DOCUMENT RESUME

ED 271 313 SE 046 667

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TITLE	When and Why Girls "Leak" out of High School Mathematics: A Closer Look.
SPONS AGENCY	Educational Testing Service, Princeton, N.J.
PUB DATE	Apr 86
NOTE	52p.; Paper presented at the Annual Meeting of the American Educational Research Association (70th, San Francisco, CA, April 16-20, 1986). The document contains small and faint print.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	*Academic Achievement; *Females; High Schools; *Secondary School Mathematics; *Sex Differences; Social Influences; Socioeconomic Status; *Student Attrition
IDENTIFIERS	*High School and Beyond (NCES)

ABSTRACT

This paper analyzes data from High School and Beyond, a two-stage nationally representative study of goals, attitudes, experiences, and achievement patterns of high school sophomores and seniors in 1980. The present study provides an indication of levels and patterns of sex-differentiated attrition from high school mathematics courses by determining specific points at which students in general, girls in particular, leave college preparatory mathematics sequences. It identifies predictors of persistence in terms of course numbers and transition from course to course. The relationship between course-taking in mathematics and the Scholastic Aptitude Test (SAT-M) quantitative scores is examined with the aim of providing evidence on the extent to which gender differences in mathematics course enrollment "explain" gender-specific scores. The final sample (N=8321) had at least some experience in academic courses in mathematics, representing those for whom skill in mathematics is likely to be required for future success. The findings show greater attrition of females as compared to males in less advanced courses with the reverse at advanced levels. The grade in the students' last mathematics course had a negative relationship to persistence and was greater for females than males. Results showed a strong relationship between socioeconomic status and persistence in mathematics. Evidence reported indicated that mathematics course-taking had a strong positive influence on SAT-M scores. (JM)

BACKGROUND

Objectives

Perhaps the most striking illustration of the marked discrepancy that has consistently characterized the mathematics achievement levels of high school girls and boys is the 40-50 point gender difference in average scores on the mathematics section of the SAT (SAT-M) that has existed for at least sixteen years (see Figure 1). While the role of additional, as yet undetermined factors must also be recognized (Armstrong, 1981; Benbow & Stanley, 1980, 1983; Fennema & Carpenter, 1981; Ridley & Novak, 1983), there is compelling evidence that gender differences in patterns of mathematics course enrollment at the secondary level contribute substantially to this discrepancy (Fennema & Sherman, 1977; Pallas & Alexander; Wise, Steel & MacDonald, 1979). As the importance of mathematics course-taking for the development of mathematical skills becomes increasingly clear, so also does the need to find ways of reducing the attrition of women students from high school mathematics courses.

Insert Figure 1 about here

Focusing on a nationally representative sample of 1982 high school seniors, we hope to provide current and highly reliable data which relate to this question. The specific aims of the study are three-fold. First, we provide an indication of current levels and patterns of sex-differentiated attrition from high school mathematics courses by determining the specific points at which students in general, and girls in particular, are especially likely to "leak" out of the college preparatory course sequence in mathematics. Second, we identify the predictors of persistence in mathematics -- both in terms of the total number of academic mathematics courses and specifically in transition from each particular course in the college-preparatory mathematics sequence to the next course -- with the aim of suggesting ways of stopping these important and gender-specific "leaks". Third, we examine the relationship between course-taking in mathematics and SAT quantitative scores for the subsample of these students who chose to take the test, with aim the of providing current evidence on the extent to which the sex differences in math course enrollment "explain" these gender-specific scores.

Theoretical Framework

In a now-classic paper designating high school mathematics preparation as the "critical filter" regulating entry into occupations and professions which require competence in quantitative skills, Lucy Sells (1973) documented a large discrepancy in the high school mathematics background of male and female students entering the University of California at Berkeley in 1972. The nature and extent of gender differences in high school mathematics course-taking has since been the subject of a number of investigations, with mixed results. Relatively small-scale studies focusing on particular populations have revealed substantial differences, though none as big as those reported by Sells (Alexander & Pallas, 1983; Educational Testing Service, 1978, 1979; Ernest, 1976; Fennema, 1977; Fennema & Sherman, 1977). The results of some national surveys suggest, however, that girls are not less likely than boys to enroll in less advanced mathematics courses, although they tend to be increasingly outnumbered as courses become more advanced (Armstrong, 1981; Fennema & Carpenter, 1981). The fact that most of the smaller-scale studies where stronger sex differences were observed were based on college-bound students suggests that gender differences in mathematics course-taking may be greater among more academically able students.

Researchers have invoked a wide variety of factors in their attempts to explain why female students tend to avoid the study of mathematics. A few have emphasized the properties of schools (Casserly, 1980; Marret & Gates, 1983), but more have focused upon the social and psychological characteristics -- females' attitudes toward mathematics (Armstrong, 1979; Brush, 1980; Fennema & Sherman, 1977; Haven, 1971; Sherman, 1981, 1982, 1983; Sherman & Fennema, 1977; Wise, 1978); their mathematical abilities and/or aptitudes (Brush, 1980; Sherman, 1981, 1983; Stallings & Robertson, 1979); their confidence in those abilities (Sherman, 1981, 1982, 1983); their images of scientists and themselves (Brush, 1979, 1980; MacCorquodale, 1984); their socioeconomic status (Brush, 1980); and the encouragement they have received from parents, teachers, and friends (Casserly, 1980; Fox, 1977; Schlossberg & Goodman, 1972; Sherman, 1982; Stallings & Roverison, 1979). There emerges from this research, however, no clear or comprehensive picture of the factors that exert the most powerful influences upon persistence in mathematics, or of how these factors fit together.

METHOD

Sample and Data

This study is based on data from High School and Beyond (HS&B), a two-stage nationally representative longitudinal study of the goals, attitudes, experiences, and achievement patterns of students who were high school sophomores or seniors in 1980. The sample for this study is drawn from the base-year sophomore cohort, 28,000 students in over 1,000 American high schools, who were followed up as seniors in 1982. More specifically, a sub-sample of this HS&B cohort is used -- the 16,000 HS&B participants for whom complete high school transcript information was added to the previously existing base-year and first follow-up questionnaire and achievement test data. The particular sample for this study includes all the students with transcript data who meet the following criteria:

- Students who had data for both the base-year and first follow-up waves of HS&B data collection. This excludes almost 2,000 students;

- Students who were in the same high schools as sophomores and seniors (i.e. dropouts, transfer students, and early graduates are not included). This excludes 3,000 students, two-thirds of whom dropped out of school between sophomore and senior year;

- Students who have taken at least one credit of college preparatory math courses (subsequently called "academic math"). Of the 11,074 students who fit all the above criteria, 2,753 were eliminated by this data filter. That is, almost 25 percent of high school seniors have not taken any academic math courses.

Our final sample of 8,321 students is a representative sample of 1982 high school graduates who have had at least some experience with academic courses in mathematics. As such, they represent a somewhat select group compared to their age cohort. However, it seems very likely that it is from this group that potential college attenders are drawn, and from which the group of future scientists, engineers, mathematicians, and potential professionals will emerge. As such, this sample of students represents those for whom skill in mathematics is likely to be required for their future success.

The availability of transcript information on a random sub-sample of HS&B participants allows serious investigation of the questions posed in this study for the first time. In particular, information is available which relates students' specific course-taking patterns and their achievement and aptitudes in mathematics as demonstrated by performance in those courses. Although both the base-year and first follow-up waves of HS&B data include information on students' courses of study and academic success in school, those data have been supplied by students themselves, are summary in nature, and are unreliable to unknown degree. Using student self-reports, it is difficult to separate academic from non-academic course work, to assess the actual number of credits students earn in each of their courses, or to evaluate the sequence in which courses are taken. Even more important, the students' report of their academic performance on previous HS&B files is a categorical reponse to a survey question that asks about their overall grades, and is thus related to neither curricular areas nor specific courses.

Using transcript information, we are able not only to differentiate courses quite specifically (e.g. Algebra I from pre-Algebra, functional, or "checkbook" math), but also to measure the actual exposure to such courses, measured by the credits earned for each of these courses (in Carnegie units, or proportions of credit for a course which meets every day for one year -- see NCES, 1983). In addition, we can evaluate the exact sequence in which the courses have been taken -- not only in which year, but in which quarter, trimester, or semester of the year. Specific grades earned <u>in each of these courses</u> are included as well. Therefore, we can compute students' overall grade point average (GPA) from courses on the transcript as well as their grade point average in mathematics. A central focus of this study is to identify the exact point at which stucents stop taking math. and if possible to determine the reasons why students either drop out of or persist in mathematics at each particular course juncture. Therefore, being able to identify both the last math course students taken, and the grade in that course, is extremely valuable to this investigation. With such data, we can trace the effect of mathematic performance on subsequent course-taking on a course-by-course basis. In addition, for a subset of students who have taken the Scholastic Aptitude Test (SAT) during their last year of high school, these scores are available on the file, both in composite and subtest (i.e. mathematics) form.

This study focuses on the identification, explanation, and consequences of gender differences in course enrollment patterns in high school mathematics. Therefore, it was decided to conduct most analyses separately for males and females. Previous research has documented a different constellation of factors which predict math-related behaviors for males and females (Thomas, 1984; Ware & Lee, 1985; Ware, Steckler & Leserman, 1985). Rather than computing numerous interaction terms for those cross-gender differences, we present separate but parallel analyses for the sexes in most investigations. Before introducing analyses which investigate the mathematics course-taking behaviors of high school young men and women, we present descriptive information on important characteristics of the sample. Examination of the gender-specific background and outcome differences begins to indicate the nature of the problems addressed by this study.

Background differences. The background characteristics of the sample are presented in Table 1. We can see that males come from families with a somewhat higher social class (SES) rating than do females (.16 vs .08 on this standardized measure, or a difference of about .1 standard deviation). Although both gender groups are composed of about 18 percent minority students, that minority component contains slightly more blacks, and slightly fewer Hispanics, in the female than in the male sample (see Note 1).

Insert Table 1 about here

In addition to personal and family background characteristics, there are certain differences in students' academic backgrounds which are likely to relate to their academic behaviors. For example, the girls in the sample are slightly more likely to be in the college-preparatory, or academic, curricular track (49 vs. 44 percent). In line with this slight differential track placement, we see that girls have very slightly higher educational ambitions. However, in a measure of sophomore-year composite achievement (including reading, vocabulary, and mathematics), girls score slightly below boys (54.1 vs. 53.4, or a difference of about .1 standard deviation unit). At sophomore year, students who planned to attend college were asked their probable major in college. Of those who indicate a probable field of study, substantially fewer females than males named a technical field -- 33 percent of males compared to 12 percent of females. Technical fields, in this definition, include mathematics, engineering, computer science, biological and physical sciences. This is very similar to the percentage of males and females who actually declare these major as college students. In an earlier study of the predictors of science major choice among males and female college students using HS&B, Ware & Lee (1985) found that 40 percent of the men, but only 14 percent of the women, chose a science major.

Outcome differences. Females in this representative sample of 1982 high school seniors take fewer math courses than their male counterparts (2.5 vs. 2.3 years of academic math courses, or a difference of .2 standard deviation units). They also stop taking math sooner than do males. In a four-year high school sequence, on average girls stop before their junior year, whereas boys persist until after the beginning of the junior year, on average.

Does the lower "persistence rate in math" for females relate to lower demonstrated performance in math as reflected by grades? A simple answer: no, it doesn't. Even though girls "leak" out of math at an earlier point in time, with fewer courses completed, their performance in math, as indicated by grades, is somewhat higher than for boys. Not only do girls get better grades in general (overall GPA is 2.9 vs 2.6 for boys), but their grades in math are also higher (math GPA is 2.4 for girls, compared to 2.1 for boys -- see Note 2). For both sexes, the average grade in the last math course students have taken is somewhat lower than their overall math GPA. However, for girls the discrepancy is somewhat greater. Perhaps the observed sex difference in persistence is related to differences in tested mathematics achievement. Consistent with the SAT data from ETS shown in Figure 1, we see that for the 30 percent of the analytic sample who have taken the SAT test in their senior year of high school (1982), the gender difference in favor of males is 45 points on the SAT-M. On Figure 1, which includes all students who have taken the SAT, the sex difference for 1982 is reported as 50 points, with the group means slightly lower than those reported for this sample.

We see, therefore, that there are some differences in the backgrounds of males and females which might confound the observed differences in outcomes explored in this paper. Compared to boys, girls are slightly disadvantaged in terms of SES, developed ability (i.e. sophomore achievement) and in the proportion who show interest in pursuing technical careers. In addition, the racial/ethnic composition of that group is somewhat different from boys. However, girls are slightly advantaged compared to boys in other areas: academic track placement, educational aspirations, and school grades. The grade advantage extends across all courses taken, courses taken in math, and the last course taken in math. The major outcome difference of interest is course enrollment in college-preparatory mathematics, where girls are disadvantaged. They also stop taking math sooner in their high school career than do boys. Finally, for those college-bound students who take the SAT test, girls score substantially below boys on the mathematic section of that test.

Research Questions

It seems clear that we must adjust for the many differences between males and females in this sample in any analysis which seeks to identify the factors related to persistence or "leakage" in high school mathematics, particularly since we focus on the cross-gender differences in the strength of these causal factors. Based on the differences in background and outcomes, and considering the previous research which has examined these issues, we propose to investigate the following questions in the remainder of this paper. Although many of the questions are interrelated, we present empirical evidence on each of them separately.

Question 1: Which is the most likely place for students in general, and females in particular, to "leak out of" the college preparatory math sequence?

Question 2: Is the sex difference in math course-taking which favors males stronger or weaker among high-ability students than for the sample as a whole?

Question 3: What is the effect on persistence in math of the student's performance in the previous math course, relative to his or her average performance in math? Is this effect similar for students of high ability compared to the average student?

Question 4: Are there gender differences in the strength of the predictors of persistence in mathematics? If so, are these gender differences more or less likely to occur among high-ability students?

Question 5: What are the characteristics of the groups of students who take each progressively more advanced course in the high school college-preparatory mathematics sequence?

Question 6: For students who have taken the previous course in the college-preparatory sequence in mathematics, what are the major predictors of persistence to the next course? Are there gender differences in these persistence rates, once background and performance differences have been taken into account?

Question 7: Is the gender difference in performance on the math section of the SAT test "explained away" by the differential course-taking rates between males and females?

Question 8: Is the pattern of effects for predicting SAT-M performance similar for the males and females who take this test?

Analytic Approach

A substantial part of this study consists of descriptive differences between males and females, and between high-ability students and the total sample, on a number of background and outcome factors. Determining the points at which studen.s are most likely to drop out of high school mathematics, or whether high-ability students show the same course-taking differencess as the total sample (Questions 1 and 2) are essentially descriptive questions. We have chosen not to present statistical tests for these mean differences for two reasons. First, with such a large sample, virtually every differences between groups is statistically significant. Second, the overall aim of the study focuses on determining the possible causes of these differences, or upon investigating whether the effects persist after statistical adjustment for other background differences between and within the groups in question. Therefore, unadjusted differences are only the beginning of the investigation.

When effect sizes are the issue -- determining the magnitude of unique relationships between particular independent variables and outcomes of interest -- we have used ordinary least squares (OLS) regression for most analyses. With OLS, we are able to estimate the magnitude of particular relationships after adjustment for other differences among the subjects. For example, we know that the males in this sample are of higher SES, but the females of slightly higher educational aspirations. Although these are interesting relationships in themselves, we want to evaluate their unique contribution to the variance in a particular outcome, after adjusting for many other differences. Regression does this for us. As a proxy for student ability, we use a composite measure of achievement in three areas (reading, vocabulary, and mathematics), evaluated at students' sophomore year. We certainly recognize that this variable taps what students have learned, and thus is less a measure of innate ability than abilities acquired as a result of schooling. Nevertheless, it is the best measure available on the HS&B file to adjust for student differences in intellectual development as of the 10th grade.

In several instances, we are interested in identifying causal relationships. Although regression estimates all effects in a technically similar manner (SES, gender, developed ability, grades, etc.), certain of these effects are not causal in nature. Specifically, we follow the advice of Holland (1985) in identifying as causal relationships only those which students or schools can change. Thus, SES, gender, race/ethnicity, or acquired ability are not considered as causal factors in these analyses, but are seen as covariates for which some adjustment is necessary. The investigations which attempt to provide answers for Questions 3, 4, 6, 7, and 8 fall in the category of causal analyses. For each of these analyses, we have used regression methods. For most regression models, we report standardized (beta) regression coefficients. The various outcome measures in this study (number of math courses, persistence to one course from another, math GPA, and SAT-M scores) are each evaluated in a different metric. Standardized regression coefficients represent measures of effect size which are directly comparable across different metrics.

One set of analyses (Question 6) investigates the reasons why students who have taken a particular math course (say, Algebra II) either persist in mathematics by enrolling in the next course in the series (Trigonometry) or drop out of math at that point. Therefore, these analyses use progressively smaller samples to investigate persistence/non-persistence, a dichotomous outcome variable. We are fully cognizant of the fact that for analyses with dichotomous outcomes, logistic methods are recommended. However, we have chosen to use OLS regression instead of logistic regression for two reasons. First, with these progressively more and more select samples, the proportion of persisters compared to "dropouts" is consistently above 20 percent, and usually in the range of over 40 percent. This avoids the problem of extreme distributions which might result if the whole sample were used to predict future enrollment. Calculus, for example, is taken by only 6.2 percent of all sample students, but is chosen by 46 percent of those who have taken Pre-Calculus. Markus (1979) states that in the middle ranges (20-80 percent) of dichotomous (binomial), OLS produces results similar to, and equally unbiased as, logistic regression. Second, the multi-stage sampling procedure for HS&B, and particularly for the transcript sample, requires the use of design weights to adjust for the considerable oversampling of certain groups. Logistic regression, which proceeds on a case-by-case basis, does not accept the use of case weighting. Since our samples for the analyses for Question 6 do not have extreme distributions, we have used least-squares regression for these analyses.

RESULTS

Where Are Students Most Likely to "Leak Out Of" Mathematics? (Question 1)

The proportion of students who have taken each of the courses in the academic mathematics sequence as their last course in high school mathematics is shown in Table 2. Recall that all of the students in the sample have taken at least one Carnegie unit (year) of academic math, and it is very likely that the first course in that sequence is Algebra I. Fully a quarter of the students in the full high school senior cohort sample never take Algebra I. Of those who have taken Algebra I (i.e. our analytic sample), roughly another quarter drop math at that point. Moreover, the "math dropout rate" is considerably higher for females than for males at that point -- 28 percent of females, compared to 24 percent of males, drop math after Algebra I. This differs from the findings of some researchers (Armstrong, 1981; Fennema & Carpenter, 1981) that girls and boys are equally likely to enroll in less advanced math courses.

Insert Table 2 about here

The sequence of academic mathematics branches somewhat at this point. Although most students take Geometry before Algebra II, some schools reverse the sequence, and have Algebra II follow directly after Algebra I. Our empirical evidence suggests that the sequence which has Geometry coming before Algebra II is considerably more common (see Note 3). Taking this evidence into account, and after consulting with several high school math teachers who confirm the prevalence of the "Geometry first" sequence, we decided to focus on the AlgebraI-Geometry-Algebra II sequence rather than the alternative.

Geometry is the last math course for roughly one-fifth of the sample. Again, slightly more females "leak out" at this point. However, the differential "math dropout rate" is cumulative. Of those who took Algebra I over 49 percent of females, compared to 44 percent of males, have stopped taking math after Geometry. The selective attrition continues, with another fifth leaving math after Algebra II, again slightly more females than males. Seventy-one percent of females, and 64 percent of males, have now stopped taking math.

However, the differential rate of dropping math changes at the next point in the sequence -- Trigonometry. For this and the succeeding advanced math courses (Pre-Calculus and Calculus), females are slightly less likely to stop at each of these points. These findings differ from those of Alexander and Pallas (1983) where boys were more than twice as likely to take either Trigonometry or Calculus. Of course, the sample of women who actually make it to Trigonometry is considerably smaller than the male group. We may conclude at this point that girls are more likely than boys to drop math at the earlier points in the sequence -- Algebra I, Geometry, Algebra II. However, once girls persist beyond that point, to the relatively advanced courses, the differential drop out rate is somewhat reversed. Because the actual proportions of "persisters" is so small and the proportions dropping earlier favored females, however, the overall difference in coursetaking in mathematics betwcen the sexes is far from reversed.

Figure 2 displays the cumulative effect of these "leakage" differences. Out of every 1,000 students who have taken at least a single academic course in math, almost no girls, and few boys, are still taking math after Trigonometry (Note 4). Moreover, the cumulative effects of fewer female "persisters" at each step in the sequence results in a dramatic difference in the proportions of males and females in higher-level math courses. We can see that the biggest differences between the sexes in this "leak rate" comes at two points: after Algebra I and after Algebra II.

Insert Figure 2 about here

Are There Sex Differences in "Leakage" for High-Ability Students? (Question 2)

It is logical to assume (and easy to prove) that it is students of high ability who persist in mathematics. Since we have seen in Table 1 that girls exhibit slightly lower measured ability at sophomore year, does this ability difference account for the course-taking differential we have seen above? Were that the case, we might see fewer females among a group of students of high ability, but then no proportional course-taking differences within that high-ability group. In other words, we want to know whether or not we see the same math course enrollment differences between the genders if we examine only students of high ability levels. Table 3 presents such an analysis.

Insert Table 3 and Figure 3 about here

High-ability students are defined as those who have scored in the top quartile of the sophomore-year composite test described above. The proportions of males and females who fall in each quartile of general ability are presented in parentheses, below the average number of Carnegie units of academic math taken by each group. A smaller proportion of girls (36 percent) than boys (40 percent) fall in the high-ability group. However, we can see that these high-ability girls take fewer math courses than their male counterparts -- 2.88 years of math for girls; 3.07 years of math for boys. In fact, the "course-taking differential" is slightly greater for this group (.19 fewer courses taken by females than males) than for the remainder of the group (which average .07). This is also evident in Figure 3, where the difference in the heights of the bars between the sexes is greatest for the students of high ability, but reasonably equivalent for students of moderate ability levels.

Therefore, we cannot conclude that for males and females of high ability there is no difference in the number of math courses taken. In fact, the difference which favors males seems somewhat stronger among students of high ability. Of course, high-ability students are the prime candidates for enrollment in these courses, for obtaining higher SAT scores, and for entry into careers in science, math, and engineering. Therefore, we must look further for an explanation about why girls take fewer math courses than boys. The explanation is <u>not</u> because they show somewhat lower demonstrated ability.

Another way to look at this problem focuses on questions of "when" instead of "how many". Besides numbers of courses taken, we may also examine the proportion of students (males compared to females) who are still taking math during each of their four years of high school. Figure 4 shows the declining proportions of students "in the pipeline" during each year. The decline is steady over time, and it is consistently faster for females. The relative (and small) increase in the persistence of females at the end of the pipeline is shown by the very slight decrease in slope of the line depicting females after junior year. We can also see, however, that by senior year less than 20 percent of females, and over 25 percent of males, are still taking math.

Insert Figures 4 and 5 about here

The same diagram, for students in the high ability group is shown in Figure 5. Although the male and female "persistence lines" are slightly closer together, females are still consistently below males. However, the "dropout rate" is somewhat less linear for these high-ability students. Over 80 percent of all students are taking math at sophomore year, but the slopes of both "persistence lines" take sharper declines after that point. Even in this high-ability group, less than one-third are taking math during their senior year. Although we are concentrating on gender differences in persistence in mathematics in this paper, we should not lose sight of the fact that the overall lack of persistence in math, even for students of high ability, is considerable.

<u>How Does Performance in Math Affect Persistence</u>? (Question 3)

We know that students perform less well in mathematics than in their other high school subjects. In Table 1 we see that students' grade point averages in math are about .5 standard deviation below their overall GPA. This is roughly equivalent to the difference between a 'B-minus' and a 'C' for boys, and between a 'B' and a 'C-plus' for girls. Less dramatically, but consistently, we know that students' grades in the last class they took in math are lower than their overall GPA in math, on average. This differential is greater for females than for males. This would suggest that the grade in that particular math class acts to discourage students from continuing in math. However, what might be perceived as a low grade to a strong student could be considered a high grade for a weaker student. That is, self-perception of earning a 'B' for a 'C' student is quite different from the way an 'A' student might see a 'B' grade. Therefore, a particular grade might act as an encouragement or discouragement factor depending on its value <u>relative</u> to students' overall performance in math. Moreover, we have already noted the anomoly that even though females get better grades in math, they are less likely to persist. Computing the effect of that last grade relative to overall performance in math also adjusts for the generally higher grades earned by females (see Note 5).

In Table 4, we present results from four parallel regression analyses which investigate the effect of a student's last grade in math, relative to the overall math GPA, on the total number of math courses he or she takes. The effects have been evaluated separately for males and females, both the total sample and those of high demonstrated ability. Comparisons are made between males and females in the total sample (Column 1 vs. Column 3), and then those cross-sex patterns are compared for the two high-ability groups (Column 2 vs. Column 4). Social class is a strong positive predictor of math course enrollment, apparently stronger for males than for females. Once SES has been adjusted, there are no racial/ethnic group effects, with one noteworthy exception. Black girls tend to take more math.

Insert Table 4 about here

Not surprisingly, ability is a strong predictor of math course enrollment. The effect appears to be equally strong for both sexes among the total sample, but somewhat stronger for males among the students of high ability. Whether or not students are enrolled in the academic track is also a strong (and understandable) predictor. Although academic track placement is an equally strong predictor for both sexes for the entire sample, high-ability girls in the academic track appear to be more likely than their male counterparts to take more math. Only 65 percent of the high-ability group is enrolled in the academic track, which is perhaps lower than might be expected for students in the top quartile of achievers.

The effect of students'last grade in math on their persistence is strong and negative. Since we saw that students' grades in their last math courses were lower than their overall math grades, on average, this negative relationship is understandable. The inverse of this relationship is, of course, that higher grades predict persistence. The effect of this relative grade on total math course enrollment appears to be somewhat stronger for females than males, and this seems to be particularly marked for the high-ability females. This finding indicates that students in general, but girls in particular -- especially the most able girls, are more likely to drop math after receiving a math grade below their average grade in math.

Thus, we have confirmed that a student's grade in the last math course he or she takes, relative to the overall performance in math, relates strongly to pe istence. And this relationship is after adjustment for social class, race/ethnicity, acquired ability, and academic track placement. We have noted that other effects are either stronger or weaker for males or females, and that the strength of the cross-sector differences in these effects is sometimes affected by whether the sample is restricted to those of high demonstrated ability. But are these cross-gender differences in the size of the effects real, or statistical artifacts of either the slight differences in sample sizes or differences in the amount of variance explained (R^2) by the models for each gender? Note that the model on the total sample explains variation in the course-taking behavior for males better than for females for the entire sample, but equally well (but not very well, at the same time) for both high-ability samples.

<u>Are There Gender Differences in Effect Sizes</u> ? (Question 5)

Table 4 reveals statistically significant effects of social class, developed ability, academic track, being black, and last math grade on persistence in mathematics. In certain cases, it appears that there are some differences in the strength of these relationships (i.e. the magnitude of the regression coefficients) for males and for females, both in the total sample and (less sharply) for students of high ability. But are the apparent differences in the size of these effects between the sexes statistically significant?

Fortunately, it is a simple matter to test the difference between two regression coefficients, particularly between two independent samples. Table 5 presents the t-statistics for these differences. It should be noted that statistically significant results here say nothing about the strength of the effects, but the significance level of those effects was documented previously. In fact, the only effects tested in Table 5 are the significant predictors of math course enrollment from Table 4. Because of the method of computation, a negative t-statistic in Table 5 indicates that the effect is stronger for females, a positive t-statistic means that the effect is stronger for males. For the total sample, social class is a much stronger predictor of math course enrollment for males than females. Black females are significantly more likely than black males to take more academic math courses. However, the effects of ability level and academic track on math course enrollment are not significantly different between the sexes. As mentioned earlier, we see that the relative last grade females receive in mathematics does in fact exert a significantly stronger effect on the total number of math courses females take, compared to that of males.

Insert Table 5 about here

The pattern of significant sex differences is somewhat different for students of high demonstrated ability. In fact, for neither social class, relative math grade, nor being black is there a sex difference in the size of the effects for these students. However, we see that ability is a stronger predictor of total math courses for males than females. This could be interpreted slightly differently. That is, the very brightest girls are not as likely to take advanced math classes as their male counterparts. Of course the magnitude of the effect of ability on course enrollment for students of either sex is considerably reduced for the high-ability sample because the variability of that variable is constrained. Nevertheless, the effect is still powerful, more so for males. Recalling that less than two-thirds of these able students are in fact enrolled in the academic track, we see that track placement has a stronger effect on females' than males' persistence in mathematics for these highly able students.

Thus, we see that there are substantial sex differences in the factors which predict persistence in mathematics. Although strongly related to persistence for both sexes, social class is a stronger predictor for boys than girls. On the other hand, black girls are more likely to persist than black boys, an important finding. For students of high ability, that ability is a stronger determinant of persistence for boys than girls, whereas academic track enrollment is more important for girls than boys. Perhaps academic track placement is seen by able girls as an external signal of their competence, and thus acts as an encouragement.

However, we believe that the most important finding in this analysis involves the sex difference in the motivational effect of grades on persistence. For girls, the grades they receive in the last course they take in mathematics, relative to their overall performance in math throughout high school, is a stronger determinant in their decision not to persist in the mathematics course sequence. A possible interpretation of this finding is that females have less confidence in their abilities in mathematics. Therefore, even with a relatively strong performance record in math, a single negative signal (i.e. a lower grade in a particular course) might be taken relatively more seriously by these less secure young women. The relative insecurity about their abilities could be mean that females believe they must be better than males at the same skill in order to consider themselves equal.

Characteristics of Students in Each Course of the Math Sequence (Question 5)

By now, we have firmly established that there is substantial attrition out of the college-preparatory math course sequence after each course. We know that such attrition is far from random, and we have already determined that more females than males "leak out" after the earlier courses. It is likely that such attrition is also related to students' demonstrated ability. But how does the "group demographic character" of those taking each succeeding math course change, with regard to those model variables we have earlier seen to be related to persistence? These characteristics are summarized in Table 6.

Insert Table 6 about here

The progressive changes in those group characteristics, as we move up the course sequence ladder, are quite predictable and at the same time rather discouraging. Besides the declines in the proportion of females in increasingly advanced math courses (the greatest of which is between Algebra II and Trigonometry), we can see that each successive "course group" is more advantaged in several ways: increasingly higher social class, increasingly lower proportions of blacks and Hispanics, increasingly higher proportions of academic track students, and -- most predictably -- increasingly higher ability students. Students are also increasingly likely to be planning a technical major in college, and to have higher educational aspirations. That is, the sample becomes progressively whiter, brighter, more male, more socially advantaged, more educationally ambitious, and more technically oriented. However, students' relative grades decline somewhat. Recall that the relative course grade has been computed as the ratio of the grade to the overall math GPA. If that ratio is less than one, the grade in the course is lower than the math GPA. In each case, that relative grade average is less than one. As the group becomes more selective, we can see that students' grades in those courses are declining (i.e. the ratio is lower), until Pre-Calculus, where the trend levels off.

Which Factors Predict Persistence From Course to Course? (Question 5)

We have already seen in Table 4 that all variables considered in the analytic model are related to overall persistence in mathematics, as measured by the total number of academic math courses taken. However, we also want to investigate the effect of each of these variables on students' decisions about whether or not to take the next course in the series. In order to do this, we must use a separate sample for each analysis. For example, to determine how these factors relate to the choice to enroll or not enroll in Trigonometry, we examine only those students who have taken the previous course in the series -- Algebra II. In order to estimate these same relationships on the decision of whether or not to enroll in Calculus, we look at those students who have completed Pre-Calculus. The results of these analyses are presented in Table 7. It should be noted, based on the results in Table 6, that the range of variation of each of these independent variables is increasingly restricted. Therefore, it is understandable that the proportion of variance explained by these analyses

(R^2) is quite small -- usually less than 10 percent. Nevertheless, the results show some interesting and statistically significant patterns worth noting.

Insert Table 7 about here

The proportion of students who actually make the transition from one course to another (also called "transition probabilities" in other research) declines over the sequence from Geometry to Pre-Calculus. That is, although 52 percent of Geometry students take Algebra II, only 39 percent of Algebra II students take Trigonometry. Of those students, only 22 percent take Pre-Calculus. After Pre-Calculus, it becomes slightly more probable (46 percent) that students will subsequently enroll in Calculus. Because there is some variation in the sequence in which students take these courses, the transition probability of eventually going from, say, Geometry to Pre-Calculus is somewhat higher than the product of those probabilities presented in this table.

After adjusting for each variable in the model, we see that females are significantly less likely than males to move from Algebra II to Trigonometry, and slightly more likely to make the transition from Trigonometry to Pre-Calculus. Neither social class nor race/ethnicity are contributing factors in these step-by-step analyses, nor is interest in a technical major. Both academic track and demonstrated ability, however, are strong predictors of the choice to enroll in the subsequent course. Track seems especially important for the Geometry-to-Algebra II and the Pre-Calculus-to-Calculus transition. Higher educational aspirations are more important for the earlier transitions (Geometry-to-Algebra II and Algebra II-to-Trigonometry) than for the more advanced course progressions, where all students have high educational ambitions. This demonstrates the particular importance of encouraging higher educational aspirations for students early in their high school experiences, both independently and by means of academic track placement. Demonstrated ability is a consistently important predictor of persistence to the next course in the sequence. Although many of these relationships are consistent with the group demographic differences shown in Table 6, the relationships estimated by these regressions are <u>net</u> of other differences.

Most interestingly, we can see that the student's grade in the preceeding course, relative to his or her overall math GPA, is a very important predictor of persistence. This is a much more specific test of this "relative grade" hypothesis than in previous analyses, since the grade in question is exactly the one the student earned in the course which immediately preceeds the decision of whether or not to continue. In fact, this piece of information is likely to be the student's best (and perhaps only) source of information about his or her current skill level in mathematics. If the student chooses not to persist in mathematics, that grade is his or her last grade in math; if the student continues to take math, it is not. This result confirms and re-emphasizes the importance of student performance as an important factor, perhaps the important factor, in this crucial decision. However, in this analysis, we are unable to make any statements about the relative importance of such information for males and females for these decisions. Separate analyses by gender would reduce sample sizes considerably, and correspondingly limit the stability of parameter estimates. However, we know from Tables 4 and 5 that the relative grade is more important for females' overall persistence.

We have now clarified the factors which influence persistence in mathematics, and found important differences across the genders in the structure of these prediction equations. We know that females are somewhat less likely to persist at each juncture of the math sequence. The particular points at which they are most likely to "leak out" are after Algebra I, and especially between Algebra II and Trigonometry. We also know that performance in mathematics is particularly important to persistence for females, and it is likely that this is especially true for the important transition from Algebra II to Trigonometry.

But in what ways does this differentially lower math course enrollment specifically disadvantage females? Although there are many possible consequences (college admission, choice of major, career choice, test scores), we have chosen to focus only on the latter. Although most of the effects of "math dropout" occur after students finish high school, a particular occurance near the end of students' high school experiences is likely to reflect course enrollment patterns in mathematics: the quantitative section of the Scholastic Aptitude Test (SAT-M) which many students are required to take as part of the process of application for admission to college.

What is the Effect of Course-Taking on the Sex Difference on SAT-M Performance? (Question 7)

We investigate the question of why young women score lower than their male counterparts on the math section of the SAT test within a single context. It was documented in Table 1 that about 30 percent of this random sample of 1982 high school seniors have SAT scores reported on their high school transcripts. Clearly, this is a select sub-sample of the cohort, but the proportion of that sub-sample is about equally divided between the sexes. We have seen that these females' scores show a 45-point disadvantage on this test. Is this female SAT-M disadvantage explained away by adjusting for the fact that they take fewer math courses? Since we know that the females are also of slightly lower demonstrated ability and social class, but of slightly higher educational aspirations and academic track enrollment, we should adjust for these factors as well. Motivation to perform well on this test might be affected by whether or not students plan technical majors or not, so this factor is taken into account. Also, performance (i.e. grades) in math -- which are higher for females -- might influence this outcome.

Table 8 presents the results of a path analysis which investigates this question. The final outcome examined by this analysis is students' SAT-M scores, and only students who have taken this test are included in the analysis. Using the path analysis format, several intermediate outcome variables are included: ability (at 10th grade), math GPA, and the total number of academic math courses (both over the four years of high school). Covariates which are adjusted for in all regressions include gender, social class, minority status (with blacks and Hispanics combined into a single 'minority' category), propensity for technical major choice at 10th grade, and educational aspirations (also measured at 10th grade). Both standardized and unstandarized regression coefficients are included in this table, since each has a substantive but somewhat different interpretation (see footnote 2 on Table 8).

Insert Table 8 about here

Concentrating on the right hand column of Table 8, which shows the results of a regression analysis on SAT-M scores, we see that the analytic model explains over 60 percent of the variance in SAT-M scores. By far the biggest explanatory factor is, understandably, ability, as measured by sophomore-year achievement. However, even after adjusting for this ability proxy, several other factors make substantial contributions. In particular, students with high educational aspirations score higher. Students who plan technical majors in college score higher. Students with higher grades in math are particularly likely to achieve higher scores. Taking more math courses contributes to higher scores. Also, more advantaged students (measured by SES) are likely to score higher, and minority students score somewhat lower. Of all variables in this analytic model, only academic track placement shows no significant contribution to the explanation of SAT-M performance. The fact that all of these factors are still significantly related to SAT-M scores <u>after</u> adjustment for student ability is noteworthy.

However, even after adjusting for all these factors, we see that females score significantly below males on this test. That is, after taking into account their lower course-taking pattern, there is still a very large (and negative) gender effect which favors males on this test. Consideration of the unstandardized regression coefficients (in parentheses) underscores this point. Even after all of these adjustments, young women still score 33 points below their male counterparts (see Note 6). Correspondingly, those who indicate a probable technical major score 16 point higher, minority students score 12 points lower, and those in the academic track score 7 points higher. The interpretation of the unstandardized regression coefficients for continuous variables is less straightforward. Students one standard deviation above the mean on the SES measure score 10 points higher. A single point higher on the test of demonstrated ability, which contains 50 items, produces a 7-point gain in SAT-M performance. A one-point difference in GPA (for example, the difference between a "B-plus" and a "C-plus") produces a 32-point difference in score performance. Taking a full year more of mathematics produces a 7-point score advantage. All of these are direct effects.

Certain model variables are stronger indirect than direct predictors of SAT-M scores, however. That is, their effect on SAT performance is mainly exerted through their influence upon those factors which, in turn, affect SAT score. Social class, minority status, and academic track show strong indirect effects through sophomore-year ability. Technical major has an indirect effect which passes through all intermediate outcomes, particularly through math grades. Academic track exerts its strongest indirect effect through students choice of courses, understandably. Math GPA is strongly related to the total enrollment in math courses (as we have discussed previously). Although the female effect on SAT-M score performance is indirect as well, passing through the number of math courses taken and grades in math, the fact that females earn significantly higher grades in math but score lower on the test actually augments the negative effect of being female on SAT-M performance (see Note 7). That is, most of the variables in this rather parsimonious model exert both direct and indirect effects on SAT-M scores.

Again, the direct effect of being female, after having adjusted for the number of math courses taken, is a 33-point disadvantage on SAT-M performance. We must conclude, therefore, that even though females take fewer math courses (and clearly that course differential goes some distance in explaining why the unadjusted female disadvantage of 45 points is reduced to 33 points), the difference in course-taking behavior does not explain why females are scoring considerably below males on this important test. The set of analyses presented in Table 8 is limited in another respect, moreover. It is possible that certain model variables affect SAT-M score performance differently for males and females. This is equivalent to hypothesizing interactions between being female and other predictor variables, something we have demonstrated in earlier analyses. Therefore, before concluding our investigation of how course enrollment in math affects SAT-M performance, we present a supplementary set of path analysis regressions which are conducted separately by gender. Of course, with such analyses, we are no longer able to investigate the magnitude of the gender difference on SAT-M score performance.

<u>Is the Prediction Model for SAT-M Performance Different for Males and Females?</u> (Question 8)

The analyses which document results from the regressions predicting SAT-M scores separately by gender are found in the two right-hand columns of Table 9. Although the proportion of explained variance is quite similar for the sexes, the patterns of strength of the individual predictors appears to evidence some sex differences. Similarly strong effects for the sexes are seen for math courses and minority status. These will be discussed no further. Effects which are somewhat stronger for males are seen for social class, technical major, and math grades. Stronger effects for females are seen for educational aspirations, academic track membership, and demonstrated ability. However, when subjected to statistical tests of the difference between these effect sizes, using the same method used for the computations on Table 5, we find that only the difference in math grades is significantly different between the sexes (and stronger for males than females). We may conclude, therefore, that although the model shows some differences across the sexes in the prediction pattern of direct effects for SAT-M scores, these gender differences are not significant, on the whole.

Insert Table 9 about here

However, examination of the prediction patterns for intermediate outcomes shows more extreme differences between the sexes. Female minority students are less likely to show high 10th grade ability scores, whereas educational aspirations for males are more strongly related to ability. Girls of lower social class are considerably <u>less</u> likely to show high math GPA's, whereas boys who have selected technical majors show much stronger GPA's in math, compared to their female counterparts. Interestingly, minority males, but not minority females, are considerably less likely to take more math courses, whereas girls academic track membership is more important in predicting their course-taking in math. Several of these cross-gender relationship differences vary -- either stronger or weaker -- from those we saw in earlier analyses. This is because the sample for these analyses includes only those students who have taken the SAT test, whereas the earlier sample includes all high school seniors who have taken at least some academic math. That is, the present sample is considerably more selective than the previous one.

DISCUSSION

The results of this study have revealed a somewhat different pattern of female attrition from high school mathematics from that described by earlier investigations using nationwide survey data. Previous research using national samples has tended to conclude that girls lag furthest behind in the most advanced courses. In contrast, in this study we have found that they tend to drop out of the less advanced courses in the academic math sequence at a greater rate than boys, but the proportion of females at the advanced level is actually slightly higher. However, these differential "leakage rates" at earlier stages mean that the pool of advanced math students who are female is considerably smaller, so that the more sex-equitable transition probabilities for the higher level courses cannot make up for earlier discrepencies. The overall result finds young women, at the point of high school graduation, with fewer credits in college-preparatory mathematics.

In addition to the question of "when" girls are most likely to abandon high school mathematics, we have also asked the question, "why?" The effect of cognitive, affective, and social factors upon the mathematics participation of males and females has been amply explored in previous research. We have therefore chosen to focus on an examination of the influence of school experiences, which have received less attention.

For example, it seems reasonable to suppose that the grades students earn in a particular subject, as powerful indicators of achievement and success, would function as important influences on subsequent persistence in that subject. Given that girls earn higher overall grades in mathematics than boys, we might expect this to encourage them to continue to enroll in math. In fact, the analysis of the effect of earned grades on total math course enrollment presented here suggests that the reality is quite different. The grade earned in the student's last course relative to overall math GPA has a particular and negative influence on persistence. The effect, although important for all students, is particularly salient for females. That is, young women appear to be more easily discouraged from persisting by a relatively lower grade in math. This result makes sense in light of the fact that "last math grades earned" tend to be lower than math grades in general, and that this descrepancy is greater for girls than boys.

Teachers and guidance counselors are in a position to offset this possible negative consequence of "last math grade" for girls by addesssing this issue directly in discussions with their students. Since girls are likely to be accustomed to earning high grades, a less high grade in a particular course is likely to seem lower, and therefore more discouraging, than it probably should. When mathematics teachers have females student who earn unusually (for them) low grades in their classes, they would do well to take those students aside for a short pep talk, in an effort to ensure that students may place such an event in the proper perspective and avoid concluding that they are "not smart enough" to continue in mathematics. Information about the consequences of dropping mathematics, as well as the considerable future benefits of persisting, should of course be presented explicitly to all students. It is girls, however, who are especially in need of such information, and of direct encouragement from high school staff.

The results of the study also show a direct positive relationship between social class and persistence in mathematics. SES is a stronger predictor of persistence for boys, however, than for girls, a finding which is somewhat inconsistent with the results of previous research (Armstrong, 1979; Brush, 1979). When SES is held constant, however, we find that black females are more likely to persist in mathematics, even though in general, the proportion of minority students decreases with each more advanced course. The strong (and negative) correlation between SES and minority status explains lower persistence rates for minority students, but the pattern of special persistence for black females has not been noted in previous research. This interesting phenomenon deserves special attention in subsequent research. The weaker relationship of SES to persistence for girls, coupled with a significantly stronger and positive effect for black females, could imply that social advantage plays a somewhat less deterministic role in mathematics courses enrollment for females. This is a encouraging finding, in our opinion.

The fact that demonstrated ability is more strongly associated with persistence for males than females among students of high ability may have serious implications. This could mean that within this select group, the very brightest girls are not persisting to the same degree as are the very brightest boys. Under such an interpretation, this phenomenon could represent a loss of the most able female students to professional areas where that level of ability and strong mathematical skills are often required. Another interpretation is that, for girls, measured ability makes less difference to persistence, and that other factors besides ability are relatively more important. Not only is the proportion of females within this high ability group slightly below that of males, but the mean score on the ability measure at sophomore year is .2 standard deviation units higher for boys than for girls (62.3 vs. 61.5). We would expect that virtually all students in the top ability quartile are capable of succeeding in the more advanced math courses, so the differential relationship of ability to persistence within this group is likely to result from girls relatively lower perceptions of thier abilities in mathematics.

Guidance counselors will also wish to be aware of the implications of academic track placement for especially able girls persistence in mathematics. While it is of course important that all students be situated in a curricular program where they have the best chance of fully realizing their academic potential, the results of this study suggest that girls in the academic track are more likely to continue to enroll in mathematics. The observation that less than two-thirds of the talented students in this group are actually in college-preparatory programs represents a probable loss of talented students to higher education, since it has been shown elsewhere (Oakes, 1985) that it is highly unlikely that any student who was not in the academic track in high school will eventually graduate from a four-year college. This, together with the special importantce of academic track placement for females, suggests that more careful attention to appropriate "track placement" in the future could help keep talented students in general, and girls in particular, in math.

Having acquired some understanding of when girls tend to "leak out of" high school mathematics and why, we now arrive at the inevitable question: "So what?" The consequences of abandoning the study of mathematics before finishing high school are serious and have been widely discussed. Here, we have confined ourselves to a single issue: the impact of mathematics participation upon SAT-M performance. A number of researchers have argued that the fact that females have consistently scored 40 to 50 points lower than males on the quantitative section of the SAT test over a period of years is largely, if not entirely, attributable to their greater rate of attrition from high school mathematics (Armstrong, 1979; Chipman & Thomas, 1985; Fennema & Sherman, 1977; Pallas & Alexander, 1983; Wise, Steel & MacDonald, 1979). Others have looked to genetic differences between the sexes to explain this discrepancy (Benbow & Stanley, 1980, 1983).

The available evidence in support of the claim that mathematics course-taking exerts a profound and positive influence on SAT-M scores seems indisputable. There has, however, been some debate over the issue of whether it is the actual content of the courses that is the crucial factor, or simply the general familiarity with mathematics acquired thorugh continued contact. To test this, we conducted regressions identical to those represented in Tables 8 and 9, substituting the semester students most recently took math for the total number of courses taken. There was virtually no difference in the results, indicating that contact with mathematics is equally validly measured by time or number of courses, in terms of its relationship to SAT-M performance. The 45-point advantage in SAT-M scores for males is substantially, but by no means completely or even mostly erased when gender differences in math course enrollment are taken into account (see Note 8). We have yet to adequately understand the reasons underlying females' poorer performance on the SAT-M, however, and future researchers may wish to incorporate other factors (e.g. attitudinal and socialization differences) into their research models in order to develop a fuller explanation of these important gender differences.

This study began with the question of whether, on the basis of highly reliable nationally representative data from student transcripts, we can conclude that high school girls are still taking fewer mathematics courses than boys. Our answer to this question is consistent with the conclusion reached by Chipman and Thomas (1985) in their recently reported review of the available data on this topic. That is, females overall level of participation in high school math _is_ lower than males', but the difference is not nearly as great as early research on specific populations of students suggested, or as has been widely accepted by the general public. However, it is our opinion that any difference is an important difference. Although the female disadvantage in math course-taking may have declined somewhat over time, we consider that certain stereotypes about the "appropriateness" of technical professions for women, as reflected by these data, continue. We have found that high school girls still take fewer academic math courses than their male counterparts, that they stop taking math sooner than boys, and that their relative lack of persistence in mathematics has serious consequences for their educational and professional futures.

TECHNICAL NOTES

1. We have chosen to include the 2 percent of the sample who are Asian Americans with whites. In the area of participation in mathematics, they behave more similarly to whites than to blacks or Hispanics, and their small sample size cannot support separate subgroup analysis.

2. It has been argued that girls grades in math are higher precisely <u>because</u> they take fewer courses. That is, there are fewer difficult courses to be figured into the math GPA. However, that is not the case. That is, girls have a higher average for each course taken. The average grades students earned in each course break down as follows:

	MALES	FEMALES
Algebra I	2.22	2.43
Geometry	2.33	2.43
Algebra II	2.25	2.54
Trigonometry	2.43	2.69
Pre-Calculus	2.71	2.90
Calculus	2.72	2.98

Note that the average grade, for both sexes, increases as the courses become more advanced. That is due, of course, to the fact that the sample of students who take each of these courses is different (and more and more selective), a point which will be extensively investigated later in the paper.

3. We have two pieces of evidence to support this contention. First, for those students who stopped taking math after Geometry, only 15.1 percent had taken Algebra II. However, for those who stopped after Algebra II, fully 62.0 percent have taken Geometry. Second, we found that for those who have taken Algebra II, 51 percent took it in their junior year, compared to only 13 percent who took is as sophomores. For those taking Geometry, the pattern is reversed -- a larger proportion have taken it as sophomores than as juniors.

4. There are probably some high schools which do not offer math courses more advanced than Trigonometry, causing some students to stop taking math at that point. This information is not available from HS&B. However, we have no reason to believe that females are any more likely than males to be in such schools.

5. The notion that it might be useful to consider students grades in a particular course <u>relative</u> to other grades they have earned, either in the same curricular area or in all school subjects, has come out of discussions with Thomas L. Hilton, a senior researcher at the Educational Testing Service. We believe that it is a particularly useful construct when trying to unpack the set of information students use to make important decisions about their futures. This is something Dr. Hilton has spent many years thinking about. We investigated several methods of computing this relative relationship. Specifically, we first tried entering both the last grade in math and the math GPA into regressions. However, these two variables are of course highly correlated, and produced serious supression effects which led to biased parameter estimates in regressions. Second, we compared the use

of a difference score (GPA in math minus last grade in math) with the ratio approach (last grade in math divided by math GPA). Both of these methods produced unbiased estimates, but estimates of the contribution of the ratio score produced higher R-squared values. We therefore settled on the ratio approach.

6. There is some question about whether it is advisable to adjust for ability in an analysis in which the dependent variable is also purported to measure essentially the same thing (ETS calls it "acquired ability"). We have included ability as a control factor to keep the analytic model as consistent as possible. However, in an absolutely parallel regression to that shown in Table 8 <u>except</u> that the ability control was removed, the unstandardized regression coefficient associated with being female was -48 points. That means that controlling for other model variables really does not explain much of the gender difference, net of ability. Of course, the R-squared figure for that regression is considerably lower (.450).

7. This is a case of cooperative suppression, as documented by Cohen & Cohen (1975). That is, the independent variables -- being female and grades -- are positively correlated with each other. However, female status is negatively correlated with the outcome, whereas grades are positively correlated. As a result, the variables are mutually enhancing when in the presence of each other, and each accounts for a larger proportion of variance when entered together than each would singly. Clearly, this is also true for the regression on SAT-M which includes no abiity control, as described in Note 3.

8. The Pallas & Alexander (1983) study also found that including Math GPA in these regressions actually <u>increases</u> the gender difference in favor of males, confirming the suppressor effect of this variable as discussed in Note 7. Although these researchers found a 21-point "female disadvantage" compared to our findings of a 33-point effect in the same direction, Pallas & Alexander also included the science course-taking in their regression model, in addition to courses in mathematics. Also, since we have excluded students who have taken no academic math courses in high school, our sample is somewhat more selective than theirs.

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Figure 1

SAT Score Averages, College-bound Seniors, 1968-1984*

	Verbal			Mathematical		
	Male	Female	Total	Male	Female	Total
1968	464	466	466	512	470	492
1969	459	466	463	513	470	493
1970	459	461	460	509	465	488
1971	454	457	455	507	466	488
1972	454	452	453	505	461	484
1973	446	443	445	502	460	481
1974	447	442	444	501	459	480
1975	437	431	434	495	449	472
1976	433	430	431	497	446	472
1977	431	427	429	497	445	470
1978	433	425	429	494	444	468
1979	431	423	427	493	443	467
1980	428	420	424	491	443	466
1981	430	418	424	492	443	466
1982	431	421	426	493	443	467
1983	430	420	425	493	445	468
1984	433	420	426	495	449	471

**The averages for 1968 through 1971 are estimates of the averages that would have been reported for college-bound seniors of those years if such reports had been produced.*

Source: The College Board (1984)

TABLE 1

High School Seniors: Means of Variables Which Relate To Persistence in Mathematics (Separately by Gender)

	MALES	FEMALES
Sample Size[1]	n=3928	n=4404
Variable:		
Social Class[2]	.159	.079
% Black	.075	.095
% Hispanic	.103	.081
% Academic Track	.435	.480
Achievement Composite[3]	54.11	53.43
Educational Aspirations[4]	5.96	6.04
% Technical Major[5]	.325	.115
Total Years of Math	2.47	2.29
Year, Last Math Course	3.10	2.87
Grade Point Average	2.62	2.85
Math GPA	2.14	2.35
Grade, Last Math Course	2.13	2.28
SAT, Math[6]	497.7	453.0

----

[1] The sample contains only those students who have taken at least a single Carnegie unit of academic math courses. This selection criterion eliminates 24.9 percent of the sample.

[2] The social class measure is standardized on the entire cohort of students on the HS&B file (HS&B item FUSES). Since the sample for this study is a selected sub-sample of that group, the mean social class for the group is somewhat higher than 0. The SES measure is a composite of family income, parental occupational prestige, parental education level, and the sum of certain educationally related household possessions.

3
The achievement composite is measured at sophomore year, and contains math, reading, and vocabulary. It is standardized at mean=50, standard deviation= 10 on the entire HS&B sample. This variable is used to control for ability elsewhere in this study.

4
Educational aspirations is the HS&B survey item BB065, measured at students sophomore year. It is coded so that higher aspirations have a higher rating. Aspiration to high school graduation is coded a '2', college graduation a '7'.

5
This is a dummy variable, created from students' statement of probable college major (HS&B item BB120), taken at sophomore year. "Technical major" includes mathematics, biological and physical science, computer science, and engineering. All other majors are coded '0'.

6
SAT scores are available only for the students who have taken that test, and this subgroup is clearly not a random sample of the group. They represent only about 30 percent of the total analytic sample described here, and girls are slightly more likely than boys to have taken the test.

TABLE 2

LAST MATH COURSE: Proportion of Students For Whom Each Math Course Was The Last One They Took (Separately by Gender)

Math Course Sequence:[1]	MALES	FEMALES
Algebra I[2]	.235	.278
Geometry	.205	.216
Algebra II	.200	.218
Trigonometry	.228	.172
Pre-Calculus[3]	.062	.055
Calculus	.068	.057

----

[1] The list of courses, as presented on this table, represent the most common sequence in which these courses are taken by the students on the HS&B transcript file. Although there is an alternate sequence, which reverses the order of Algebra II and Geometry, this second sequence is considerably less common. The sequence presented here is confirmed by consultation with several high school math teachers.

[2] We know that a not insubstantial proportion of students -- particularly high ability students -- take Algebra I before entering high school. If this were the case, those students would not have Algebra I on their high school transcripts. However, we believe that such students would be highly unlikely to stop taking academic math courses, and would thus not be included in the 25 percent of the HS&B transcript sample who took no academic math courses. However, the possibility of "missing" these students altogether exists.

[2] What we have called "Pre-Calculus" is also known as "Math Analysis" in many high schools. We consider the two titles interchangable.

FIGURE 2
LEAKS IN THE PIPELINE: Students Who Drop Out of Math After Each Course, Out of 1,000 Students

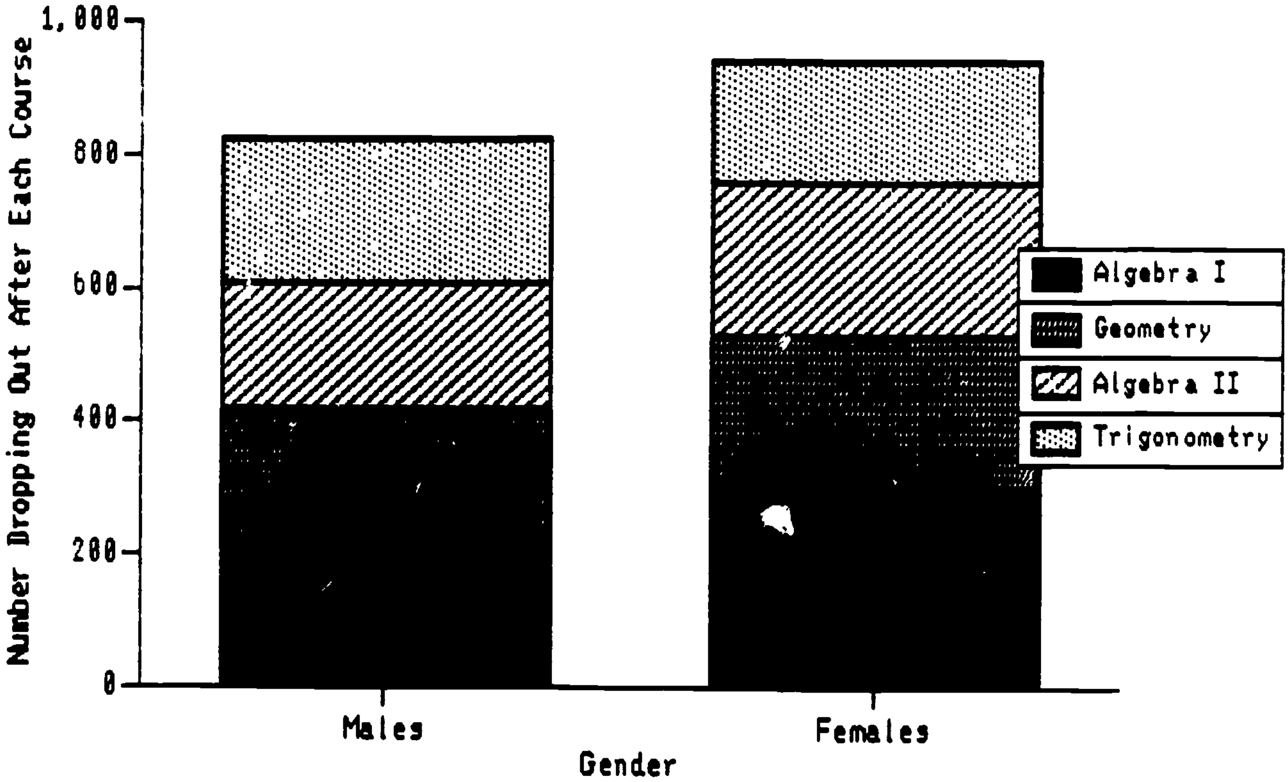

TABLE 3

TOTAL MATH COURSES TAKEN: Carnegie Units of Academic Math Courses Taken By Students in Each Ability Quartile (Separate by Gender)

Ability Quartile:[1]	MALES	FEMALES
Low	1.58[2]	1.44
	(.088)[3]	(.119)
Medium Low	1.82	1.87
	(.201	.219)
Medium High	2.39	2.27
	(.308)	(.299)
High	3.07	2.88
	(.404)	(.363)

---

1 This is the HS&B variable BYTESTQ, which is the categorized version of the same sophomore-year achievement test described in footnote 3 of Table 1. The variable was divided into quartiles on the entire cohort. However, due to sample selection described previously, the distribution for this study is skewed to the higher quartiles for both genders.

2 A Carnegie unit is a standard one-year course. Details of actual computation of Carnegie units are given in Jones, et al., (1983). This was done very carefully in preparing the transcript file.

3 The figures in parentheses represent the proportion of each gender which fall into each ability quartile.

FIGURE 3
Years of Academic Math Courses Completed for 1982 High School Seniors
Separately by Ability Group and Gender

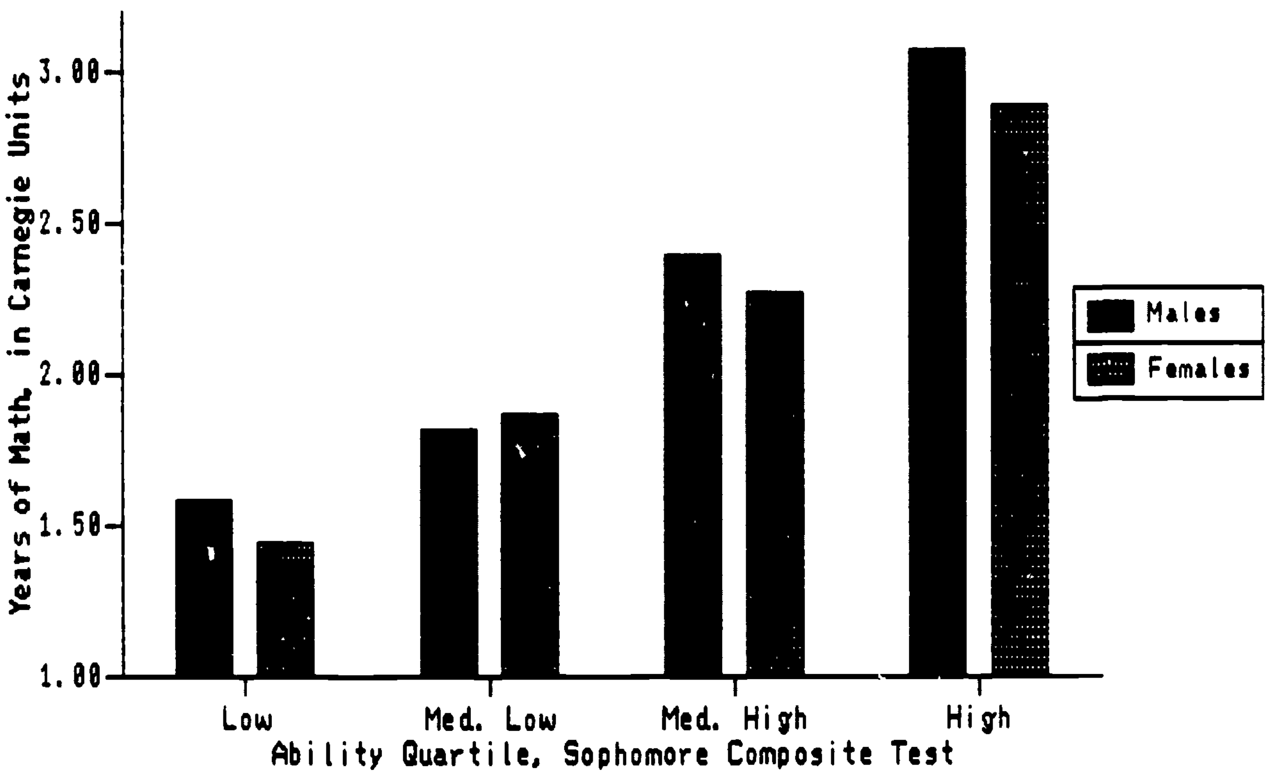

FIGURE 4
Proportion of 1982 High School Seniors
Who Are Still Taking Math at the End of Each Year
(Separate by Gender)

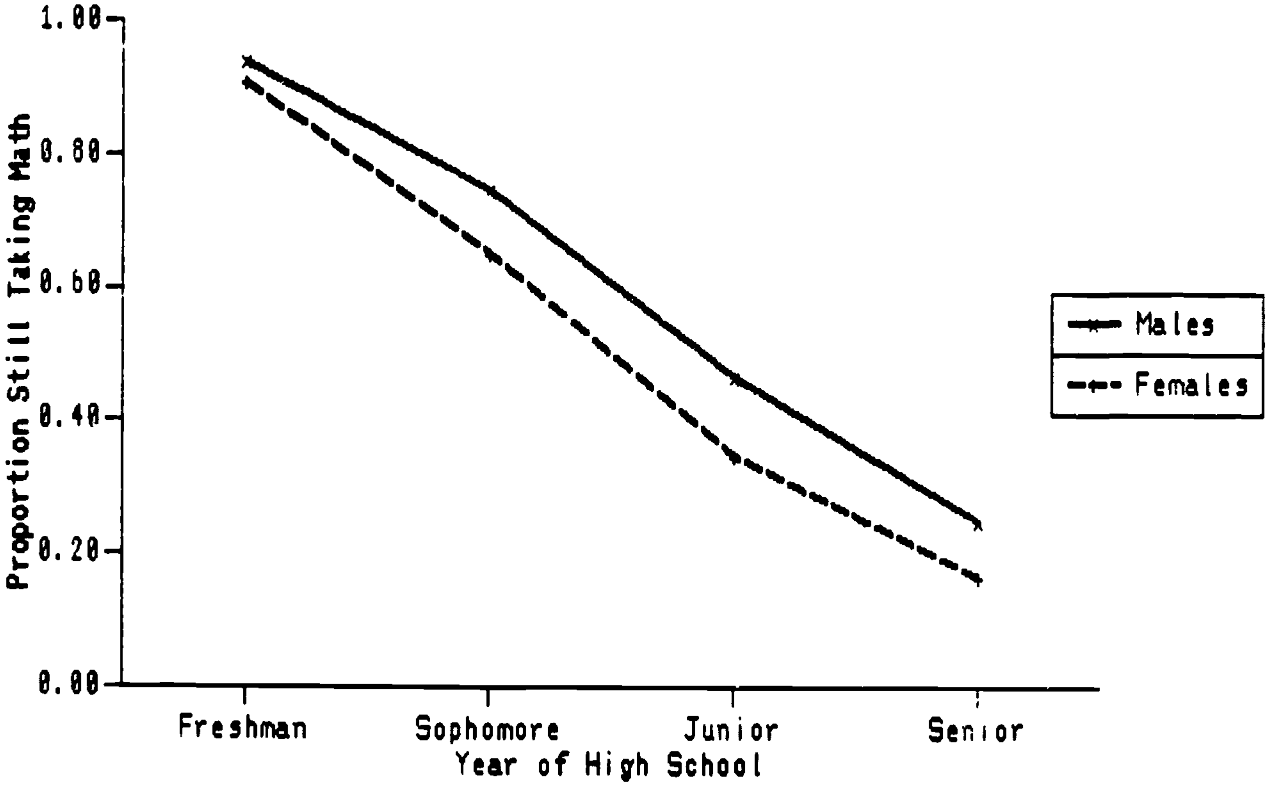

FIGURE 5
Proportion of 1982 High School Seniors of High Ability
Who Are Still Taking Math at the End of Each Year
(Separate by Sex)

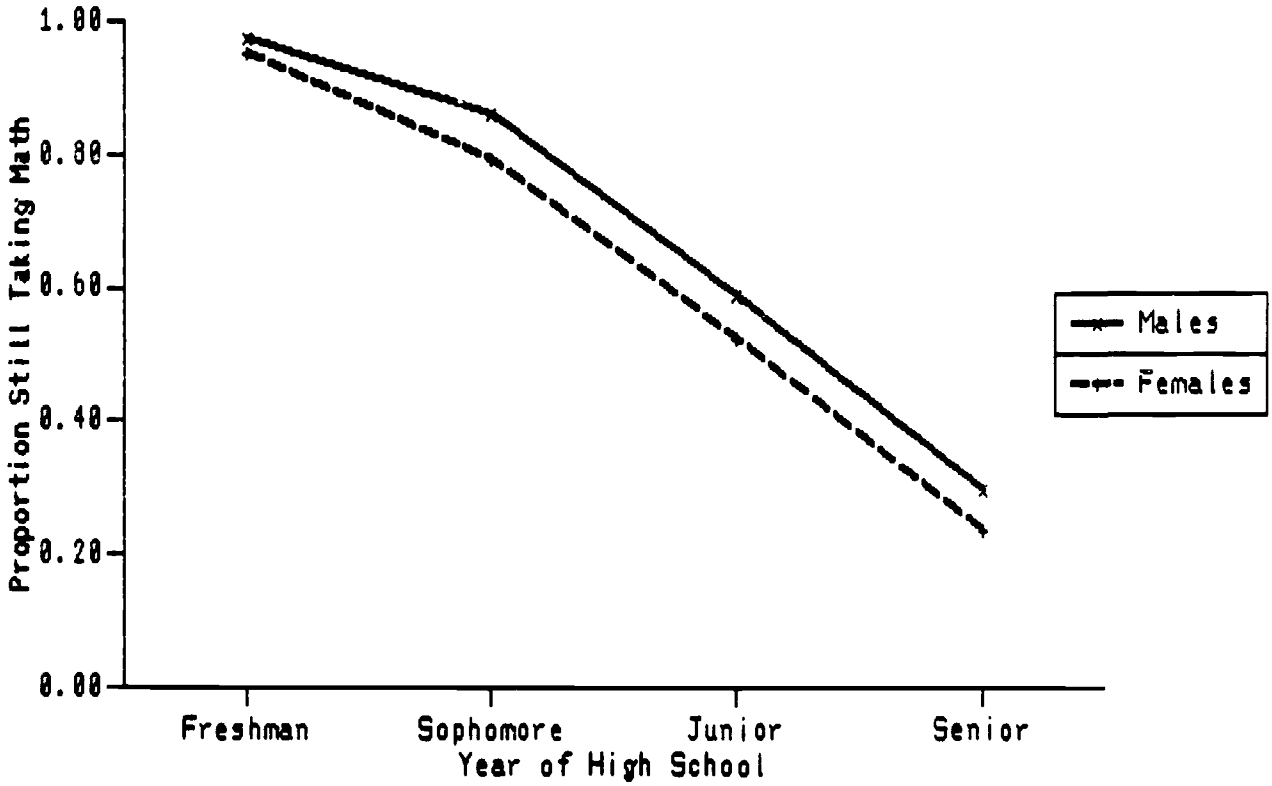

TABLE 4

TOTAL MATH COURSES TAKEN: Standardized Regression Coefficients (Betas) Comparing the Effect of Students' Grades in the Last Math Courses They Took, Relative to Their Overall Grades in Mathematics

(Separate by Gender, Total Sample vs. High-Ability Sample)

	MALES		FEMALES	
	Total Sample[1]	High Ability[2]	Total Sample	High Ability
Sample Size	3918	1474	4404	1516
Independent Variables:				
Social Class	.12***[3]	.09***	.07***	.06***
Black	.01	.04	.08***	.01
Hispanic	.01	.00	.01	.03
Developed Ability	.36***	.18***	.37***	.15***
Academic Track	.21***	.14***	.21***	.21***
Relative Last Math Grade[4]	-.12***	-.11***	-.13***	-.14***
% Total Variance Explained	.312	.099	.279	.107

[1] The sample contains only those students who have taken at least a single Carnegie unit of academic math courses. This selection criterion eliminates 24.9 percent of the sample.

[2] The high ability sample contains only those students who score in the highest quartile in BYTESTQ, as explained in footnote 1 of Table 3.

[3] These asterisks indicate nominal significance levels (* = $p < .05$; ** = p .01; *** = $p < .001$). No correction has been introduced for the design factor associated with the probability sampling plan. This applies to all results reported in this paper.

[4] As described in the text, a student's grade in the last math course he or she took is considered relative to the overall grade performance in math. It is computed as a ratio:

$$\text{Relative Last Math Grade} = \text{Grade, Last Math Course Taken} \,/\, \text{Math GPA}$$

TABLE 5

TOTAL MATH COURSES TAKEN: Tests of Statistical Significance of the Difference Between Regression Coefficients Across The Genders

	Total Sample	High-Ability Sample
	t-Statistic[1]	t-Statistic
Relative Math Grade:	-2.06*	-1.25
Social Class:	2.74**	0.72
Developed Ability:	0.32	-3.01*
Academic Track:	0.76	-2.19*
Black:	-2.97**	0.74

[1] The difference between two regression coefficients for independent samples is tested as follows (Draper & Smith, 1966):

$$t_{\Delta b} = \frac{b_1 - b_2}{\sqrt{s.e._{b_1}^2 + s.e._{b_2}^2}}$$

Where

b_1 = the unstandardized regression coefficient for males; and

b_2 = the unstandardized regression coefficient for females.

It should be noted that a positive t-statistic means that the particular effect is stronger for males than for females; a negative t-statistic signifies that the effect is stronger for females than for males.

TABLE 6

COLLEGE-PREPARATORY MATH SEQUENCE: Means on Model Variables For Samples of Students Who Have Taken Each Math Course
(Genders Combined)

	For Students Who Have Completed:			
	GEOMETRY	ALGEBRA II	TRIGONOMETRY	PRE-CALCULUS
Sample Size[1]	6143	4392	2649	1002
Model Variables:				
% Female	.51	.50	.47	.49
Social Class	.21	.27	.37	.48
% Black	.08	.07	.05	.04
% Hispanic	.08	.07	.06	.05
% Academic Track	.54	.60	.67	.77
Developed Ability	55.2	56.5	58.7	60.9
% Technical Major	.24	.27	.31	.35
Ed. Aspirations[2]	6.43	6.80	7.15	7.45
Relative Grade in Course[3]	.98	.94	.91	.92

---

1 The samples are composed as follows. The sample in the first column contains only those students who have completed Geometry. For the sample in the second column, only those those students who have completed Algebra II are included. For Trigonometry and Pre-Calculus, the samples are constructed in the same manner. Note that the means on these variables for the entire analytic sample shown in Table 1 are, in effect, for those who have completed Algebra I.

2 Educational aspirations are scored as follows: 2=high school graduation; 7=graduation from a 4-year college; 8=masters degree; 9=doctoral degree.

3 These relative math grades are computed as explained in footnote 4 of Table 4. In each case, the grade in each particular math course is computed as a proportion of the overall grade point average in mathematics.

TABLE 7

PERSISTENCE TO NEXT MATH COURSE: Standardized Regression Coefficients (Betas) For Model Variables For Progressively Smaller Samples
(Genders Combined)

	ALGEBRA II	TRIGONOMETRY	PRE-CALCULUS	CALCULUS
Sample Size	6143	4392	2649	1002
% Persisting From[2] Previous Course	.512	.391	.217	.462
Independent Variables:				
Gender (Female)	.00	-.05**	.06*	.03
Social Class	-.04	.01	.01	.02
Black	.01	.01	-.05	-.03
Hispanic	-.03	.00	.00	.04
Academic Track	.06***	.05*	.05	.13**
Developed Ability	.06**	.16***	.07*	.21***
Technical Major	.02	.05	.04	.04
Ed. Aspirations	.12***	.07***	.05	-.01
Relative Grade in Previous Course[3] (Which Course?)	.03* (Geometry)	.12*** (Algebra II)	.10*** (Trigonometry)	.21*** (Pre-Calculus)
% Total Variance Explained	.034	.079	.036	.130

1 The sample for each regression is composed as follows. For the sample investigating persistance to Algebra II, only those students who have completed Geometry are included. For the sample investigating persistance to Trigonometry, only those who have completed Algebra II are included. For Pre-Calculus and Calculus, the sample are constructed in the same manner.

2
The proportion persisting consists of the proportion of the progressively reduced samples who take the next course. For example, for those who have taken Geometry, 51.2 percent persist to Algebra II; for those who have taken Algebra II, only 39.1 percent persist to Trigonometry, etc. These progressively smaller samples, where all persistance rates exceed 20 percent, allow the use of OLS regression for the analysis, even though the dependent variable is dichotomous.

3
These relative math grades are computed as explained in footnote 4 of Table 4. In each case, the grade in the previous particular math course is computed as a proportion of the overall grade point average in mathematics.

TABLE 8

PATH MODEL PREDICTING SAT MATH SCORE: Standardized (Beta) and Unstandardized Coefficients for Each Regression Analysis (Genders Combined)[1]

Sample Size: 2481

	Dependent Variables			
	ABILITY, 10th	MATH GPA	MATH COURSES	SAT, MATH
Independent Variables:[2,3]				
Gender (Female)	-.04*** -.58	.15*** .28	-.10*** -.27	-.14*** -32.72
Social Class	.15*** 1.79	-.07** -.09	.03 .05	.06*** 9.61
Minority Status	-.24*** -5.67	-.03 -.09	-.05* -.17	-.04* -11.37
Technical Major	.08*** 1.45	.10*** .22	.06** .17	.06*** 15.86
Ed. Aspirations	.19*** .91	.04 .02	.11*** .09	.07*** 4.62
Academic Track	.17*** 2.93	.02 .03	.18*** .48	.02 7.14
Ability (10th)		.47*** .05	.10*** .02	.51*** 7.32
Math GPA			.32*** .44	.25*** 31.85
Math Courses				.08*** 7.26
% Total Variance Explained	.234	.259	.278	.639

---

[1] This sample is all of those on the HS&B transcript file who have taken the SAT tests. We assume that students took these tests during their senior year, in 1981-1982. As stated in footnote 6 of Table 1, this is about 22.5 percent of high school seniors, and 29.8 percent of the analytic sample used elsewhere in this study. The SAT takers are approximately evenly divided between males and females.

[2] We present both the standardized (above) and unstandardized (below) regression coefficients for two reasons. The standardized coefficients are useful in order to examine the relative effect of a particular independent variable -- being female, for example -- on each dependent variable, even though those outcomes are each measured in a different metric. However, the unstandardized regression coefficient has a substantive interpretation lost by the beta coefficients. That is, the unstandardized coefficents indicate the exact number of points in the outcome measure (SAT-M, for example), which are attributable to membership in certain groups. For example, the unstandized regression coefficient of -32.7 for gender indicates that females score 33 points below males <u>even after adjustment for the course taking differences</u>. Similar interpretations are possible for other dummy variables in the model: minority status, academic track, and technical major.

[3] These asterisks indicate nominal significance levels (* = $p<.05$; ** = $p<.01$; *** = $p<.001$). No correction has been introduced for the design factor associated with the probability sampling plan. This applies to all results reported in this paper. The significance level applies to both standardized and unstandardized coefficients.

TABLE 9

PATH MODEL PREDICTING SAT MATH SCORE: Standardized Coefficients (Betas) for Each Regression Analysis
(Separate by Gender)

	Dependent Variables							
	ABILITY, 10th		MATH GPA		MATH COURSES		SAT, MATH	
	Male	Female	Male	Female	Male	Female	Male	Female
Independent Variables:								
Social Class	.15***	.16***	-.03	-.10***	.00	.06	.07***	.04
Minority Status	-.21***	-.27***	-.01	-.05	-.11***	.01	-.04	-.04*
Technical Major	.08*	.06	.13***	.06*	.04	.08**	.07**	.04*
Ed. Aspirations	.23***	.17***	.07*	.01	.09**	.12***	.04	.09***
Academic Track	.18***	.18***	.02	.02	.15***	.20***	.04	.09***
Ability (10th)			.46***	.48***	.11***	.09**	.50***	.53***
Math GPA					.33***	.32***	.28***	.24***
Math Courses							.08**	.08***
% Total Variance Explained	.231	.234	.267	.247	.287	.272	.635	.624

---

1 This sample is all of those on the HS&B transcript file who took the SAT tests. We assume that students have taken these tests during their senior year, in 1981-1982. As stated in footnote 6 of Table 1, this is about 22.5 percent of high school seniors, and 29.8 percent of the analytic sample used elsewhere in this study. The SAT takers are approximately evenly divided between males and females.