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ABSTRACT

Gender differences in mathematics proficiency have received considerable attention. This study explored some potential gender differences in mathematics achievement using data from the 1988 National Education Longitudinal Study. Obvious gender differences in mathematics proficiency did not seem to exist when comparisons were made on central tendency measures. When the high ends of the math score distributions were examined, meaningful gender difference favoring male students emerged. These gender differences increased from the 8th to the 12th grade, and became more prominent as more extreme score ranges were examined. It is argued that the observed gender differences within the extreme score ranges are practically meaningful, since these students are very likely to be those who will consider going into areas such as science, mathematics, or engineering. Significant gender differences within these high math score ranges are likely to be one reason for the gender imbalance in the inflow of new students choosing these areas as careers. Contains 20 references. (MKR)

CHANGE IN MATHEMATICS PROFICIENCY FOR MALE AND FEMALE STUDENTS FROM 8TH TO 12TH GRADE: A STUDY BASED ON A NATIONAL LONGITUDINAL SAMPLE

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Abstract

The present study explored some potential gender difference in mathematics achievement using data from *NELS:88* national samples. Ob·ious gender difference in math proficiency dID not seem to exist when comparisons were made on cent.:al tendency measures. When the high end of math score distributions was examined, meaningful gender difference favoring male students emerged. Such gender difference became larger from the 8th to 12th grade, and became more prominent as more extreme score range was examined. It is argued that the observed gender difference within the extreme score ranges is practically meaningful, since these students are very likely to be those who will consider going into areas such as science, mathematics, or engineering, etc. Any significant gender difference within these high math score ranges are likely to be one potential reason for the gender imbalance in the inflow of new students choosing these areas as careers.

INTRODUCTION

Gender differences in mathematics proficiency has received considerable attention over the years, and the research interest intensifies as we realize that mathematics proficiency plays an important role in later educational and professional achievement. It is the purpose of this paper to examine the potential difference in math proficiency between male and female students from 8th to 12th grade. The data collected in *National Education Longitudinal Study: 1988* (NELS:88), a nationally representative longitudinal database, were used in this investigation.

Background and Perspectives

Researchers have long been interested in potential gender differences in mathematics proficiency in school years. Many studies have been conducted to investigate such differences. Most of the studies performed during the 1960s and 70s found gender differences in math achievement beginning at puberty and continuing through adulthood, with males generally having superior scores (Fennema & Sherman, 1977; National Assessment of Educational Progress, 1975, 1979; Schonberger, 1976). It has been reported, however, that gender difference in mathematics achievement did not seem to be constant across age groups. It appeared that young girls seemed to have some advantage in mathematics achievement, but such relative advantage seemed to get lost gradually. By the end of high school, some gender difference in math achievement was generally reported which tended to favor male students (Brandon, Newton, & Hammond, 1985; Callahan & Clements, 1984; Cannor & Serbin, 1985; Carpenter, Lindquist, Mathews & Silver, 1983; Dossey, Mullis, Lindquist & Chambers, 1988; Hawn, Ellet & Des Jardines, 1981). TEntatively, the period from 8th to 12th grade was suggested to be important, since it was during this transitional period that male students seemed to surpass female students in math achievement (Armstrong, 1985).

The findings in the area of gender difference in math achievement have not been consistent (Hashaway, 1981; Baker & Jones, 1993). Most of the studies conducted in this area also tended to be local studies without much comparability across studies both in terms of samples and mathematics tasks on which the performance was measured. A few meta-analysis studies have been conducted which attempted to integrate the findings from a variety of sources (Friedman, 1989; Hyde, Fennema, & Lamon, 1990; Matsumoto, 1995)). In general, meta-analytic results showed some slight superiority of male over female students in math achievement. Furthermore, such male superiority in math achievement also seems to be related to age to certain extent.

If gender difference indeed becomes more obvious as a function of age as some studies suggested, then it implies that the math proficiency of male and female students progresses at different rates over certain developmental period. From the educational point of view, it is meaningful to understand the nature of such phenomenon, as well as when and how such phenomenon occurs. Large-scale longitudinal data lend themselves well to such investigation, since many questions which are difficult to deal with in cross-sectional design, or in small-scale studies, can be addressed through longitudinal design. This paper reports the results of an exploratory study which utilized a national longitudinal database to answer the following questions:

1) What differences exist between male and female students in mathematics proficiency at 8th, 10th, and 12th grade?

2) Does the pattern of gender difference in mathematics proficiency change as students progress from 8th grade to 12th grade? And what is the nature of such change?

DATA SOURCE AND METHODS

The data source for the reported study is a nationally representative sample from the longitudinal database of *National Education Longitudinal Study, 1988 (NELS:88)*. The data collection was designed and conducted by the *National Center for Education Statistics (NCES)* under the U.S. Department of Education. As a large-scale longitudinal database, *NELS:88* follows a nationally representative sample of approximately 25,000 students from 8th grade on (1988), and data are collected every two years. Currently, three waves of data are available: data from the base year of 1988, the first follow-up of 1990, and the second follow-up of 1992. (The third follow-up data collection is currently underway).

Three major types of questionnaires (student, parent, and teacher) were administered to each student, his/her parent (one parent for each student), and teachers (two teachers for each student). Proficiency tests of reading, mathematics, science, and social studies were administered to each student. Data on a variety of variables were collected, including academic, demographic, social, environmental, psychological, and familial variables. Besides, data were also collected on students' attitudes toward mathematics and science and on the students' actual course-taking patterns (transcripts data) in schools, etc. Because of the longitudinal nature and the richness of the data, this database offers good opportunities for investigating the issue of gender difference in mathematics achievement, and math proficiency progress for male and female students during the period from 8th to 12th grade.

In *NELS:88*, the students' math proficiency was measured by mathematics proficiency tests administered during each of the three waves of data collection (1988, 1990, and 1992). Since considerable variation of mathematics proficiency existed among students sampled in 1988, it was anticipated that such variation would become larger as students progress to higher grades. Using a single form of math test would certainly produce ceiling effect for some students and floor effect for others. To avoid such ceiling and floor effect, multiple forms of math tests of varying difficulty were administered during 10th and 12th grade. These multiple test forms were equated through equation methods of Item Response Theory (IRT). Furthermore, the three math test scores collected in the three waves of data collection (8th, 10th, and 12th grade) were scaled to be on the same measurement scale through application of Item Response Theory (IRT) scaling. As a result, student performance on the math tests is expressed as IRT-estimated score which is directly comparable across the three waves of data collection without rescaling (NCES, 1994).

In this study, three waves of data (1988 for 8th graders, 1990 for 10th graders, and 1992 for 12th graders) were examined. These three waves of data collection, among other things, resulted in nationally representative samples for the three grades at the time (NCES, 1994). Potential gender differences were also examined for different ethnic groups. There is some indication that a simple comparison of two central tendency measures (those of male and female) may camouflage some meaningful differences between male and female students within different ranges of score distribution (National Science Foundation, 1992). For this reason, close attention was paid to potential gender differences near the higher end of math score distributions. In order to investigate if the math proficiency patterns between gender groups were consistent for ethnic groups, similar analyses were conducted separately for each of the four major ethnic groups: Caucasian, African-American, Hispanic-American, and Asian-American.

Due to the complex sampling design for *NELS:88* data collection, different weights were created to reflect the fact that each individual sample member in *NELS:88* represents a differential proportion of the national student population (NCES, 1994). In data analysis of this study, appropriate weights were included in analysis procedures. Since this paper focused on describing the gender differences in math proficiency, rather than on inferential hypothesis testing, the design effect, which is necessary for inferential testing, was not applicable for the data reported in this paper.

RESULTS

Lack of Obvious Gender Difference on Means

Table 1 presents the descriptive statistics on the IRT-estimated math test scores of male and female students at 8th, 10th and 12th grades. Cross-sectional weights provided in the data sets for the three grades were used in the calculation of these descriptive statistics. The use of these cross-sectional weights for the three grades produced the most accurate estimate for math proficiency for U. S. national population of 8th, 10th, and 12th grades at the time. In other words, the entires in Table 1 are weighted means and standard deviations which best represent population values.

Insert Table 1 about here

If gender difference in math proficiency is the primary focus, Table 1 data quickly show that not much difference can be found in any of the three grades. In most of the cases, male students seem to have a slight advantage over females, but the advantage does not seem to be large enough to be practically meaningful and important. Hispanic sample tends to exhibit larger gender difference favoring males than other ethnic groups. Black sample shows an opposite pattern from other ethnic groups in that females tend to have a slight advantage over male students. The effect size for the gender difference is obviously very small in the majority of cases. Although Table 1 data show very small gender difference, the difference across ethnic groups does seem to be striking in some cases. Since this is not the focus of this study, no further attempts were made in this direction.

The lack of obvious gender difference in math on central tendency measures of NELS:88 math tests seems to be discrepant with what has been generally reported in the literature, especially for students in high school, since high school years is when gender difference tends to become more obvious. Considering the representativeness of *NELS:88* sampling, such discrepancy was not expected, nor could it be readily accounted for.

Gender Difference at Higher Score Ranges

There has been some indication that gender difference in math proficiency may be camouflaged by overall central tendency measure comparisons (NSF, 1992), since gender difference may exist near the tail of score distributions. To investigate about such possibilities, the higher end of math score distributions was examined. Students within three differentially extreme math score distribution ranges were closely examined: those scored within the first quartile (at or above 75th percentile), those scored within the first decile (at or above 90th percentile), and those scored at or above 95th percentile. In examining these three score distribution ranges, close attention was paid to gender proportions within these extreme score ranges, as well as any potential shifts of such gender proportions from the 8th grade to 12th grade.

Table 2 presents male and female proportions among those who were in extreme score distribution ranges: the first quartile, the first decile, and those at or above 95th percentile. Several observations warrant comments. First of all, among those within the high score ranges, male students definitely outnumber female

Insert Table 2 about here

students by a comfortable margin. Second, such proportion differences tend to increase with grades: the hi,her the grade, the larger difference between gender group proportions is observed. For example, the proportion difference of gender groups among those in the first quartile at 8th grade is less than three percentage points (i.e., 51.14 - 48.86). When the students reached 12th grade, the difference becomes more than ten percentage points (i.e., 55.18-44.82). In other words, at 12th grade, among those who scored within the first quartile of math scores, male students outnumber female students by about 20 percent. Third, the more extreme the score ranges are, the larger the margins become. For example, the gender proportion difference becomes larger from score range of first quartile to the range of the first decile; it becomes even larger from the first decile to the range above 95th percentile. At the extreme, for those scored above 95th percentile at 12th grade, male students outnumbered female students by 2:1 (66.27 : 33.73) margin. Such trends were graphically depicted in Figure 1. Compared with the impression we earlier got from the simple comparison of central tendency measures between gender groups, the information revealed from the examination of these higher score ranges is indeed different.

Insert Figure 1 about here

In *NELS:88* data, math ability of individual students was estimated by classifying students into different hierarchical proficiency levels. Five levels of math proficiency were defined and estimated using item clusters contained in the math test. According to NCES publication (NCES, 1994), the five math proficiency levels are defined as follows:

Level 1: simple arithmetical operations on whole numbers

Level 2: simple operations with decimals, fractions, powers and roots

Level 3: simple problem solving, requiring the understanding of low level mathematical concepts

Level 4: understanding of intermediate level mathematical concepts and having the ability to formulate multi-step solutions to word problems

Level 5: proficiency in solving complex multi-step word problems and the ability to demonstrate knowledge of math material found in advanced math courses

In *NELS:88* math test, the highest level of math proficiency estimated at 8th grade is Level 3 (19% reached this level), at 10th grade is Level 4 (22% reached this level), and at 12th grade is Level 5 (close to 6% reached this level). Information about these proficiency levels, the item clusters and reliability estimates of these clusters is available elsewhere (NCES, 1994; Rock, Owings, & Lee, 1994; Rock & Pollack, 1991). Among those who reached the highest level of math proficiency at 8th, 10th and 12th grade, the composition of male and female students was examined to see if any meaningful difference in gender group proportions exist. Figure 2 presents the results of such examination.

Insert Figure 2 about here

Essentially, Figure 2 confirms what was observed in Table 2 and Figure 1: gender group proportion differences exist at the highest level of math proficiency. Such difference tends to get larger as grade becomes higher, and to become larger as more extreme proficiency level is examined. At the highest grade (12th grade) and for those who are classified into the highest level of proficiency (Level 5), the male outnumber female students by almost two to one.

The trends observed and discussed at the extreme score ranges were similar for three of the four ethnic group samples examined (Asian, Hispanic and White), with the Hispanic sample exhibiting more prominent gender differences than the total sample discussed above. The black sample, on the other hand, showed the opposite trend, with larger proportion of girls in the higher score ranges than boys. But such anomaly should be viewed with caution, since only very small number of subjects from this group scored in the higher score ranges. For example, at 12th Grade, from the black sample, only 84 (6.7%, compared with 25% for the total sample) scored in the first quartile, 13 (0.72%, compared with 10% for the total sample) scored in the first decile, and only 3 (0.25%, compared with 5% for the total sample) scored at or above 95th percentile. Due to such small numbers, no definite conclusions could be drawn.

One meaningful question about the discussion presented above might be related to the practical meaningfulness of those differences at extreme score ranges. After all, only a small proportion of students ever reach those high score ranges anyway, should we be concerned about gender difference in those score ranges at all? The answer to the question requires a perspective different from our usual mean-difference mentality. In conventional group comparison research, we are usually concerned about group mean difference. In mathematics education, however, the concern about group mean difference may not be enough, and gender difference in extreme score ranges conveys important practical meaning. To appreciate the potential impact of such gender difference in extreme score ranges, we need to relate such difference to students' future career choices.

Let's assume that 30% of high school graduates desire to be highly trained professionals in the future, and they choose and eventually go to college or university. Out of this 30% going to university, what percentage would choose careers which heavily involves mathematics, such as science, mathematics, and engineering (S&E) careers. Although no statistics are available to the author, some approximation would help to highlight the issue. According to *Longitudinal Study of American Youth* (LSAY) sponsored by the National Science Foundation (NSF), about 3.2 percent of high school seniors in 1990 reported a high level of certainty about an S&E career expectation. An additional 4.0 percent expressed a moderate level of certainty (NSF, 1992). It is logical to assume that those high school seniors who expressed high certainty about an S&E career tend to be those who have done well in mathematics in high school, since an S&E career so heavily involves mathematics.

Viewed from the perspective presented above, it is easy to see that those high school seniors who decide to go into S&E careers are very likely those who have scored at the top percentiles of mathematics and science tests. If we are concerned about encouraging women to go into S&E related careers, the gender proportion differences in high percentile ranges of math scores as presented previously become very meaningful. After all, those very high scorers on math and science tests are likely candidates to be our future leaders in mathematics, physics, chemistry, computer science, etc. If we are indeed concerned about our future leaders in these areas as we are now (NSF, 1992), and if we want to encourage women to become leaders in these areas, we will be compelled to pay attention to gender difference at extreme ranges of math score distributions.

Conclusions

The present study explored some potential gender difference in mathematics achievement using data from *NELS:88* national samples. It is observed that obvious gender difference in math proficiency does not seem to exist when comparisons are made on central tendency measures, nor on the estimated mathematics proficiency levels. When attention focuses on the high end of math score distributions, however, meaningful difference between gender groups is revealed. Specifically, among high scorers on math tests, female students are definitely outnumbered by their male counterparts. Such gender difference within high score ranges of distribution becomes larger and more obvious as students progress from the 8th to their high school senior year. Furthermore, the more extreme score distribution one examines at the higher end, the larger the gender difference becomes.

It is argued that although relatively small proportions of high school students reach the high scc... ranges on math test as examined in this study (75th percentile, 90th percentile, and 95th percentile), the observed gender difference within these high score ranges is practically meaningful and warrants our attention, since these students are very likely to be those who will consider going into science, mathematics, or engineering related areas as their career choices. Any significant gender difference in terms gender group proportions within these high math score ranges are likely to be one potential reason for the gender imbalance in the inflow of new students choosing these areas as careers.

The tentative results presented in this paper also highlight some difficulties in the investigation of gender difference in mathematics. Most of the research in this area is typically concerned about group mean comparisons. As indicated by the results of this study, we may not be able to notice obvious difference in gender group mean scores. As a result, we may become complacent about such superficial lack of gender difference in math achievement. Such complacency may not be warranted if we understand that it is those high scorers who are likely to become our future scientists, engineers, chemists, physicists, etc., and it is in those high score ranges we see that obvious gender difference still exists.

REFERENCES

Armstrong, J. M. (1985). A national assessment of participation and achievement of women in mathematics. In Chipman, S. F., Brush, L. R., & Wilson, D. M. (Eds.), Women and Mathematics: Balancing the Equation. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Baker, D. P. & Jones, D. P. (1993). Creating gender equality: Cross-national gender stratification and mathematical performance. Sociology of Education, 66, 91-103.

Brandon, P. R., Newton, B. J., & Hammond, O. W. (1985). The superiority of girls over boys in mathematics achievement in Hawaii. Paper presented at the Annual Meeting of the American Educational Research Association, 1985, Chicago.

Callahan, L. G. & Clements D. H. (1984). Sex differences in rote-counting ability on entry to first grade: Some observations. Journal for Research in Mathematics Education, 15, 378-382.

Cannor, J. M. & Serbin, L. A. (1985). Visual-spatial skills: Is it important for mathematics? Can it be taught? In S. F. Chipman, L. R. Brush, & D. M. Wilson, (Eds.), Women and mathematics: Balancing the equation. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

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

Dossey, J. A., Mullis, I. V. S., Lindquist, M. M., & Chambers, D.

L. (1988). The mathematics report card: Are we measuring up? Trends and achievement based on the 1986 national assessment. Princeton, New Jersey: Educational Testing Service.

Fennema, E., & Sherman, J. (1977). Sexual stereotyping and mathematics learning. The Arithmetic Teacher, 24, 369-372.

Friedman, L. (1989). Mathematics and the gender gap: A meta-analysis of recent studies on sex differencec in mathematical tasks. Review of Educational Research, 59, 185-213.

Hashaway, R. M. (1981). Sex-differences in mathematics achievement - Are they real? Phi-Delta-Kappan, 63, 139-140.

Hawn, H. C., Ellet, C. D., & Des Jardines, L. (1981). Differences in mathematics achievement between males and females in grades 1-3. Paper presented at the Annual Meeting of the Eastern Educational Research Association, 1981, Philadelphia, Pennsylvania.

Hyde, J., Fennema, E., & Lamon, S. (1990). Gender differences in mathematics performance: A meta-analysis. Psychological Bulletin, 107, 139-155.

Matsumoto, A. R. (1995). Gender differences in mathematics performance: A comparison of meta-analyses. Paper presented at 1995 Annual Meeting of American Educational Research Association, April 18-22, 1995, San Francisco, California. Session #: 44.03.

National Assessment of Educational Progress. (1975). The first national assessment of mathematics: An overview, 1972-1973 Assessment.

National Assessment of Educational Progress. (1979). Mathematical knowledge and skills: Selected results from the second assessment of mathematics.

National Center for Educational Statistics (1994). A guide to using *NELS:88* data.

National Science Foundation. (1992). Indicators of science & mathematics education 1992. Washington, D.C.: National Science Foundation.

Rock, D. A., Owings, J. A., & Lee, R. Changes in math proficiency between 8th and 10th grades. Statistics in Brief series, 1994, NCES 94-137.

Rock, D. A. & Pollack, J. M. (1991). Psychometric Report for the *NELS:88* Base test battery, April 1991, NCES 91-468

Schonberger, A. K. (1976). The interrelationship of sex, visual spatial abilities, and mathematical problem solving ability in grade seven. Unpublished doctoral dissertation, University of Wisconsin.

Table 1

Means and Standard Deviations of IRT-Estimated Math Scores for Male and Female Students

Sample	Gender	Grades 8th	10th	12th
Total Sample	Male	34.95(12.03)[a]	43.48(13.90)	49.38(14.44)
	Female	34.60(11.54)	43.01(13.31)	48.28(13.45)
Asian	Male	39.45(10.39)	48.69(11.21)	54.07(11.97)
	Female	39.20(9.30)	47.70(10.14)	52.35(10.55)
Hispanic	Male	30.45(9.31)	38.50(11.31)	44.77(12.90)
	Female	29.00(8.00)	35.76(10.37)	40.95(10.70)
Black	Male	27.48(9.11)	34.22(12.33)	38.66(12.94)
	Female	27.76(8.96)	35.27(13.55)	39.79(14.50)
White	Male	36.92(12.31)	45.56(13.87)	51.39(14.21)
	Female	36.69(11.85)	45.36(12.99)	50.62(12.97)

a mean (standard deviation)

Table 2

Gender Group Proportions near the Higher Tail of IRT-Estimated Math Score Distributions: 8th to 12th Grade

	Gender	8th(%)	10th(%)	12th(%)
Among Those in the 1st Quartile				
	Male	51.14	52.70	55.18
	Female	48.86	47.30	44.82
Among Those in the 1st Decile				
	Male	53.74	54.25	58.57
	Female	46.26	45.75	41.43
Among Those at or above 95%ile				
	Male	57.19	57.22	66.27
	Female	42.81	42.78	33.73

Among Those in the 1st Quartile

Among Those in the 1st Decile

Among Those at/above 95th Percentile

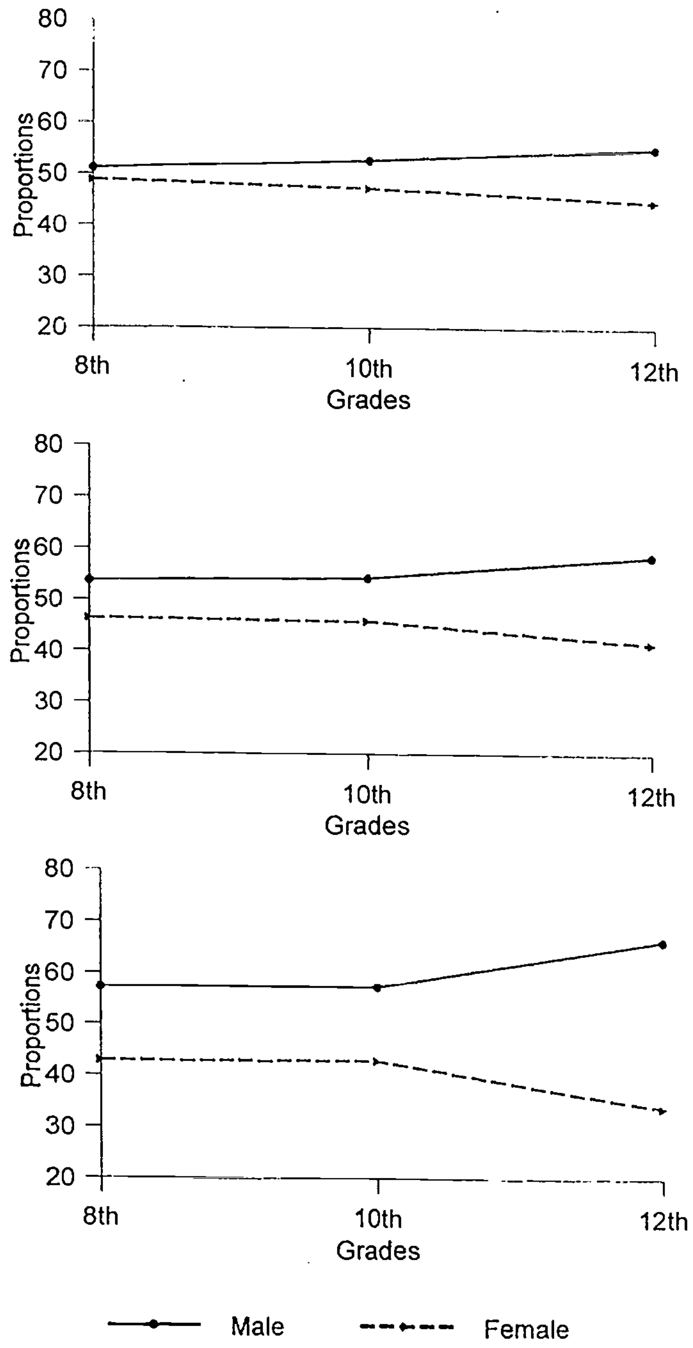

Figure 1: Male-Female Proportions in Three Extreme Score Ranges

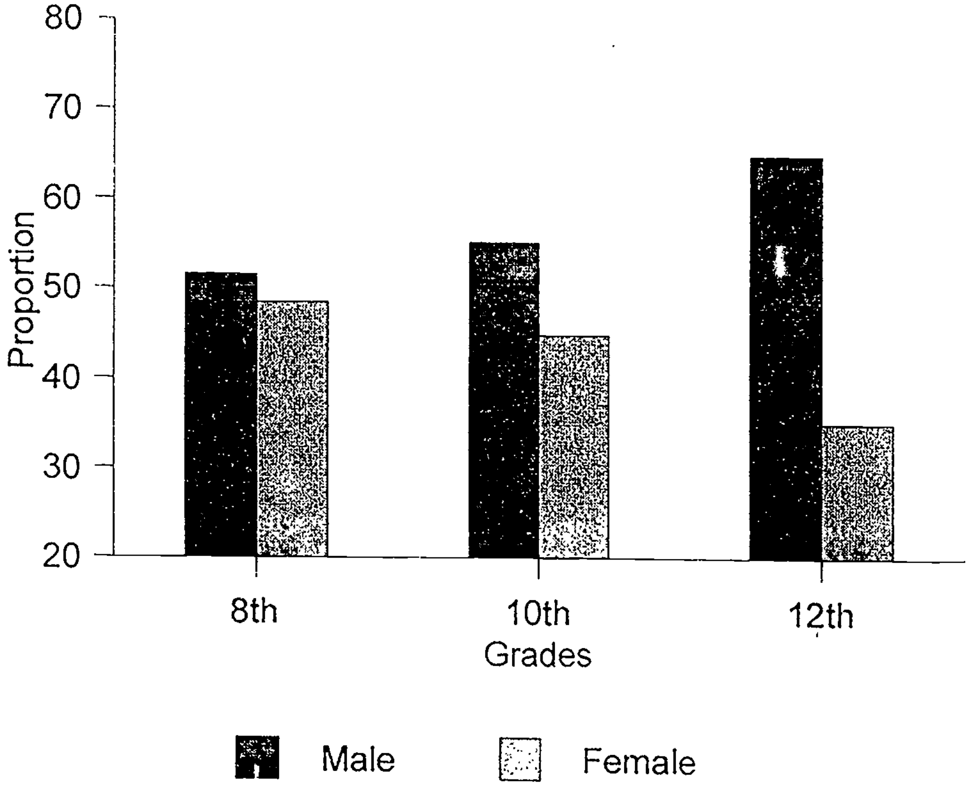

Figure 2: Male-Female Proportions Classified to be in the Highest Math Proficiency Level