMITATIONS, DISCUSSION, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate mathematics and science student performance of a single-sex learning environment. The research was undertaken by the administration and faculty of an elementary, independent coeducational day school in Miami, Florida, as an exploratory study to address the gender differences in the participation and achievement of girls in mathematics and science. This being Cushman School's initial efforts in implementing an experimental design and statistical analysis of a "field-based study," the administration contacted the leaders of the Iowa State University School Improvement Model (SIM) to assist in evaluation of the study.

Aware of the growing enthusiasm for single-sex classes as intervention strategies designed to increase the participation and achievement of girls in mathematics, school personnel prepared for the implementation of single-sex classes in mathematics and science for one grade level in the fall of 1994. School officials decided that all students in the fifth grade class would be assigned to the gender separate treatment groups for the 1994–1995 academic year. The fifth grade class at Cushman comprised 28 students: 19 girls and 9 boys. The mathematics and science curricula were delivered through the use of an interdisciplinary approach for approximately 90 minutes daily. The school's administration assigned like-gender faculty members to instruct the respective gender treatment groups. The two faculty members were given a common planning period to provide similar instructional experiences for both single-sex classrooms.
This research study used a quasi-experimental, single-group (pretest/posttest) design. The design was selected by the faculty of the participating school. The following instruments were utilized to measure academic growth and student performance: 1) criterion-referenced mathematics and science examinations (pretest/posttest assessments aligned with the respective state's grade level curriculum), 2) standardized mathematics and science achievement tests (Stanford Achievement Test [Eighth Edition]), and 3) Cushman School year-end mathematics and science report card grades.

The literature reviewed for this investigation identified numerous attribution variables which influence students' perceptions of their own achievement, benefits, and attitudes toward the study of mathematics and science. A Student Response Inventory was designed to examine the gender difference in student opinion data relating to five categories of attribution variables.

This study was designed to answer the following questions: 1) Will girls and boys demonstrate similar academic performance, when assigned to a single-sex mathematics and science class, as measured by year-end report grades? 2) Will girls and boys demonstrate similar academic achievement, when assigned to a single-sex mathematics and science class, as measured by standardized achievement tests? 3) Will girls and boys demonstrate similar academic growth, when assigned to a single-sex mathematics and science class, as measured by criterion-referenced examinations (aligned with the respective state's grade level curriculum)? 4) If statistically controlling for gender differences in previous academic achievement, will girls and boys demonstrate similar academic performance, when assigned to a single-sex mathematics and science class as measured by year-end report grades? 5) If statistically controlling for gender difference in previous academic achievement, will girls and boys demonstrate similar academic growth, when assigned to a single-sex mathematics and science class, as measured by criterion-
90

referenced examinations (aligned with the respective state’s grade level curriculum)? 6) Will girls and boys have similar perceptual opinions regarding five categories of achievement-related beliefs (attribution variables), which may influence the learning of mathematics and science, after one year of instruction in a single-sex mathematics and science class?

Although all independent t-tests for between group analyses indicated no significant gender differences, statistically controlling for gender differences in previous academic achievement (MSAT, SSAT) was undertaken in this study for several reasons. Research shows that one result of bias in standardized testing is that scores may provide an inaccurate picture of girls’ and boys’ abilities. On average, girls receive higher grades than boys at all levels of schooling yet score lower than boys on standardized tests (particularly, those administered at the secondary level). The results of this study corroborate such findings.

Because the findings indicated no significant differences, this investigator proceeded with a more rigorous approach (ANCOVA) for testing between treatment group differences. Analyses of covariance (ANCOVA), adjusting for preexisting differences among the groups (using MSAT and SSAT scores as the covariates), did yield significant results when testing for gender differences on year-end mathematics and science report card grades (GPA).

Research on these questions was conducted to strengthen the knowledge base concerning the effectiveness of single-sex mathematics and science instruction as a vehicle to promote girls’ participation and achievement in mathematics and science. Evidence supports that instructing students in single-sex classroom environments for mathematics and science does increase the likelihood of similar performance by both gender. The results of this study indicate that single-sex classroom instruction in mathematics and science does positively impact the learning and performance of girls.
Conclusions

1. The participants in the study demonstrated commendable academic performance as measured by year-end report cards in mathematics report card grades. The girls’ performance resulted in a mean mathematics GPA of 3.40; the boys reported a year-end mathematics GPA of 3.17. Overall, the total group reported a mathematics GPA of 3.35. There was no significant difference between the girls and the boys in academic performance in mathematics throughout the study.

2. Overall, the participants demonstrated a slightly higher level of academic performance in science than in mathematics, as measured by year-end report grades. The total group GPA mean in science was 3.53. Although the mean GPA score for girls (3.72) appears to be much higher than the boys’ mean GPA score (3.05), it is not significantly higher.

3. As measured by year-end mathematics and science report card grades, girls and boys were able to demonstrate similar academic performance when assigned to gender separate classes for mathematics and science. Although Cushman School has a standardized grading scale, the gender differences in year-end report card grades (GPA) may be a result of differences in grading philosophy, practices, and/or criteria of the teachers participating in the study.

4. The participants also demonstrated they were highly capable students as measured by grade level equivalent scores from the Stanford Achievement Test (SAT), Total Mathematics Battery. In contrast to the mean GPA gender differences in mathematics, the boys achieved a slightly higher mean SAT score (9.70) than the girls (8.26).

5. Boys also outperformed the girls in the Stanford Achievement Test (SAT), Science Battery. However, the difference was minimal (mean difference of .87). The boys’ mean
grade level equivalent score was 9.16 and the girls’ mean score was 8.29. Once again, there was no significant gender difference in achievement. The overall gender differences in MSAT and SSAT grade level equivalent scores may be related to the sex differences in standardized achievement test performance highlighted in Table 3.

6. In both subjects, the girls demonstrated higher academic performance, as measured by year-end report card scores; however, the boys performed at a higher achievement level in both subjects, as measured by respective standardized achievement tests.

7. As measured by standardized achievement tests in mathematics and science, girls and boys are able to demonstrate similar academic achievement when assigned to gender separate classes for mathematics and science.

8. Each gender demonstrated some growth between the pre/posttest administration of the criterion-referenced mathematics and science examinations. Girls and boys demonstrated modest, yet similar gain scores in mathematics (girls, 1.16; boys, 1.30). In science, the girls’ gain score (4.83) was moderately higher than the boys’ (2.14). This moderate gain for girls in science did yield statistically significant results. In overall pre/posttest treatment comparisons between gender, the boys outperformed the girls on all of the criterion-referenced examinations. All in all, no between group treatment comparisons resulted in significant differences. Summarizing these findings, girls and boys were able to demonstrate similar academic growth when instructed in single-sex mathematics and science classes.

9. All the participants did demonstrate some academic growth in both mathematics and science, as measured by the respective criterion-referenced examinations; however, in most instances when these same examinations have been administered in neighboring districts, the results generally reflect considerably higher gain scores (SIM, 1995). The modest gain scores
may reflect a lack of alignment between the participating school's grade level curriculum and
the content strands assessed on the criterion-referenced examinations. And, the administration
of the pretest examinations, three months following the initial implementation of the single-sex
classes, may have limited the potential for optimal student growth as measured by the criterion-
referenced gain score analyses.

10. Both analyses of covariance (ANCOVA) of mathematics and science achievement
(MSAT, SSAT) on mathematics and science performance (GPA) resulted in statistically
significant differences for the regression analysis and the ANOVA. The ANCOVA generated
raised GPA means for the girls, due to lower SAT scores (mathematics GPA: 3.40 to 3.55;
science GPA: 3.72 to 3.76), and lowered GPA means for the boys, due to higher SAT scores
(mathematics GPA: 3.17 to 2.72; science GPA: 3.05 to 2.95). Overall, these results indicate,
when statistically controlling for previous achievement (MSAT, SSAT), gender differences in
mathematics and science performance (GPA) do exist.

11. Neither of the analysis of covariance (ANCOVA) of mathematics or science
achievement (MSAT, SSAT) on mathematics and science gain scores resulted in significant
differences between the covariates and the dependent variables. Therefore, when statistically
controlling for previous achievement between gender, there was no need for the ANCOVA to
make adjustments in the covariates (generating adjusted mean scores on the dependent variables
[mathematics and science gain scores] in the ANOVA analysis).

12. Although it is difficult to draw general conclusions from the five categories of
attribution variables surveyed in the Student Response Inventory, a pattern of gender
differences seemed to emerge. The results indicate a slightly stronger perception among the
boys as to the degree of influence the attribution variables may have in learning materials and
science. Results similar to these are reflected in the literature. Possible explanations for these gender differences are highlighted in Table 2.

Limitations

The conclusions drawn from this study are constrained by the limitations listed below. Approximately half of the limitations are due to the design of the study.

1. All students and teachers were from a single school and grade level. Due to the participating school’s enrollment criteria (academic and financial), issues relating to the uniqueness and homogeneity of this sample may limit the generalizing of these findings in normally distributed elementary school populations. Further study of student performance from a variety of schools in size, location, and educational organization would increase the diversity of students in the sample.

2. The sample of participants (26) was small due to the limited number of students enrolled in the participating grade level. Class size is typically small in this school.

3. The sample population did not contain an equal number of girls (19) and boys (7) in the treatment groups. There were almost three times as many girls in the study.

4. It was not feasible to use a control group as there was no pool of similar students available. And, due to the involvement of only one grade level, it was not possible to randomly assign the participants to treatment groups.

5. The treatment groups consisted of students attending an elementary, independent coeducational day school. For students in grades 1–6, annual tuition is approximately $6,400. This type of financial investment by families for elementary age students represents a significant financial commitment for young students’ education.
6. Traditionally, enrollment is designated for girls and boys of average and above average development and learning ability. Overall, this represents a highly capable, motivated group of participants.

7. The criterion-referenced mathematics and science examinations (aligned with the respective state’s grade level curricula) may not have been in total alignment with the mathematics and science grade level curricula implemented during the investigation. The teachers in the study incorporated new curriculum materials to support the interdisciplinary approach for mathematics and science utilized in the study.

8. School personnel administered the mathematics and science pretest examinations approximately three months following the implementation of the gender separate investigation.

9. School officials assigned like-gender faculty members to instruct the respective gender treatment groups. Assigning the same teacher to deliver the instruction to both treatment groups may have minimized the influencing effect of the teacher as a variable.

10. Students were asked to complete the Student Response Inventory during the final month of the study. No attempt was made to collect student opinion data regarding the five categories of attribution variables prior to the students’ participation in the study.

11. No formal attempt was made to collect parent or teacher feedback throughout the study. Periodically throughout the investigation, school personnel provided informal progress reports.

Discussion

Single-sex classes are attracting a significant amount of national attention and debate. The classes generally fall into two categories: 1) those designated to redress past inequities in
mathematics and science using a single-sex approach to instruction; 2) those meant to prepare
girls to participate fully in mixed-sex mathematics and science classrooms (AAUW, 1995). The
focus of this study was to examine the effects of mathematics and science student performance
in a single-sex learning environment.

The findings in this study indicate the gender gap in mathematics can be reduced or
eliminated by changing teaching practices and providing opportunities for both girls and boys to
practice building mathematics skills. Lee and Bryk (1986) and Riordan (1990) indicate that
single-sex schooling does tend to benefit students, especially females. Compared with females
in mixed-sex schools, females in single-sex schools were more interested in math and English,
associated with more academically oriented friends, spent more time on homework, and
enrolled in more mathematics classes.

The hypotheses that instructing students in single-sex classroom environments for
mathematics and science would increase the likelihood of similar performance by both genders
were supported. Overall, the results of this study indicate that single-sex classroom instruction
in mathematics and science does positively impact the learning performance of girls (Leder &
Forgasz, 1994; Lee & Bryk, 1986; Roirdan, 1990). At a minimum, the data analyzed show
neither girls nor boys were disadvantaged in the gender separate design.

Although slight gender discrepancies were noted, only two of the analyses were
statistically significant: 1) girls demonstrated significantly more academic growth between the
administration of the pre/posttest criterion-referenced examinations in science than did boys; 2)
when statistically controlling for previous mathematics and science achievement (using students’
MSAT and SSAT as covariates), the adjusted mean GPA scores for the girls were raised in both
mathematics and science and lowered for the boys in both subjects areas.
Despite the fact that the specter of a mathematics gene favoring males is often in the news, there is strong evidence against arguments for biological/genetic causes of gender differences in mathematics (AAUW, 1992). This study would corroborate such findings. The gender gap in mathematics is rapidly decreasing (U.S. Department of Education, 1993; CCSSO, 1995). Genetic differences tend to remain stable (AAUW, 1995). Gender differences in mathematics achievement are not consistent across racial/ethnic groups (CCSSO, 1995; AAUW, 1995). If there were a sex-linked mathematics gene, differences would be consistent across all groups.

Even though the review of literature did address sex differences in mathematical ability and problem solving and gender differences in spatial skills in mathematical ability, these concepts were not statistically tested in isolation during this investigation. Analyses of spatial abilities and differences and mathematical ability and problem solving are extremely complex undertakings. Although these analyses were not incorporated into this study (in isolation), this investigator felt it pertinent to research the literature related to both topics because of the influencing factors each may contribute to student performance on mathematics assessment instruments in general.

According to the literature, family and school, rather than peers, have the greatest impact on the self-esteem and aspirations of young people (Mid-Atlantic Equity Consortium and Network, 1993). A study conducted by AAUW (1992) found that pride in schoolwork and students’ feelings of being good at a lot of things declines rapidly through adolescence for both boys and girls. However, as boys found that others expressed confidence in males’ ability to do things, they grew in self-esteem. As girls found that others, including their teachers, believe that females cannot do things they believe they can, their self-esteem declines. Thus, teachers
and parents can play a key role in building self-esteem in girls. The findings relating to the five categories of attribution variables reflect similar beliefs and perception of the participants in the study.

In summary, a guarded enthusiasm is growing for single-sex classes. Most classes are generally short term in nature, intended as a bridge to a fair learning environment. Within the public school arena, organizers of single-sex classes have generally taken care to comply with Title IX requirements for nondiscrimination. This is generally done by initiating classes specifically in response to sex differences in achievement, keeping participation voluntary for male and female students and teachers (Riechmann, 1996).

As a rule, legal experts advise that girls can be the only participants in such programs as long as the classes advertise themselves as open to both girls and boys. Classes that bill themselves as “building confidence in mathematics” or “mathematics plus,” for example, have passed some federal muster (AAUW, 1995; Riechmann, 1996). But because these initiatives are so highly variable and visible in school settings, full legal consultation is advisable. The overarching importance to advance research for measuring student mathematics and science performance in single-sex environments is the underlying aspect that mathematics and science concepts permeate most academic fields.

Recommendations for Practice

Based on the information gained from the review of literature for this study, the following recommendations are offered to school personnel (AAUW, 1995; Riechmann, 1996; Frazier-Kouassi, 1992).
Teachers:

1. Adopt gender-equitable teaching strategies. Require the same effort from girls and boys; pay as much attention to compliant students as to disruptive ones; create both mixed and single-sex discussion groups.

2. Research gender issues and incorporate findings into the curriculum, emphasizing the needs and backgrounds of the students.

3. Provide an atmosphere in which girls feel comfortable aspiring, achieving, and excelling. Communicate high expectations for girls. Do not over-help them; allow them to make mistakes and solve problems on their own.

4. Encourage girls to excel in mathematics and science. Bring girls into classroom discussions and make learning about these subjects exciting and fun.

5. Request that all classrooms have the resources to create hands-on activities that will intrigue and excite students about mathematics, science, and technology.

6. Expose girls to nontraditional careers. Invite women and men in nontraditional professions to visit the classroom and take field trips to technological companies.

7. Use classrooms as teaching laboratories. For example, test using mixed-ability groupings and single-sex groupings. Experiment and share findings with other practitioners.

8. Solicit help from parents, youth groups, and community leaders in implementing ideas that promote girls' achievement.

9. Within grade levels, departments, or an entire school, initiate programs that directly address girls' self-esteem. Encourage girls to take risks.

10. Set up mentoring programs so that selected students have opportunities to spend time with either older students or adults who can help strengthen their self-esteem.
Counselors:

11. Encourage girls to pursue high-level classes in mathematics and science, regardless of career interests. Show how these classes can expand their educational and career choices.

Offer girls nontraditional models.

12. Intervene at key decision-making points: seventh and eighth grades for the gateway courses and ninth and tenth grades for the advanced courses. Enlist support of the parents.

13. Focus on career exposure rather than career choice. Providing students with many opportunities to talk with and learn about people in careers requiring mathematics and science may be more effective in helping girls select more courses in these areas than simply stressing the need for broad-based preparation.

14. Help students create support groups that address their gender needs.

15. Build ties with community groups that work with young people (such as Big Brothers/Big Sisters and local scouting organizations).

Administrators:

16. Promote awareness by gathering and disseminating enrollment information in secondary schools and standardized test score item analyses by problem type and gender.

17. Support staff development in mathematics equity to help promote equitable teaching strategies and curriculum.


19. Support staff development for other subject teachers who suffer from mathematics avoidance, to help them promote mathematics related activities and positive attitudes in their classrooms.
20. Allow short-term experimentation with single-sex classes to boost girls’ lagging mathematics and science skills or prepare for better mixed-group interaction. Ensure that the classes comply with Title IX by using them only to redress inequities and by making participation voluntary.

Recommendations for Further Research

The establishment of single-sex classes as intervention strategies, designed to increase the participation and achievement of girls in mathematics and science, should continue to be researched. As controversial as this strategy may be, it is recommended that future research be conducted at all levels of schooling (elementary, middle, and high schools). The results of this study suggest further research as described below.

1. This study should be replicated in other districts and at other grade levels. It is recommended that districts varying in size, location, socio-economic conditions, racial composition, and educational programs be used. It is recommended that future studies be conducted in both independent and public schools.

2. Further studies should expand the research to include a larger sample to permit a more statistically valid comparison between the variables. The sample should consist of an equal number of female and male participants. The participants should be randomly assigned to the gender separate instructional treatment groups.

3. Further studies should expand the data collected regarding the five categories of attribution variables. Parent and teacher feedback should also be collected.

4. Continued research efforts should conduct studies using more sophisticated research designs with multiple sections of single-sex treatment groups (incorporating a control group
[mixed-sex class] into the statistical analysis). The same instructor should teach each of the experimental sections, varying gender-specific learning strategies per section.

5. Further studies should investigate longitudinal patterns of gender differences in student performance when single-sex learning environments are implemented over time—for approximately three or four years.

6. Studies should be conducted to determine whether classroom sex-mix (in the lower grades) has an effect upon secondary course selections and post-high school career aspirations.

7. Further studies should investigate the correlation between specific academic self-concept and specific areas of academic achievement.

8. University-based researchers should team with school district personnel to promote a variety of intervention programs to increase girls' engagement in mathematics and science. Short-term activities such as conferences, workshops, and science fairs to long-term efforts involving courses and curricula, staff development, and support programs should be explored. In particular, researchers could provide the expertise in how to effectively measure the effects and impact of the various intervention strategies.
REFERENCES


Putz, D. J. (In progress). *An examination of performance on criterion-referenced math tests by fourth grade students*. Doctoral dissertation, Iowa State University, Ames, IA.


ACKNOWLEDGMENTS

In many respects, the most gratifying part of completing a doctoral program and writing a
dissertation is now, when I am able to take the opportunity to thank all of the individuals who
have helped make this milestone possible.

I would first like to express my gratitude to my major professor, Dr. Richard Manatt. He
models an uncompromising dedication to the field and challenges his students to do the same. I
also want to thank the other members of my committee—Dr. Norman Boyles, Dr. Gary
Downs, Dr. Thomas Loynachan, and Dr. Shirley Stow. Each provided support and guidance
throughout my doctoral studies and during the writing of this dissertation.

This study could not have been completed without the efforts of many others. I would
like to thank Dr. Joan Lutton and Cheryl Rogers, Cushman School administrators, for allowing
me to become involved in an exciting “action research-based” study in their school. They,
along with their faculty, should be commended for promoting single-sex instruction to foster
the engagement of girls in mathematics and science.

At times, the labors of completing a dissertation seem endless. The support and
assistance of friends and family help “make it happen.” I would like to personally thank the
following: Carisa Ripley, my niece, for her research assistance and word processing talent;
Bonnie Trede, for her tireless efforts in assembling the final product; and Frances Kayona, for
her companionship during our many study sessions.

In completing this project, I want to extend special appreciation and gratitude to two
educators who have been true inspirations for me. Don Carlson and Dr. Jim Sweeney are both
exemplary administrators who have taught me more about school administration and leadership
than they will ever know. I am forever grateful for their encouragement and guidance throughout my career.

I dedicate this study to my family: Betty Friedrich, my mother; Vicki and Bob Ripley and their children, Carisa and Brandon, my sister’s family; and Dr. Lon Wilson, my brother. Each has touched my life in very special ways. We are a family that places a high value on education, hard work, and self-discipline. How fortunate I have been to have had such a loving family to guide me, to inspire me, and to care for me. And, in memory of my father, Leo Wilson, I will always cherish his willingness to have been a model student in my “play school.”
APPENDIX A. CUSHMAN SCHOOL INTRODUCTION LETTER
Richard P. Manatt  
Professor and Program Coordinator  
Iowa State University  
N229 Lagomarcino Hall  
Ames, Iowa 50011-3190

Dear Dick,

Our separate gender instruction in math and science for the fifth graders has initially received a good reception. These details may be helpful to your doctoral student:

1. Girls - 18  
   Boys - 11
2. The girls have a female teacher and the boys have a male teacher.  
3. Each class has 1½ hours of math/science instruction daily.  

I'm excited about your doctoral students action research project. Looking forward to having you back in our area this fall.

Sincerely,

Cheryl Rogers  
Elementary Principal

CR:prb
APPENDIX B. RESPONSE LETTER TO CUSHMAN SCHOOL
Dear Cheryl:

During the past several weeks, I have been able to devote a significant amount of time toward the "Cushman School Project" of separate gender instruction for fifth graders in math and science. My review of literature, relating to previous research studies of gender equity instruction, has greatly enhanced my interest in our efforts.

At this time, we need to identify specific measures to assess student progress and achievement within the instructional model. I would like to suggest we select the 5th and 6th grade math assessment instruments developed by the School Improvement Model (SIM) at Iowa State University. The SIM instruments would bring credibility to our research efforts. The rationale for my recommendation of these instruments is the following:

1. The instruments were developed and aligned with Florida's curriculum
2. The instruments have been nationally normed by SIM
3. The instruments have been designed to reflect reliability and validity

The assessment instruments should be administered in the near future to provide us with the opportunity to establish a pre test/post test research design. We would then re-administer the instruments in the spring. We should discuss the process and logistics of the test administration as soon as possible.

Once we have established the instruments for measuring student progress and achievement, I would like to discuss the following aspects of our endeavor:

1. Student Feedback of the Model
2. Longitudinal Achievement Data
3. Access to Student Enrollment Data
4. Curriculum Material and Publisher's Instruments

5. Expansion of the Project for 1995-1996

I look forward to working with you as we undertake our research project at Cushman School and hope to be able to visit your school this year.

Sincerely,

[Signature]

Teri J. Wilson
APPENDIX C. CUSHMAN SCHOOL PARENT LETTER
January 23, 1995

Dear Fourth and Fifth Grade Parents,

As you know, in the fifth grade math and science are being taught to classes of single gender. Our intent is to be proactive in engendering the achievement of both boys and girls.

We are fortunate that Dr. Richard Manatt, Professor of Educational Administration at Iowa State University, has become interested in our project. Through the administration of pre and post tests, data will be gathered over several years on gender - separate instruction in math and science.

Dr. Manatt and his associate, Teri Wilson, will be at Cushman on January 30, our teacher workday. We invite you to hear their views on our separate gender project from 11:00 to 11:45 A.M. on that day in the library.

Fifth grade students only are invited to meet with Dr. Manatt and Ms. Wilson on January 30 from 10:00 - 11:00 A.M. Student input is needed.

Please R.S.V.P. to the main office if you and/or your child will be at Cushman on January 30.

Thank you for your support.

Sincerely,

Cheryl Rogers
Elementary Principal
APPENDIX D. CUSHMAN SCHOOL AUTHORIZATION LETTER
March 7, 1995

Dr. Richard P. Manatt
Educational Administration
N229 Lagomarcino Hall
Iowa State University
Ames, Iowa 50011

Dear Dr. Manatt:

This memorandum grants you permission to use The Cushman School student achievement and student feedback data for conducting analysis of same for Cushman purposes.

You also are authorized to use such data, assign such data, and to have analyzed such data, for use in dissertations by appropriate candidates under your supervision.

Sincerely,

Joan D. Lutton, Ed.D.
Headmistress

Cheryl Rogers
Elementary Principal

592 Northeast 60th Street • Laura Cushman Circle • Miami, Florida 33137
APPENDIX E. CUSHMAN SCHOOL PARENTAL PERMISSION LETTER
Dear Fifth Grade Parents:

Data have been and will be collected this year regarding the single gender math and science classes in the fifth grade. The data in the form of pre-tests and post-tests will be used to assess the effectiveness of our program.

The data will be compiled in a summative report. If you would prefer that your child's results not be analyzed in this report, please fill out the form below and return it to me by April 18, 1995.

Information about your child will only be used for the purpose of the study. We hope to have all students be a part of the study so that a clear analysis of the program will be generated.

Please feel free to call me with any questions.

Sincerely,

Cheryl Rogers
Elementary Principal

I prefer that my child's, ________________________________

pre-test and post-test results not be used in analyzing Cushman's fifth grade single-gender math and science program.

Date ________________________________

Parent or guardian ________________________________

592 Northeast 60th Street • Laura Cushman Circle • Miami, Florida 33137
APPENDIX F. HUMAN SUBJECTS RELEASE FORM
Information for Review of Research Involving Human Subjects

Iowa: 126 University

Preparing Independent Schools for Precise Measurement

1. Title of Project of Student Achievement: A Research Study of Single Sex Instruction in Elementary School Mathematics and Science

2. I agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects are protected. I will report any adverse reactions to the committee. Additions to or changes in research procedures after the project has been approved will be submitted to the committee for review. I agree to request renewal of approval for any project continuing more than one year.

Terri J. Wilson
Typed Name of Principal Investigator

3/21/95
Date
Signature of Principal Investigator

Professional Studies
Department

N225A Lagomarcino Hall
Campus Address

294-4143
Campus Telephone

3. Signatures of other investigators

4. Principal Investigator(s) (check all that apply)

☐ Faculty ☐ Staff ☑ Graduate Student ☐ Undergraduate Student

5. Project (check all that apply)

☐ Research ☐ Thesis or dissertation ☐ Class project ☐ Independent Study (490, 590, Honors project)

6. Number of subjects (complete all that apply)

# Adults, non-students # ISU student # minors under 14 # minors 14 - 17

7. Brief description of proposed research involving human subjects: (See instructions, Item 7. Use an additional page if needed.) This proposed study will assist an independent elementary school (Cushman School, Miami, Florida) assess and analyze student achievement data and student response feedback regarding the school's recent implementation of single sex instruction for mathematics and science. All fifth graders (approximately 30 students) are presently receiving mathematics and science instruction within single sex environments. The school has requested the same assessment measurements be provided to the sixth grade students (approximately 30 students). However, the school is presently instructing the sixth graders in a traditional model. Cushman School initiated the single-sex instructional design as an "action research laboratory" to gather more precise student achievement data regarding gender separate instruction. School administrators informed the parents in the Spring of 1994 that the gender separate approach would be implemented in the Fall of 1994.

8. Informed Consent: ☐ Signed informed consent will be obtained. (Attach a copy of your form.)

☑ Modified informed consent will be obtained. (See instructions, item 8.)

☐ Not applicable to this project.
9. Confidentiality of Data: Describe below the methods to be used to ensure the confidentiality of data obtained. (See instructions, item 9.)

All data collected will remain confidential. Only the school personnel directly responsible for the instruction of the single sex mathematics and science classes, the school administration, and the investigators will work directly with the data. Summative data will be shared with school faculty and parents. The parents of each student participant will be provided their student's data.

10. What risks or discomfort will be part of the study? Will subjects in the research be placed at risk or incur discomfort? Describe any risks to the subjects and precautions that will be taken to minimize them. (The concept of risk goes beyond physical risk and includes risks to subjects' dignity and self-respect as well as psychological or emotional risk. See instructions, item 10.)

There are no foreseeable discomforts or risks with this study.

11. CHECK ALL of the following that apply to your research:
   - [ ] A. Medical clearance necessary before subjects can participate
   - [ ] B. Samples (Blood, tissue, etc.) from subjects
   - [ ] C. Administration of substances (foods, drugs, etc.) to subjects
   - [ ] D. Physical exercise or conditioning for subjects
   - [ ] E. Deception of subjects
   - [x] F. Subjects under 14 years of age and/or
   - [ ] Subjects 14 - 17 years of age
   - [ ] G. Subjects in institutions (nursing homes, prisons, etc.)
   - [ ] H. Research must be approved by another institution or agency (Attach letters of approval)

If you checked any of the items in 11, please complete the following in the space below (include any attachments):

Items A - D Describe the procedures and note the safety precautions being taken.

Item E Describe how subjects will be deceived; justify the deception; indicate the debriefing procedure, including the timing and information to be presented to subjects.

Item F For subjects under the age of 14, indicate how informed consent from parents or legally authorized representatives as well as from subjects will be obtained.

Items G & H Specify the agency or institution that must approve the project. If subjects in any outside agency or institution are involved, approval must be obtained prior to beginning the research, and the letter of approval should be filed.

Item F: Cushman School administrators have informed all of the participating students' parents of their school's "action research design" to measure student achievement within a single-sex instructional model. As the legally authorized representatives of Cushman School, the Head of School and Principal have requested assistance from and given written consent to the investigators for the purposes of analyzing and interpreting student achievement data and student response feedback.
Checklist for Attachments and Time Schedule

The following are attached (please check):

12. **X** Letter or written statement to subjects indicating clearly:
   a) purpose of the research *(See attached correspondence from Cushman School)*
   b) the use of any identifier codes (names, #'s), how they will be used, and when they will be removed (see Item 17)
   c) an estimate of time needed for participation in the research and the place
   d) if applicable, location of the research activity
   e) how you will ensure confidentiality
   f) in a longitudinal study, note when and how you will contact subjects later
   g) participation is voluntary; nonparticipation will not affect evaluations of the subject

13. □ Consent form (if applicable)

14. **X** Letter of approval for research from cooperating organizations or institutions (if applicable)

15. **X** Data-gathering instruments

16. Anticipated dates for contact with subjects:
   **First Contact**
   - January 30, 1995 (Planning Conference)
   **Last Contact**
   - August 29, 1995

17. If applicable: anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased:

18. Signature of Departmental Executive Officer
   - **Daniel C. Robinson**
   - 3/21/95
   - **120**
   - **Department or Administrative Unit**

19. Decision of the University Human Subjects Review Committee:
   - **X** Project Approved
   - **Project Not Approved**
   - **No Action Required**

   - **Patricia M. Keith**
   - 4-11-95
   - **Signature of Committee Chairperson**

   - **Name of Committee Chairperson**
   - **Date**
   - **Signature of Committee Chairperson**

   GC: 1/90
Brief description of proposed research involving human subjects:

Cushman School administrators requested assistance from one of the investigators regarding methodologies for measuring student achievement and soliciting student feedback in regards to the instructional design. The investigators will assist school personnel with analyzing and interpreting student achievement data via the following assessment measures:

1) Standardized Tests (Stanford Achievement Tests)
2) Criterion-Referenced Tests (Pre/Post Tests using the Monroe County, Florida, Instruments)
3) Cushman School Annual Report Cards
4) Student Response Inventory (Multiple Choice and Narrative Format)

School administrators have informed the investigators that at the initial parent meeting in the Spring of 1994, no parent objected to their student's participation in the "action research design" to measure student achievement within a single sex instructional model. Therefore, school personnel will be administering the above listed instruments to all of the fifth graders. The sixth graders will be assessed with all of the instruments, excluding the Student Response Inventory. Student achievement data will be disaggregated by gender and grade level. (See attached correspondence to parents and Iowa State University from Cushman School).
APPENDIX G. STRANDS FOR MATHEMATICS PROGRAM (MONROE COUNTY, FLORIDA)
Strands for the MATHEMATICS Program
Monroe County Schools
Key West, Florida

The NUMBER SENSE strand involves a study of the system of numbering, i.e., reading and writing of numbers, place value, factoring, regrouping of members, and order relation between numbers.

The ADDITION strand includes the study of performing the basic operation of combining two or more quantities to arrive at a sum.

The SUBTRACTION strand involves a study of performing the basic operation of finding the difference between two numbers.

The MULTIPLICATION strand includes the study of performing the basic operation of repeating any given quantity a certain number of times.

The DIVISION strand includes the study of performing the basic operation of finding how many times one quantity is contained in another.

The EQUATIONS AND INEQUALITIES strand includes the study of number sentences.

The PROBLEM SOLVING strand includes the procedures for solving problems.

The MONEY strand involves studying the value of coins and currency.

The TIME strand involves studying and understanding the process of measuring a duration via clock and/or calendar.

The MEASUREMENT strand involves studying and understanding the common units of reference by which the extent, dimensions, quantity, degree, or capacity of an object is determined. (The common units of measure include linear, surface, volume, and weight.)

The PROBABILITY AND STATISTICS strand involves the predictions and conclusions drawn from the study of data.

The GEOMETRY strand includes studying the relations, and properties of solids, surfaces, lines, and angles.

The LOGIC strand involves studying the elements of a set, set notation, and deductive and inductive reasoning.

(All of the above concepts may include, though not specifically stated, practical situations, use of graphs and tables, and use of various methods, the computer, calculator, and other forms of technology.)
APPENDIX H. STRANDS FOR SCIENCE PROGRAM
(MONROE COUNTY, FLORIDA)
STRANDS for the SCIENCE Program

Monroe County Schools
Key West, Florida

SCIENTIFIC INVESTIGATION AND PROBLEM SOLVING promotes the development of curiosity, experimentation, creativity and cooperative learning through the use of materials, equipment and techniques.

LIFE SCIENCE promotes the understanding of one's self and the living world.

PHYSICAL SCIENCE promotes the understanding of matter and energy and their relationship to man and the world.

EARTH/SPACE SCIENCE promotes the understanding of the interaction among space, earth, water, air and man.

SCIENCE FOR PERSONAL DEVELOPMENT promotes the understanding of the use of science and technology and their contributions to the informed choices students make in their personal and social lives.

INTEGRATION OF SCIENCE AND TECHNOLOGY AND OTHER DISCIPLINES promotes effective transfer of scientific knowledge between science and other areas of learning.
APPENDIX I. STUDENT RESPONSE INVENTORY
The following questionnaire has been developed to gather data reflecting your attitude(s) and perception(s) toward the learning of mathematics and science related curricula. Please respond to each item as accurately as possible, using the various response scales.

1. Knowledge of mathematics will be of some use in everyday life.
   A = Strongly Agree       B = Moderately Agree
   C = Uncertain           D = Moderately Disagree    E = Strongly Disagree

2. Knowledge of science will be of some use in everyday life.
   A = Strongly Agree       B = Moderately Agree
   C = Uncertain           D = Moderately Disagree    E = Strongly Disagree

3. Knowledge of mathematics will have practical value for me in earning a living.
   A = Strongly Agree       B = Moderately Agree
   C = Uncertain           D = Moderately Disagree    E = Strongly Disagree

4. Knowledge of science will have practical value for me in earning a living.
   A = Strongly Agree       B = Moderately Agree
   C = Uncertain           D = Moderately Disagree    E = Strongly Disagree

5. Mathematic courses are needed for my intended major field or future work.
   A = Strongly Agree       B = Moderately Agree
   C = Uncertain           D = Moderately Disagree    E = Strongly Disagree
6. Science courses are needed for my intended major field or future work.
   A = Strongly Agree   B = Moderately Agree
   C = Uncertain       D = Moderately Disagree   E = Strongly Disagree

7. Describe the attitude of your mother toward your pursuit of mathematics.
   1 = Very Supportive   2 = Moderately Supportive
   3 = Neither Favorable nor Unfavorable
   4 = Moderately Unfavorable   5 = Very Unfavorable

8. Describe the attitude of your mother toward your pursuit of science.
   1 = Very Supportive   2 = Moderately Supportive
   3 = Neither Favorable nor Unfavorable
   4 = Moderately Unfavorable   5 = Very Unfavorable

9. Describe the attitude of your father toward your pursuit of mathematics.
   1 = Very Supportive   2 = Moderately Supportive
   3 = Neither Favorable nor Unfavorable
   4 = Moderately Unfavorable   5 = Very Unfavorable

10. Describe the attitude of your father toward your pursuit of science.
    1 = Very Supportive   2 = Moderately Supportive
     3 = Neither Favorable nor Unfavorable
     4 = Moderately Unfavorable   5 = Very Unfavorable

11. I like mathematics.
    A = Almost Always   B = Sometimes
     C = Uncertain
     D = Seldom   E = Almost Never

12. I think I am good at mathematics.
    A = Almost Always   B = Sometimes
     C = Uncertain
     D = Seldom   E = Almost Never
13. I like science.
   A = Almost Always  B = Sometimes  C = Uncertain
   D = Seldom  E = Almost Never

14. I think I am good at science.
   A = Almost Always  B = Sometimes  C = Uncertain
   D = Seldom  E = Almost Never

15. I think I'm good at a lot of things.
   A = Almost Always  B = Sometimes  C = Uncertain
   D = Seldom  E = Almost Never

16. Do you think your math teacher has different expectations for girls and boys?
   A = No Difference  B = Expects girls to do better
   C = Expects boys to do better  D = Uncertain

17. Do you think your science teacher has different expectations for girls and boys?
   A = No Difference  B = Expects girls to do better
   C = Expects boys to do better  D = Uncertain

18. Do you think the gender of your math teacher has an effect on your learning?
   A = Yes  B = No  C = Uncertain

19. Do you think the gender of your science teacher has an effect on your learning?
   A = Yes  B = No  C = Uncertain