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ABSTRACT

The mathematics achievement and mathematics attitudes of eighth-grade female students attending independent coeducational middle schools were compared with those of students in independent all-girls middle schools. Participants were 467 8th-grade girls from 10 all girls middle schools, 208 girls from 10 independent coeducational middle schools, and 123 11th and 12th grade girls from 2 independent high schools. An attitude questionnaire was completed by all subjects, and achievement test data were obtained. Results from high school students were used to support attitude measures. The only statistically significant difference in mathematics achievement was found for one (higher) level of the Comprehensive Testing Program. Overall, large differences were not found for mathematics achievement quantitative ability or attitude for mathematics for eighth-grade girls in single-sex or coeducational schools. Implications for mathematics education for females are discussed. (Contains 6 tables and 62 references.) (SLD)

Single-Gender Education Versus Coeducation for Girls: A Study of Mathematics Achievement and Attitudes Toward Mathematics of Middle-School Students

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Purpose of the Study

The purpose of this study was to determine whether or not there were identifiable and statistically significant differences between the mathematics performance and attitudes toward mathematics of females who attended independent all-girls schools at the middle-school level compared with females who attended independent coeducational middle schools. It is important to investigate differences in the mathematics achievement and attitudes toward mathematics of females from different school sectors in order to ascertain whether different school types at the middle-school level are able to create environments that encourage girls not only to pursue mathematics courses but also to be successful in them.

Riordan (1990) has encouraged educators to "learn more about the potential efficacy of single-sex educational environments" (p. 152). Bauch (1988) has insisted that it is important to continue the single-gender option due to the consistent superior academic performance of students in single-gender schools compared with those in coeducational schools, particularly in mathematics and science. Lee and Marks (1990) reported that single-gender schools "empower" females and enable them to establish goals and values that differentiate them from females in coeducational schools.

In contrast to these researchers, LePore and Warren (1997) recently have concluded that since the 1980s coeducational schools may have succeeded in reducing previous gender bias favoring males in American classrooms. From an analysis of the National Educational Longitudinal Study (NELS) of 1988, they concluded that there were few differences between single-gender and coeducational Roman Catholic high schools on both 10th- and 12th-grade student achievement and psychological outcomes. Similarly, the research conducted by Gilligan (1982), Brown and Gilligan (1992), Shmurak (1998), Signorella, Frieze, and Hershey (1996), and the American Association of University Women (1998) has raised questions about the automatic advantages of single-gender schools for girls and, in particular, for middle-class and upper middle-class female students.

The results of other research have shown a strong interconnection between mathematics achievement and sociological and attitudinal variables (Hanson, 1992; Kloosterman, 1990; Meyer & Koehler, 1990). Students' attitudes toward mathematics and mathematics learning have been investigated by several researchers (Aiken, 1963; Emmerich & Shepard, 1982; Fennema & Sherman, 1977; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Lee & Bryk, 1986; Reyes, 1984; Tobias, 1987) with differing results.

There is little available research comparing the educational effects of females in single-gender middle schools with those in coeducational middle schools, particularly in regard to mathematics achievement. In a study in which he compared the achievement and affective effects of attending single-gender and coeducational Roman Catholic high schools, Marsh (1989) found that school type had almost no effect on academic achievement or affective outcomes during the last 2 years of high school and, therefore he concluded that "the onus of proof lies with other researchers to show that school type does have an effect during a different developmental period or over a longer period of time" (p. 81). Because a current trend in public education included the establishment of single-gender middle schools for both males and females (Rothstein, 1996), it was timely to investigate whether similar educational and affective benefits in mathematics were achieved by females who attended single-gender middle schools.

Research Design

This is a comparative study in which the mathematics achievement and attitudes toward mathematics of eighth-grade female students attending independent coeducational middle schools were compared with the mathematics achievement and attitudes toward mathematics of eighth-grade female students attending independent all-girls middle schools. The dependent variables, students' attitudes toward mathematics and students' mathematics achievement were assessed relative to the independent variables of middle-school sector, single-gender or coeducational. A questionnaire was used to evaluate students' attitudes toward mathematics in order to determine differences between the two school sectors. Tests of statistical significance were used in order to compare the mathematics achievement, as reported on standardized tests, of students at the two school sectors.

Procedures

Participants in this study consisted of 467 eighth-grade girls from 10 independent all-girls middle schools, 208 eighth-grade girls from 10 independent coeducational middle schools, and 123 eleventh- and twelfth-grade girls from two independent coeducational high schools. The participating independent schools were all members of the National Association of Independent Schools (NAIS) and included schools from across the United States.

An attitude questionnaire constructed and previously piloted was used to assess students' attitudes toward mathematics (see Gilson, 1999). On the response sheets, students also identified whether they attended single-gender or coeducational middle schools, the number and level of mathematics courses they had taken, and the mathematics courses in which they currently were enrolled.

Collected test score data were students' most recent quantitative achievement and ability scores from the Comprehensive Testing Program III (CTP III) published by the Educational Records Bureau (ERB). CTP III quantitative achievement and quantitative ability scores that were reported were scaled scores that could range from 200 to 450. Most of the participating schools administered the CTP III during the Spring semester.

To make it less threatening for the participating schools to provide test data and to assure the anonymity of student participants, which was an issue for several of the schools, the questionnaire results and achievement data were anonymous and, therefore, cannot be matched to each other.

Instruments

The attitude questionnaire used in this study consisted of 29 items (see Gilson, 1999). The first five items were informational and related to students' grade levels in school, the nature of their eighth-grade school, and their current mathematics classes. The remaining 24 items were revisions of items used by researchers in similar studies and were selected from a collection of similar items provided by a professor in the Learning and Instruction Department of the School of Education at the University of San Francisco. Items were chosen that fit with the theoretical models dealing with students' self-efficacy in mathematics and their attributions of their achievement in mathematics to effort. Four of the scales related to how students perceived personal attributes. The items were designed to assess students' perceptions of their ability in mathematics, their perception of their effort in mathematics, students' academic identity in mathematics, and students' interest in mathematics. Two of the scales related to impersonal perceptions involving the relationship of ability to achievement and the relationship of effort to achievement. Each construct was addressed by 4 questionnaire items, 2 worded positively (e.g., "I think I'm a good student in math") and 2 worded negatively (e.g., "I'm not very good at math"). Students responded using a 5-point Likert-type scale, from "always agree" to "always disagree." Researchers have provided evidence of the appropriateness of constructing similar multidimensional scales to measure students' attitudes toward mathematics (Aiken, 1963; Anttonen, 1970).

A pilot testing of the questionnaire was conducted to determine the clarity of the instrument and its directions, the internal consistency of the instrument, and the construct validity of the instrument. The pilot was conducted at an independent coeducational day school that was not part of the sample population for the dissertation study. Forty-six students participated in the pilot study. Rasch scaling was conducted to scale the data for each of the six subscales. Because scales composed of small numbers of items may not have adequate reliability and may not be interval data, Rasch scaling was used to score the attitude data (Wright & Masters, 1982). In addition to obtaining internally consistent scales and interval data, the Rasch scaling yields a scoring that is "sample-free." Individuals using the attitude scales on different samples can use the same scoring as obtained in this study. Rasch scales are scored 0 to 4. To avoid interpreting negative scores, the logits were converted to a scale with the origin set at –5. The tables for converting raw scores to Rasch logits can be found in the Appendix. The lowest and highest values were obtained by imputation.

Three of the reliability coefficients are acceptable. The reliability coefficient for interest in mathematics is .68; for perception of ability in mathematics .76; and for perception of effort in mathematics .72.

ERB describes Level E of the CTP III as appropriate for students in the Spring of grade six through the Fall of grade eight. Level F is appropriate for students in the Spring of grade eight through the Spring of grade twelve. Four of the participating schools (three single-gender and one coeducational) administered Level E of the CTP III at the eighth-grade level. Two of those schools (one single-gender and the coeducational school) only administered the Quantitative Ability portion of the test at that time. Independent School Norms® for the 1997-98 administrations of the CTP III mathematics tests are provided in Table 1.

Table 1
Independent School Norms® for 1997-98 Levels E and F CTP III Mathematics Achievement and Quantitative Ability

	Mathematics Achievement 50th Percentile		Quantitative Ability 50th Percentile	
Test Level	Mean	SD	Mean	SD
	Grade 7			
Level E, Spring 1997	357.70	20.66	358.60	29.62
	Grade 8			
Level E, Fall 1997	360.80	29.34	360.90	20.97
Level F, Spring 1998	367.90	32.78	367.30	20.20

Note. From Comprehensive Testing Program III Spring, Fall Norms 1997 and Comprehensive Testing Program III Spring Norms 1998, Educational Records Bureau, 1997.

Evidence of content validity, concurrent validity, and construct validity for the CTP III tests is provided by ERB. Reliability of the CTP III was estimated using Kuder-Richardson formula #20 (KR20), standard error of measurement (SEM), item-based measure of internal consistency (r biserials), and alternate forms correlations. All reliability coefficients for the CTP III determined by using KR20 are .78 or above. The SEM for the quantitative tests is 3.1. The r biserial value for the quantitative tests is .35.

Results

An inspection of the mean scores of the two school sectors on Levels E and F (Table 2) indicates that at the seventh-grade level on Level E of the CTP III mathematics achievement, the mean score for single-gender schools is .50 SD above the independent school 50th percentile. The corresponding mean quantitative ability score for single gender schools is .15 SD above the independent school 50th percentile. The mean mathematics achievement score for coeducational schools on Level E is .67 SD above the independent school 50th percentile on Level E at the seventh-grade level, and the mean seventh-grade quantitative ability score on Level E for coeducational schools is .28 SD above the independent school 50th percentile.

Table 2
Means and Standard Deviations for CTP III Scores

School Sector	*n*	Mathematics Achievement Mean	SD	*n*	Quantitative Ability Mean	SD
			Grade 7 Level E			
Single Gender	195	367.79	28.40	196	363.29	18.68
Coeducational	137	371.72	20.52	136	367.04	15.47
Total	332	369.76	24.46	332	365.17	17.07
			Grade 8 Level E			
Single Gender	81	359.32	23.00	117	362.19	18.16
Coeducational	-	-	-	22	363.55	17.06
Total	81	359.32	23.00	139	362.87	17.61
			Grade 8 Level F			
Single Gender	116	379.00	28.71	154	373.34	19.90
Coeducational	49	356.96	28.23	49	360.31	19.02
Total	165	368.13	28.68	203	367.03	19.80
Overall Total	578	365.74	25.38	674	365.02	18.16

At the eighth-grade level on Level E of the CTP III, the mean mathematics achievement score for single-gender schools is approximately at the 50th percentile for independent schools (-.04 SD). The corresponding mean quantitative ability score for single-gender schools is also near the 50th percentile for independent schools (.06 SD). The mean quantitative ability score on Level E at the eighth-grade level for coeducational schools is .30 SD above the 50th percentile for independent schools. (No coeducational schools in this study administered the mathematics achievement portion of Level E at the eighth-grade level.)

At the eighth-grade level, the mean mathematics achievement score on Level F for single-gender schools is .34 SD above the 50th percentile for independent schools, and the mean quantitative ability score for single-gender schools on Level F is .29 SD above the 50th percentile for independent school norms. The mean mathematics achievement score on Level F for the coeducational schools and the mean quantitative ability score are below the 50th percentile for independent schools. For coeducational schools, the mean mathematics achievement score on Level F is .33 SD below the 50th percentile for independent schools, and the mean quantitative ability score is .35 SD below the 50th percentile for independent schools. Overall, quantitative ability and mathematics achievement scores are highly correlated (r = .84). Although the tests are distinguished from each other, they are not really testing different constructs.

Cohen's d was calculated by subtracting the mean scores at each grade and test level for the two school sectors and dividing the difference by the standard deviation of the appropriate test and grade level from the Independent School Norms® (Educational Records Bureau, 1997). A small meaningful effect was found for seventh-grade Level E mathematics achievement scores (d = .20). No meaningful effects were found for seventh-grade Level E quantitative ability scores (d = .13) or for eighth-grade Level E quantitative ability scores (d = .06). On Level F at the eighth-grade level, moderate effects between school sectors were found for both mathematics achievement (d = .67) and for quantitative ability (d = .65).

Table 3
Students' Self-Reported Descriptions of Grade, School Type, and Mathematics-Course Taking

	Single-Gender Middle Schools		Coeducational Middle Schools		Total	
	n	%	*n*	%	*n*	%[a]
8th-Grade Students	467	100.0	208	100.0	675	84.5
General Math	63	13.5	37	17.8	100	12.5
Algebra or Geometry	366	78.4	154	74.0	520	65.2
No Math Course	1	2.1	0	0.0	1	0.1
11th-Grade Students	3	100.0	67	100.0	70	8.8
Algebra or Geometry	3	100.0	23	34.3	26	3.3
Calculus or Statistics	0	0.0	39	58.2	39	4.8
No Math Course	0	0.0	2	3.0	2	0.3
12th-Grade Students	4	100.0	49	100.0	53	6.6
Algebra or Geometry	1	25.0	3	6.1	4	0.5
Calculus or Statistics	3	75.0	36	73.5	39	4.9
No Math Course	0	0.0	9	18.4	9	1.1

[a]Percentage based on total sample size of 798

Pearson product-moment correlation coefficients were calculated to determine possible relationships between the variables of achievement, ability, school sector, and grade level. When the error rate was controlled at the .05 level, the only statistically significant correlation is between mathematics achievement and quantitative ability ($r = .84$). Seventy-one percent of the variation in mathematics achievement scores is predictable by knowing students' quantitative ability scores ($r^2 = .71$). Correlation coefficients range from $r = -.03$ (mathematics achievement to school sector) to $r = .84$ (mathematics achievement to quantitative ability). The median value for the correlation coefficients is $r = .10$.

To test the hypothesis that there were no statistical differences between students' mathematics course-selection relative to the composition of their middle schools (single gender or coeducational), chi-square tests were conducted on data reported by the students on the attitude questionnaire (Table 3). A chi-square test was utilized to identify whether the differences in the number of eighth-grade students from single-gender middle schools and coeducational-middle schools taking different levels of mathematics courses at the eighth-grade level were large. No statistically significant differences were found between the groups (χ^2 (2, 621) = .94).

Raw scores on the attitude instrument were transformed based on Rasch estimates (Table 4). The new scale is a linear transformation of the Rasch logits with a mean of 50 (see Appendix for Rasch Conversion Tables). To transform the logits to a new scale, the origin was set at –5 logit to eliminate negative values in the scale. The default unit value was raised to 10. The standard deviations are specific to each scale (perception of ability in mathematics, SD = 27.30; perception of effort in mathematics, SD = 26.25; interest in mathematics, SD = 20.45; academic identity in mathematics, SD = 17.00; relationship of ability to achievement, SD = 17.80; relationship of effort to achievement, SD = 19.26). Except for academic identity and effort, the mean scores are higher for the coeducational schools than for the single-gender schools. Mean scores for interest and for the relationship of ability to achievement are lower for both groups. The standard deviations are similar for both groups, but there is more variability in both school sectors on responses to items related to perceptions of ability and effort than on items related to the relationship of ability to achievement and the relationship of effort to achievement.

Table 4
Means and Standard Deviations for Subscales of Attitude Instrument Transformed to Rasch Estimates

	Single-Gender Schools			Coeducational Schools		
Subscale	*n*	Mean	SD	*n*	Mean	SD
Ability	439	61.82	17.07	306	62.68	17.76
Effort	439	61.18	15.48	306	59.62	17.10
Academic ID	439	68.30	12.32	306	66.79	12.48
Effort/Ach	439	55.74	8.81	306	56.39	8.72
Ability/Ach	439	52.50	8.72	306	53.68	8.49
Interest	439	53.73	10.87	306	55.80	12.60

A *t* test for independent samples was computed on the attitudinal mean responses of the participants from each school sector (Table 4). No statistically significant differences at the .01 level were found between the two groups for perception of ability in mathematics ($t = -0.99$, $df = 715$), for perception of effort in mathematics ($t = 1.09$, *df* = 705), for academic identity in mathematics (t = 1.78, *df* =555); for interest in mathematics (t = -2.06, *df* = 730), for the relationship of effort to achievement (t = -0.83, *df* = 734), or for the relationship of ability to achievement (t = -2.25, *df* = 725).

Table 5
Regression Results of School Sector Effects on Mathematics Achievement, Quantitative Ability, and Attitude Toward Mathematics

Source	*df*	Sum of Squares	Mean Square	F	R Square	Adjusted R Square
		Total Mathematics Achievement				
Regression	1	293.89	293.89	0.41	0.001	-0.001
Error	576	416450.12	723.00			
Total	577	416744.01				
		Total Quantitative Ability				
Regression	1	224.22	224.22	0.63	0.001	-0.001
Error	672	237817.64	353.90			
Total	673	238041.86				
		Grade 7 Level E Mathematics Achievement				
Regression	1	1241.38	1241.38	1.92	0.006	0.003
Error	330	213765.26	647.77			
Total	331	215006.64				
		Grade 7 Level E Quantitative Ability				
Regression	1	1131.06	1131.06	3.64	0.011	0.008
Error	330	102428.16	310.39			
Total	331	103559.21				
		Grade 8 Level E Quantitative Ability				
Regression	1	34.12	34.12	0.11	0.001	-0.007
Error	137	44357.32	323.78			
Total	138	44391.44				
		Grade 8 Level F Mathematics Achievement				
Regression	1	6312.66	6312.66	20.50*	0.112	0.106
Error	163	133065.92	816.36			
Total	164	149800.91				
		Grade 8 Level F Quantitative Ability				
Regression	1	6312.66	6312.66	16.28*	0.075	0.070
Error	201	77958.85	387.86			
Total	202	84271.51				
		Attitude Toward Mathematics				
Regression	1	1.01	1.01	1.44	0.002	0.002
Error	743	521.65	0.70			
Total	744	522.66				
		Attitude Toward Mathematics Regressed on Mathematics Achievement				
Regression	3	295.43	98.48	0.55	0.11	-0.086
Error	14	2510.32	179.31			
Total	17	2805.75				
		Attitude Toward Mathematics Regressed on Quantitative Ability				
Regression	3	219.81	73.27	1.15	0.18	0.024
Error	16	1016.89	63.56			
Total	19	1236.69				

*Statistically significant at .05 level

In this study, the general method used to analyze the achievement data was regression analyses that were conducted in order to determine the effect of the independent variable (school sector) on the dependent variables (achievement in mathematics, quantitative ability, and attitude toward mathematics). Three series of regression analyses were conducted (Table 5). The first set of analyses regressed the dummy variable of school sector on the total group of 578 individual CTP III mathematics achievement scores and then separately by grade and test level. The second set of analyses regressed school sector on the total group of 674 individual CTP III quantitative ability scores and then separately by grade and test level. The third analysis regressed school sector on attitude toward mathematics. Attitude results included the data that were provided by the 123 participating high-school students who identified the type of middle-school they had attended (single-gender or coeducational). Attitude toward mathematics was then regressed on mathematics achievement and quantitative ability scores aggregated by school. Only the three scales with acceptable reliability levels were used in the regression analyses (interest in mathematics, perception of ability in mathematics, and perception of effort in mathematics)

Inspection of the results presented in Table 5 indicate that the only statistically significant variations in mean mathematics achievement or quantitative ability scores based on school sector are on Level F at the eighth-grade level. On Level F at the eighth-grade level, school sector accounted for 8% of the variation in quantitative ability scores and 11% of the variation in mathematics achievement scores. At the other grade levels and levels of the CTP III, variations in mathematics achievement and quantitative ability scores are not attributable to differences in school sector. Variations in attitude toward mathematics also cannot be ascribed to school sector. Students' attitude toward mathematics scores are not related to mathematics achievement scores or to quantitative ability scores.

Discussion

This study attempted to answer the question: At the eighth-grade level, to what extent were there identifiable and statistically significant differences in the mathematics achievement of females who attended independent all-girls schools at the middle-school level compared with their counterparts who attended independent coeducational middle schools? Examination of the results indicate that at the eighth-grade level, the only statistically significant differences in mathematics achievement were found on Level F of the Comprehensive Testing Program (CTP III).

A minor research question was: What were the differences in the quantitative ability of female students from independent all-girls middle schools and female students from independent coeducational middle schools at the eighth-grade level? Examination of the results of this study reveal that the only statistically significant differences in quantitative aptitude were found on Level F of the CTP III, and those results accounted for only 7% of the variation in the quantitative ability scores across school sectors.

Recent research has focused on independent single-gender high schools and coeducational high schools. In her longitudinal study of 56 female students from two single-gender schools and two coeducational schools, Shmurak (1998) concluded that most of the data showed no differences between the two types of schools. Using the national standard deviation of 100 for the SAT, a small effect size for school sector favoring coeducational schools was calculated ($d = .28$) using the mean scores reported by Shmurak (1998). In this research, a small meaningful effect favoring coeducational schools was found for mathematics achievement at the seventh-grade level ($d = .20$), and moderate effects favoring single-gender schools were found for mathematics achievement ($d = .67$) and for quantitative ability ($d = .65$) at the eighth-grade level. Part of this difference may be attributed to the relatively small sample size from the coeducational schools at Level F of the CTP III, or this difference actually may reflect advantages of single-gender mathematics instruction for girls at higher levels of mathematics.

Variations in attitude toward mathematics also cannot be ascribed to school sector. Students' attitudes toward mathematics scores were not related to mathematics achievement scores or to quantitative ability scores. No statistically significant differences at the .01 level were found between the two groups for perception of ability in mathematics, for perception of effort in mathematics, for academic identity in mathematics, for interest in mathematics, for the relationship of effort to achievement, or for the relationship of ability to achievement.

The mean scores on the attitude instrument for both school sectors are similar across all six scales. Students in coeducational schools on the average report a slightly stronger sense of their ability in mathematics, the relationship of effort to achievement, the relationship of ability to achievement, and interest in mathematics than students from single-gender schools. Students in single-gender schools on the average reported a slightly stronger sense of their academic identity in mathematics and a stronger sense of the effort they apply to their mathematics classes than students from coeducational schools.

Stipek (1993) claimed that age-related perceptions of ability are affected by the classroom environment and by performance feedback. Participants from both school sectors rated themselves particularly high on items related to their ability in mathematics ("I think I'm a good student in math") and on items related to their academic identity in mathematics ("When I do well in math I feel really good about myself"). Students who ascribe their success in mathematics to their mathematical ability are more likely to experience future success in mathematics and experience positive self-concept than students who attribute their success to luck or to the assistance of others (Weiner, 1984). Self-perception of mathematics abilities, not objective ability-achievement measures, is described as an important component for the formation of academic self-concept (Marsh, 1986).

Because the student participants from both school sectors in this study were similar, school differences within each sector were important to the results. The results of this study support the 1998 report of the American Association of University Women (AAUW), which cited specific successful practices and characteristics of single-gender education that may be translatable to coeducational environments. Good educational practice is not limited to a specific type of school. In their 1986 study of students in England, Bryan and Digby found nothing to suggest that either single-gender schooling or coeducation by itself produced a particular level of student performance in mathematics. All of the participating single-gender schools (n = 10) and seven of the coeducational schools in this study reported having made efforts to deal with issues of gender equity in education. Susan Bailey, the executive director of the Wellesley Centers for Women, recommended that coeducational schools should have more female administrators and adopt more of the characteristics of all-girls schools to benefit their female students (Sedgwick, 1997). Results of this study confirm the impact that addressing issues of gender equity may have on female students' academic and attitudinal outcomes in coeducational schools.

Several researchers have concluded that student backgrounds play a greater role in academic outcomes than does school environment (McEwen & Curry, 1987; Ware & Lee, 1986; White, 1982; Young & Fraser, 1990). Marsh (1991) contended that single-gender schools enrolled a superior clientele of students, and Bell (1989) concluded that achievement differences between coeducational and single-gender schools could be explained more by the characteristics of the students who attended the schools than by school-type effects. Bell reported that there was no evidence to ascribe differences in academic achievement directly to the separation of students in schools based on gender. The failure of the current study to disprove the hypothesis of no difference may be linked to the homogeneity of the student participants. Looking at the aptitude measure, it is clear that the students were equated in terms of aptitude for mathematics (Table 2). Students' self-reported descriptions of their mathematics classes (Table 3) indicated that across school sectors the majority (77%) of the middle-school participants were taking first-year algebra, geometry, or both at the eighth-grade level. Of the single-gender middle-school participants, 78.4% (n = 366) indicated they were currently taking first-year algebra, geometry, or both compared with 74% (n = 154) of the coeducational middle-school participants. No statistically significant differences were found between the mathematics course selections from the two school sectors.

It is important to consider that in most eighth-grade curriculums students study general mathematics (National Council of Teachers of Mathematics, 1989). The large number of students in the participating schools who were taking algebra, geometry, or both is indicative of a strong academic program in those schools.

From a practical view, the small effect sizes for quantitative ability at both the seventh- and eighth-grade levels ($d = .13$, seventh-grade; $d = .06$, eighth grade Level E) indicate only small differences in students' quantitative ability between the two sectors. A moderate effect ($d = .65$) was found for quantitative ability (Level F) favoring single-gender schools.

Analysis of differences in test results at different levels of the CTP III also must consider the nature of the CTP III, which is a timed-multiple-choice type test. Many of the items in both mathematics sections of the test require reading and comprehension of written material. It is not reasonable to attribute all differences in test results to mathematics achievement or ability variations alone without considering the possibility that the nature of the test itself contributed to the differences.

Research comparing single-gender education to coeducation has assumed that certain practices and conditions such as small class size, rigorous curriculums, and equitable teaching practices are typical of single-gender schools and not characteristic of coeducational schools (Kenway & Willis, 1986). Mael (1998) reported that previous research comparing the two school sectors has taken

> as a given that each school of either type embodies the qualities or deficiencies typical of that form, without considering the possibility that within-type differences due to variables such as locale, school tradition, school administration values and ideologies, and student body characteristics may be greater than between-type differences. (p. 119)

Eta square ($\hat{\eta}^2$) was calculated to determine the proportion of variance in overall mathematics achievement and quantitative ability attributable to the effect of the individual schools. For mathematics achievement, $\hat{\eta}^2$ was calculated at .22, and for quantitative ability, $\hat{\eta}^2$ was calculated at .22. Twenty-two percent of the variation in mathematics achievement and in quantitative ability scores can be accounted for by the individual schools. Differences between the individual schools were more important than differences between the school types in explaining any variation in mathematics achievement or quantitative ability scores on the CTP III.

In both the single-gender and coeducational schools in this study, 85% of the eighth-grade mathematics teachers are female. The effect of female mathematics teachers as powerful role models for female students has been documented in studies of single-gender high schools and colleges (Monaco & Gaier, 1992; Riordan, 1990). Other studies have shown that female teachers can influence girls' attitudes toward mathematics and subsequently their achievement in mathematics (Carpenter, 1985; Oakes, 1990). Several studies (Belash, 1992; Finn, 1980; Riordan, 1994) have attributed the academic achievement of students in single-gender schools partially to the presence of mostly female teachers in those schools. Teachers who provide emotional support and who are positive role models promote female students' self-confidence (Kim & Alvarez, 1995). Results from this study confirm that female teachers may be powerful influences on female students in areas such as mathematics that typically have been identified as male (Fennema & Sherman, 1977) regardless of the configuration of the school. Good female teachers are endemic not only to good single-gender schools.

On the average, both school types in this study designate approximately the same amount of time for eighth-grade mathematics classes per day (44.4 to 46.2 minutes/day). Single-gender schools in this study reported on the average slightly smaller mean eighth-grade math class sizes (M = 14.35, SD = 2.19) than coeducational schools (M = 15.83, SD = 2.87). Small class size often has been cited as a factor that works to the advantage of girls in mathematics (AAUW, 1992), and from this study it appears that that may be a more important factor in mathematics achievement for females than the overall school composition. Both school sectors reported mean class sizes that are small relative to the mean class size of public-school mathematics classes.

Implications for Research

Today, public-school districts are considering single-gender options at the middle-school level (Asimov, 1997). New options in independent schools for females also are being explored (Trager, 1997). Such current efforts intensify the need for research into the prolonged value of single-gender education below the high-school level for young females, especially in areas traditionally dominated by males such as mathematics. Further research into the benefits of single-gender education for females may provide valuable information for educators interested in providing the optimum educational opportunities for both genders.

Although the results of this study suggest that at higher levels of mathematics (Level F) there may be an advantage for single-gender middle-school students, the small sample size from the coeducational schools on Level F may not be representative of other similar schools. On both seventh-grade Level E and eighth-grade Level E scores, the means for the coeducational schools are higher than the corresponding means for the single-gender schools and are above the 50th percentile for Independent School Norms®.. Because of the small number of student scores from the coeducational sector on Level F of the CTP III (n = 116 for single-gender schools math achievement scores, n = 154 for single-gender quantitative ability scores, n = 49 for coeducational schools quantitative ability and mathematics achievement scores) additional study is needed. Further research with comparable and larger sample sizes is needed before any definitive results can be described. It cannot be determined from this study whether the reported differences on Level F of the CTP III were attributable to school effects, to the test itself, or to the characteristics of the students at the participating schools.

As Lee, Chen, and Smerdon (1996) concluded, in research related to this study, it is important to focus on data collected in classrooms, because teaching environments can vary considerably within schools, much less between school types. Clearly, teachers are central to the educational outcomes of their students, and good teachers and good teaching practices can be present in single-gender or in coeducational schools. Future research that includes at-length classroom observations is necessary in order to ascertain what is really happening in successful mathematics classrooms.

The argument for single-gender schools for girls sometimes is based on the assumption that females do worse academically in coeducational schools than males do (Steedman, 1985). For that reason, together with earlier research that reported that females achieved at a lower level in high school than their male counterparts in mathematics (Fennema & Carpenter, 1981; Lee & Bryk, 1986), further research should be conducted to compare the mathematics achievement of male and female students in single-gender and coeducational independent schools.

Similar to earlier studies (Lee & Bryk, 1986), students from both school sectors professed slight interest in mathematics despite their demonstrated achievement in the subject. These results contrast with studies indicating that girls in single-gender schools have more interest in subjects, such as mathematics, that are perceived as "masculine" (Carpenter, 1985; Finn, 1980; Monaco & Gaier, 1992; Oakes, 1990; Sadker & Sadker, 1994). Future research, therefore, should include an investigation of the views about mathematics and gender roles held by the female students from the two school types to ascertain if their attitudes toward mathematics are stereotypical.

Recent research indicated that girls are lagging behind boys in their use of computer technology (Weinman & Haag, 1999). As well, females' attitudes toward computer technology and their perceived competency with it is less positive than their male counterparts. Because of the prominence of computer technology both in educational and occupational choices, future research related to technology is an important area to focus on. Are female students from single-gender schools more at ease with computers and more likely to use them than female students from coeducational schools?

It is also important to conduct longitudinal studies to ascertain whether differences that may exist at the eighth-grade level between students from the two school sectors persist as students further their education. Are there differences at a later time in students' self-esteem, attitudes toward mathematics, and mathematics achievement? Is middle school, in fact, a crucial factor in students' ultimate educational and career choices?

<u>Conclusion</u>

This study did not find large differences in the mathematics achievement, quantitative ability, or attitude toward mathematics scores of female middle-school students from independent single-gender and coeducational schools. Several interpretations may be offered to explain these findings, including the similarities of the student populations in both school sectors, the large number of female mathematics teachers whose students participated in this study, the relatively small-size mathematics classes, and the attention to issues of gender equity by the participating schools. The differences that were found may be attributable more to the characteristics of the students enrolled at the individual schools than to the school sector.

It is also possible that the results of this study have more to do with aspects of the participating schools than with differences between single-gender and coeducational schools. Differences may be ascribed more to the between-school and within-type distinctions than to the between-sector distinctions. Because a random sample of schools was solicited to participate in this study, one might claim that only those school administrators who perceived that their female students were achieving particularly strongly in mathematics were interested in providing data for this study.

Although the differences found in this study are not large, they do emphasize the necessity for further research. In studies that have focused on higher levels of education, single-gender education for females has been found to be an important factor in females' academic success (Carpenter, 1985; Finn, 1980; Jiminez & Lockheed, 1989; Lee & Bryk, 1986; Lee & Lockheed, 1990; Riordan, 1990). The higher scores reported by the single-gender schools on Level F of the CTP III are consistent with earlier research that documented single-gender education as an important mediating variable for female achievement as females entered adolescence (Blyth, Simmons, & Ford, 1983; Brown & Gilligan, 1992; Eccles, Midgley, & Adler, 1984; Gilligan, 1982; Gilligan, Lyons, & Hammer, 1990; Lee & Marks, 1990; Nottlemann, 1987; Pipher, 1994; Proctor & Choi, 1994; Wigfield, Eccles, MacIver, Reuman, & Midgley, 1991). More recent research, however, has found that for middle-class students the academic advantages of attending an independent or public single-gender school versus an independent or public coeducational school are "virtually zero" (Riordan, 1998). Riordan (1998) reported that single-gender schools only offer advantages for "disadvantaged students." Specific practices of single-gender schools may contribute to the academic achievement of all females, but as this study confirms, these practices also may be employed successfully by coeducational schools.

The results of this study indicate that in the independent-school sector that caters primarily to middle- and upper-middle class students, it may be difficult to attribute specific characteristics to either single-gender schools or coeducational schools. Schools in this study all reported small mathematics class sizes and more female role models in mathematics. Seventy-eight percent of the participating coeducational schools reported that their schools had made efforts to address issues of gender equity. LePore and Warren (1997) speculated that the advantages associated with single-gender high schools may have diminished because coeducational schools had addressed issues of gender equity. Ware and Lee (1988) reported that students' personal and family backgrounds contributed to students' academic achievement. Academically focused parents and supportive families may be more important to students' success in school than the type of school, especially for females (Kenway & Willis, 1986; Riordan, 1998).

Because all NAIS schools are selective and all charge tuition, the socioeconomic status of most of the students at NAIS schools would be considered middle class or higher. Higher levels of SES may have more to do with female students' academic achievement than school composition does(Kenway & Willis, 1986; Riordan, 1998).

Seventy-seven percent of the eighth-grade students in this study identified themselves as currently taking algebra or geometry. Because the standard curriculum for eighth-grade mathematics in the United States is to study general mathematics (National Council of Teachers of Mathematics, 1989), it is important to note that across both school sectors, schools in this study are providing rigorous and challenging mathematics curriculums.

It is important to be cautious about making claims that one type of education is better than another without considering the particular population and social setting that are being addressed. "It is a mistake to view gender as the 'key variable' that determines a school's effectiveness" (AAUW, 1998). What is most apparent from the results of this study is the importance of good mathematics teaching regardless of school sector.

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Appendix
Table 6
Rasch Conversion Tables for Six Scales of Attitude Instrument

Raw Score	Perception of Ability Rasch Score	Perception of Effort Rasch Score	Academic Identity Rasch Score	Interest in Mathematics Rasch Score	Ability to Achievement Rasch Score	Effort to Achievement Rasch Score
0	2.59	3.54	18.65	12.00	16.35	14.84
1	13.74	12.85	27.77	20.81	24.57	22.81
2	21.89	21.70	33.75	28.48	31.62	29.93
3	27.35	27.75	37.36	33.44	36.02	34.50
4	31.86	32.71	40.11	37.36	39.42	38.10
5	35.97	37.15	42.45	40.77	42.33	41.22
6	39.94	41.33	44.58	43.92	44.96	44.09
7	43.94	45.39	46.64	46.92	47.45	46.82
8	48.08	49.43	48.70	49.88	49.88	49.51
9	52.45	53.55	50.85	52.84	52.32	52.23
10	57.12	57.81	53.18	55.89	54.84	55.07
11	62.17	62.31	55.81	59.09	57.52	58.11
12	67.64	67.15	58.91	62.59	60.50	61.50
13	73.68	72.58	62.76	66.60	64.00	65.51
14	80.76	79.11	67.91	71.67	68.54	70.66
15	90.55	88.42	76.03	79.48	75.76	78.63
16	102.10	97.73	85.15	88.29	83.98	86.60

Raw Score	Perception of Ability Rasch Logits	Perception of Effort Rasch Logits	Academic Identity Rasch Logits	Interest in Mathematics Rasch Logits	Ability to Achievement Rasch Logits	Effort to Achievement Rasch Logits
0	.*	.	.	.	.	.
1	-3.63	-3.71	-2.22	-2.92	-2.54	-2.72
2	-2.81	-2.83	-1.62	-2.15	-1.84	-2.01
3	-2.26	-2.23	-1.26	-1.65	-1.40	-1.55
4	-1.81	-1.73	-0.99	-1.26	-1.06	-1.19
5	-1.40	-1.28	-0.76	-0.92	-0.77	-0.88
6	-1.01	-0.87	-0.54	-0.61	-0.50	-0.59
7	-0.61	-0.36	-0.34	-0.31	-0.25	-0.32
8	-0.19	-0.06	-0.13	-0.01	-0.01	-0.05
9	0.25	0.36	0.08	0.28	0.23	0.22
10	0.71	0.78	0.32	0.59	0.48	0.51
11	1.22	1.23	0.58	0.91	0.75	0.81
12	1.76	1.72	0.89	1.26	1.05	1.15
13	2.37	2.26	1.28	1.66	1.40	1.55
14	3.08	2.91	1.79	2.17	1.85	2.07
15	4.05	3.84	2.60	2.95	2.58	2.86
16	.	.	.	.	.	.

*Endpoints are imputed. Endpoints are not available for Rasch logits.

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