UNITED STATES DEPARTMENT OF EDUCATION

OFFICE OF THE SECRETARY

FAX TRANSMITTAL

TO MIKE COHEN

PHONE _____ FAX 456-5581

FROM DAVID FRANK

PHONE 401-3101 FAX 202-401-0596

PAGE(S) TO FOLLOW _____

MESSAGE: attached are draft highlights from the math (tough courses = college) report we are thinking of releasing Monday.

CONFIDENTIALITY NOTICE

DRAFT

A Letter from the Secretary of Education

Many parents, students, and educators do not realize that within the United States today, mastering mathematics has become a gateway to the road to college--and taking algebra or courses covering algebraic concepts by the end of the 8th grade is a key to the "gate." Although almost all parents want their children to go on to college or some advanced training, many 8th and 9th graders may be behind in their course taking to get on the road to college, and not realize it.

Recent analyses conducted by the U.S. Department of Education indicate that students with strong mathematics backgrounds--those who take algebra and geometry and more rigorous mathematics courses during high school--are more likely to go on to college. This is true regardless of their family's level of income. In fact, the positive impact of taking rigorous courses is most dramatic for students from low-income families. In addition, students who took chemistry, a subject which requires a strong background in mathematics, were also more likely to go to college. Other research tells us that the benefits of a strong background in mathematics are not limited to college-going, and workers with high levels of mathematics achievement earn more and are less likely to be unemployed than workers who are less proficient in mathematics.

However, not all students have access to rigorous mathematics courses--either because their school may not offer a full selection of challenging courses to all students, or because students are not prepared for and encouraged to take them. The results of the recently completed Third International Mathematics and Science Study (TIMSS) confirm that many students enter high school without a solid grounding in mathematics, closing doors very early to opportunities for further education and better career opportunities.

The implications are clear: The 8th grade is a critical point in mathematics education. Achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses important for later success. As a nation, we must ensure that all our students develop the necessary mathematics background by the end of the 8th grade--and build on that foundation throughout high school. We challenge parents, schools, community groups, colleges, universities, and employers to ensure that all children have access to rigorous mathematics courses and encourage them to go to college. To assist in that effort, the U.S. Department of Education stands ready to assist states, local communities, and individual students by providing federal student financial aid for college, by supplementing Advanced Placement Exam fees for students' who demonstrate need by providing funding through Title I of the Elementary and Secondary Education Act (ESEA) and other programs to assist schools in upgrading mathematics teaching and learning, and by providing a voluntary national test in 8th grade in mathematics to help ensure that all students are given the opportunity to excel.

Sincerely,

Richard Riley

Executive Summary

Within the United States today, mastering mathematics has become more important than ever. Students with strong mathematics backgrounds have advantages in academics and in the job market. The 8th grade is a critical point in mathematics education, and achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses that are keys to college entrance and success in the labor force. However, although most parents want their children to go on to college or some advanced training, most 8th and 9th graders are behind in their course taking to get on the road to college. Findings highlighted in this report include:

- **Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not.** Data from the National Educational Longitudinal Study (NELS) reveal that 83 percent of students who took algebra I and geometry went on to attend a two or four year college within two years of their scheduled high school graduation, compared to a college attendance rate of only 36 percent among students not taking algebra I and geometry; while nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college.

- **Algebra is the "gateway" to advanced mathematics and science in high school--yet most students currently do not take algebra during middle school.** Students who plan to take advanced mathematics and science courses during high school and study algebra during middle school are at an advantage: Forty-six percent of students who took algebra I in the 8th grade took calculus in high school, compared to only eight percent of students who took algebra I in the 9th grade. However, 1996 NAEP data reveal that only 25 percent of 8th graders in the U.S. were enrolled in algebra, and that low-income and minority students are even less likely to be enrolled in algebra during the 8th grade.

- **Taking rigorous mathematics and science courses in high schools appears to be especially important for low-income students.** Low-income students who took algebra I and geometry were almost three times as likely to attend college as those who did not: While 71 percent of those who took algebra I and geometry went to college, only 27 percent who did not went on to college. By way of comparison, 94 percent of students from high income families, and 84 percent of students from middle income families who took algebra I and geometry in high school went on to college, while 60 percent of students from high income families and 44 percent of students from middle income families who did not take algebra I and geometry still did go on to college.

- **Despite the importance of taking rigorous mathematics and science courses for low-income students, they are less likely to take these courses.** Students from higher income families are almost twice as likely to take algebra in middle school and geometry in high school and more than twice as likely to take chemistry than lower income students.

Other important findings include:

- **Mathematics achievement depends on course-taking, not the type of school a student attends.** Students at public and private school who had taken the same rigorous mathematics courses were equally likely to score at the highest level on the NELS 12th grade mathematics achievement test.

- **Students who have parents who are involved in their school work are more likely to take challenging mathematics courses early.** Students whose parents were involved in their educations were more likely to take courses like algebra and geometry in the 8th and 9th grade, than students' whose parents were not involved.

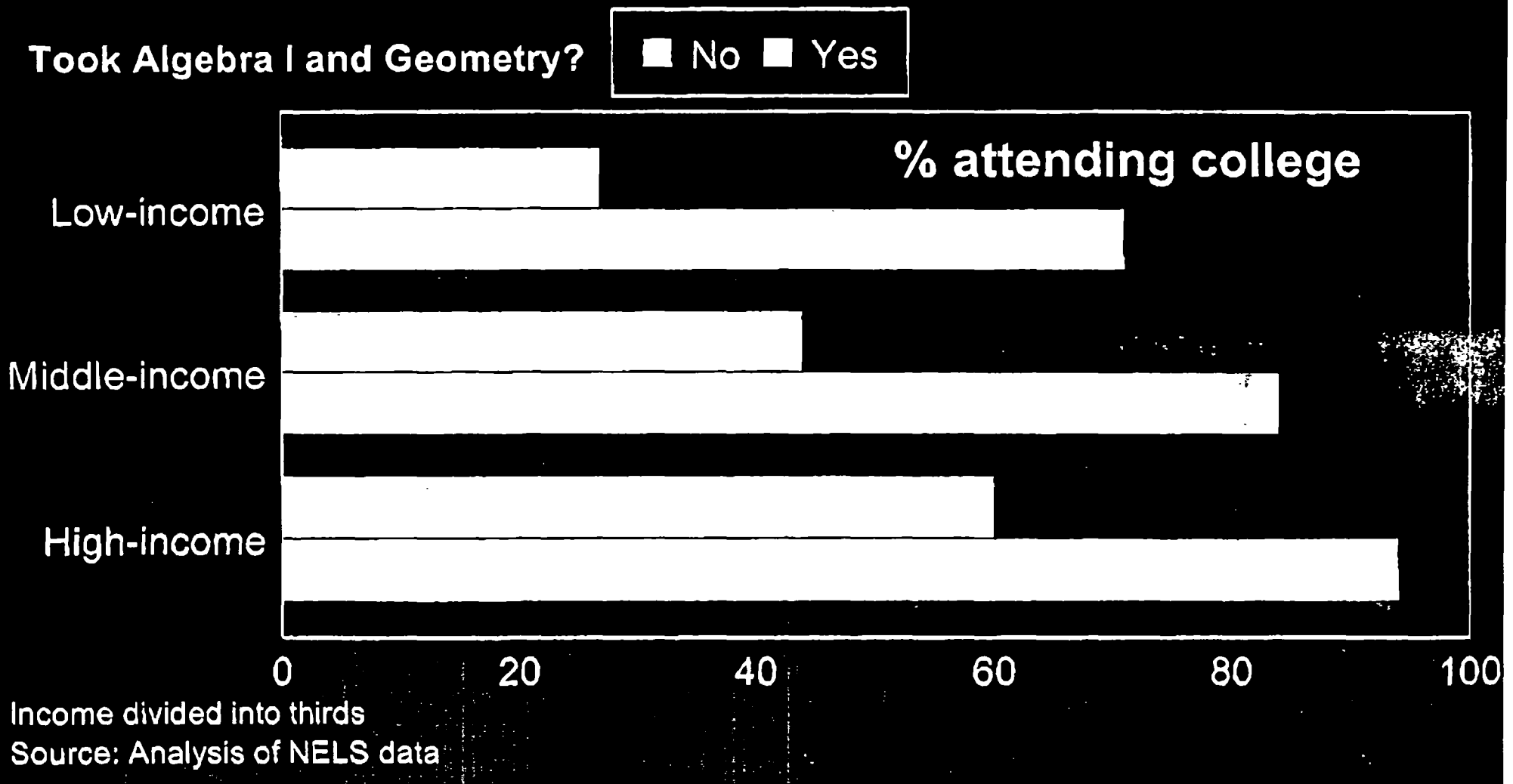
- **The results of the Third International Mathematics and Science Study (TIMSS) reveal that the U.S. middle school mathematics curriculum may be a weak link in the U.S. educational system.** While U.S. 4th graders score above the international average in mathematics and science, U.S. 8th graders score below average in 8th grade mathematics, and only slightly above the international average in science. Initial analysis of the TIMSS data also shows that the U.S. middle school mathematics curriculum is not as challenging as that of other countries. The curriculum of average 8th-grade mathematics classrooms in the U.S. resembles 7th grade mathematics elsewhere. Although algebra and geometry are important elements in the middle school curriculum taught in other countries, only a small fraction of U.S. middle school students are exposed to these topics.

Algebra in the Curriculum

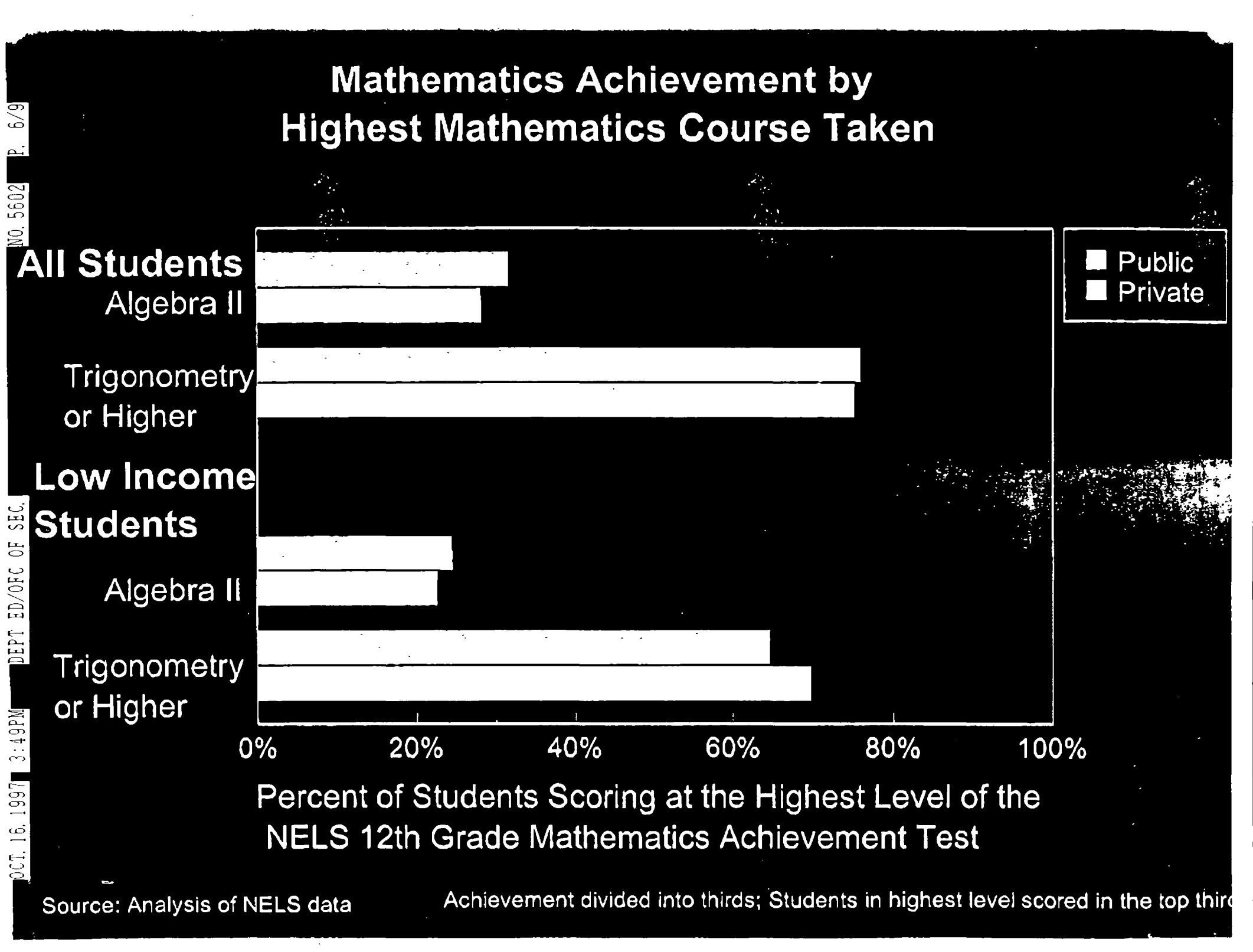
Making a successful transition from arithmetic to more advanced topics, including algebra and geometry, has often been difficult for students. As a result, many mathematics programs in the U.S. are now systematically incorporating some of the fundamental ideas from algebra and geometry into the upper elementary grades. In these programs, 5th, 6th and 7th grade students are learning about representing and solving equations, characterizing patterns and rates of change among variables, and other fundamental algebraic concepts.

In addition, the approach middle and high schools take to presenting advanced topics differs. Many schools offer the traditional model of pre-Algebra, Algebra I, Geometry, Algebra II, Trigonometry, pre-Calculus and Calculus. However, an increasing number of schools offer courses in which algebra, geometry and other advanced topics are more integrated. This approach is consistent with the practice in other industrialized nations which integrate algebra, geometry and other topics through out the elementary, middle and high school years and offer a significant component of algebra in the 8th grade. Building a firm foundation in algebra in the elementary and middle school years makes the shift from arithmetic to advanced topics more successful, regardless of the format of the middle and high school curriculum. NELS and NAEP, the two sources of national course-taking data which are analyzed in this brief, employ traditional courses titles, such as "algebra I" and "geometry" for mathematics courses. Thus, these traditional titles are used throughout the brief.

College Attendance by Income and Course-Taking



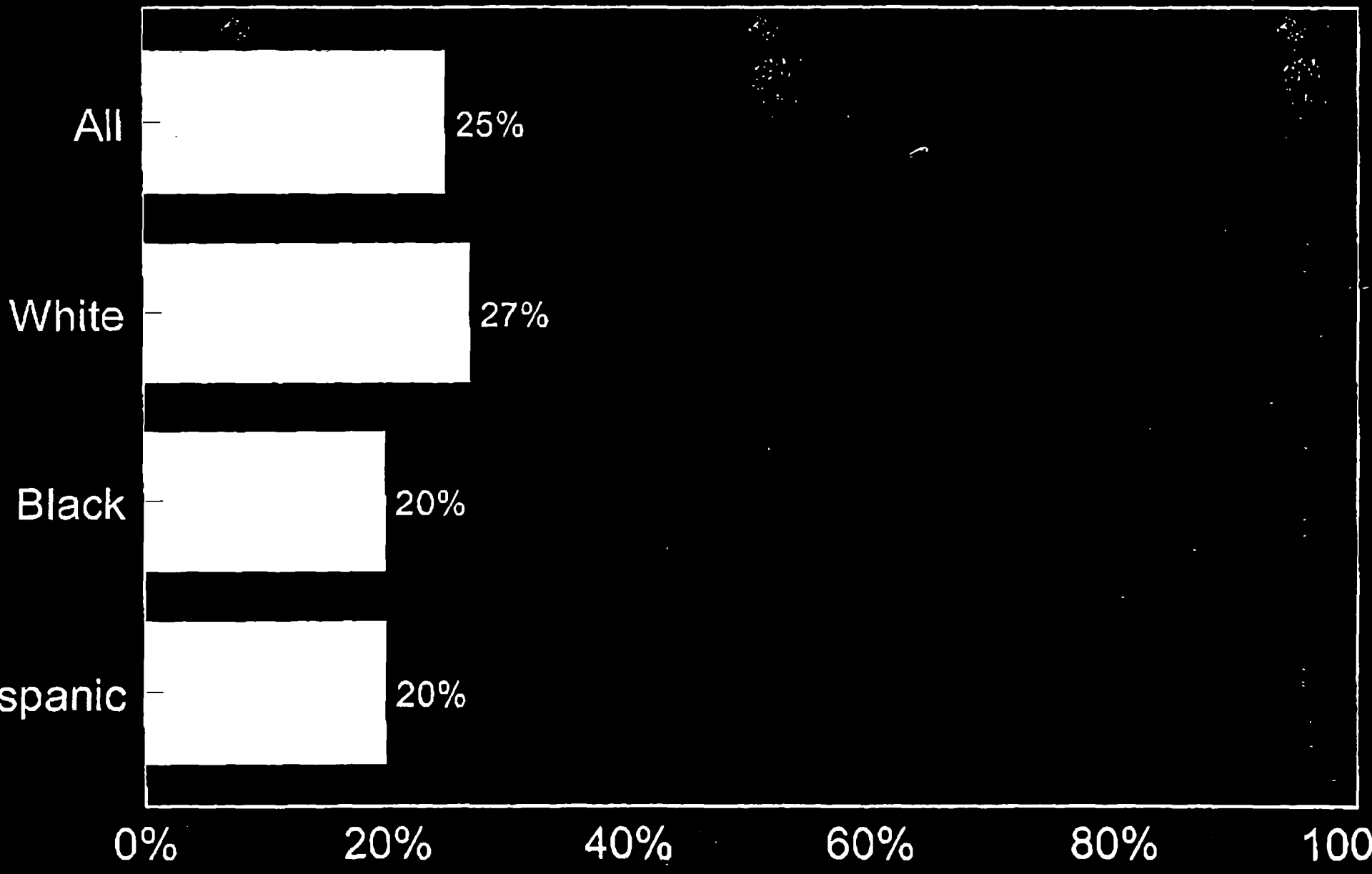
Mathematics Achievement by Highest Mathematics Course Taken



Source: Analysis of NELS data

Achievement divided into thirds; Students in highest level scored in the top third

Proportion of Eighth-Graders Enrolled in Algebra, 1996



Source: 1996 NAEP Mathematics Assessment background questionaire

Next Steps

Six things educators, policymakers and community members can do:

1. Provide all students the opportunity to take algebra I or a similarly demanding course that includes fundamental algebraic concepts in the 8th grade and more advanced math and science courses in all four years of high school.

2. Build the groundwork for success in algebra by providing a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares students for the transition to algebra.

3. Ensure that all students, parents, teachers, and counselors understand the importance of students' early study of algebra as well as continued study of rigorous mathematics and science in high school to their future college and career opportunities.

4. Prepare teachers of mathematics to teach rigorous mathematics by providing teacher preparation and professional development opportunities that increases teachers knowledge and skills in mathematics and the teaching of mathematics.

5. Support mathematics achievement outside the classroom such as math clubs, tutoring and job shadowing for students who may need extra help to ensure that they can achieve at high levels.

6. Support parent involvement in their children's mathematics education.

Six things parents can do:

1. Discuss your children's mathematics homework with them.

2. Visit your children's mathematics teacher to find out what your children are learning and how you can help.

3. Insist that your children be enrolled in algebra I or a similarly demanding course that includes fundamental algebraic concepts in the 8th grade and more advanced math and science courses in high school so they can keep all of their future options open.

4. Ensure that your children are gaining the groundwork for success in algebra through a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares them for the transition to algebra.

5. Help your children understand the importance of taking challenging mathematics and science courses to their future by visiting colleges, familiarizing them with college requirements, and

exploring financial aid options available to students.

6. Show the importance of mathematics to career choices by talking with your children about the use of mathematics in your work or the work of adults they know.

Helping Students Master Challenging Mathematics and Prepare for College
October 15, 1997 -- DRAFT

Today President Clinton returns from a Latin American trip which highlighted how countries around the world are striving to improve education for their people. The President will release a new U.S. Department of Education report which shows that students in this country -- especially low-income students -- who take rigorous math and science courses in high school are much more likely to go on to college. The study also finds that while algebra is the gateway to advanced math and science in high school, most U.S. students do not take algebra during their middle school years. Finally, the study indicates that when differences in course-taking are accounted for, student achievement is the same for students in public, private, and parochical schools. The President's noted that his proposed voluntary national test in 8th grade mathematics would encourage schools and school districts across the country to offer more challenging math courses to students in the middle school grades, and renewed his call for Republicans in Congress to support his plan for high national standards in the basics of reading and math.

Students Who Take Tough Math and Science Courses Go on to College. The study released today analyzes data from the National Educational Longitudinal Study (NELS) which show, for example, that 83% of students who take geometry in high school go on to attend college within 2 years of high school graduation, compared to just 35% of those not taking geometry. The impact of rigorous course-taking is most pronounced for low income students. Low income students who take geometry are almost 3 times as likely to attend college as those who do not; when course-taking is accounted for, income differences in college-going diminish dramatically.

Algebra is the Gateway to Advanced Math and Science, Yet Most Students Currently Don't Study Algebra During Middle School. While we know from the Third International Mathematics and Science Study (TIMSS) that students in other countries have begun to master the basics of algebra and some geometry by the end of 8th grade, today's report shows that only 25% of U.S. 8th graders enrolled in algebra during 1996, according to the National Assessment of Educational Progress (NAEP). However, students with parents who are deeply involved in their education are more likely to take challenging math courses early.

Math Achievement Is Associated with Student Course-Taking, Not the Type of School (Public or Private) that the Student Attends. Students at public and private schools who had taken the same rigorous mathematics courses are equally likely to score at the highest level on the NELS 12th grade mathematics achievement test. This is also true of low-income students.

The Voluntary National Test in 8th Grade Mathematics Will Increase Participation in Algebra in the Middle School Grades. The President's proposed voluntary national test in mathematics will be a rigorous test, including the basics of algebra and even geometry. The tests will support communities and schools working to offer challenging mathematics courses, including algebra, in middle school. The President renewed his call for Republicans in Congress to stop delaying his plan for voluntary national tests so that more students will be able to achieve to high levels in math and pursue their dreams of a postsecondary education.

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U.S. Department of Education
Office of Under Secretary, Planning and Evaluation Service
600 Independence Avenue, SW
Room 4168, FOB10
Washington, DC 20202

FAX COVER SHEET

Fax Number: (202) 401-3036

TO : Bill Kincaid

FAX NO.: 456-7028

(Number of pages, including cover sheet: 25)

FROM: Melissa Chabran

PHONE NO.:401-1265

Message:
Bill,

Attached is the most recent draft of the mathematics coursetaking brief. We will continue to update you as we make revisions. Please let me know if you have any questions or comments.

I hope that things are well with you.

Take care,
Melissa

A Letter from the Secretary of Education and Director of the National Science Foundation

Many parents, students, and educators do not realize that within the United States today, mastering mathematics has become a gateway to the road to college--and taking algebra or courses covering algebraic concepts by the end of the 8th grade is a key to the "gate." Although almost all parents want their children to go on to college or some advanced training, most 8th and 9th graders are behind in their course taking to get on the road to college.

Recent analyses conducted by the U.S. Department of Education indicate that students with strong mathematics backgrounds--those who take geometry and more rigorous mathematics courses during high school--are more likely to go on to college. This is true regardless of their family's level of income. In fact, the positive impact of taking rigorous courses is most dramatic for students from low-income families. In addition, students who took chemistry, a subject which requires a strong background in mathematics, were also more likely to go to college. Other research tells us that the benefits of a strong background in mathematics are not limited to college-going, and workers with high levels of mathematics achievement earn more and are less likely to be unemployed than workers who are less proficient in mathematics.

However, not all students have access to rigorous mathematics courses--either because their school may not offer a full selection of challenging courses to all students, or because students are not prepared for and encouraged to take them. The results of the recently completed Third International Mathematics and Science Study (TIMSS) confirm that many students enter high school without a solid grounding in mathematics, closing doors very early to opportunities for further education and better career opportunities.

The implications are clear: The 8th grade is a critical point in mathematics education. Achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses important for later success. As a nation, we must ensure that all our students develop the necessary mathematics background by the end of the 8th grade--and build on that foundation throughout high school. We challenge parents, schools, community groups, colleges, universities, and employers to ensure that all children have access to rigorous mathematics courses and encourage them to go to college. To assist in that effort, the U.S. Department of Education and the National Science Foundation stands ready to assist states, local communities, and individual students by providing federal student financial aid for college, by supplementing Advanced Placement Exam fees for students' who demonstrate need by providing funding through Title I of the Elementary and Secondary Education Act (ESEA) and other programs to assist schools in upgrading mathematics teaching and learning, and by providing a voluntary national test in 8th grade in mathematics to help ensure that all students are given the opportunity to excel.

Sincerely,

Richard Riley
U.S. Secretary of Education

Neal Lane
Director of the National Science Foundation

Executive Summary

Within the United States today, mastering mathematics has become more important than ever. Students with strong mathematics backgrounds have advantages in academics and in the job market. The eighth grade is a critical point in mathematics education, and achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses that are keys to college entrance and success in the labor force. However, although most parents want their children to go on to college or some advanced training, most 8th and 9th graders are behind in their course taking to get on the road to college. Findings highlighted in this report include:

•**Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not.** Data from the National Educational Longitudinal Study (NELS) reveal that 83 percent of students who took geometry in high school went on to attend a two or four year college within two years of their scheduled high school graduation, compared to a college attendance rate of only 35 percent among students not taking geometry; while nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college.

•**Algebra is the "gateway" to advanced mathematics and science in high school--yet most students currently do not take algebra during middle school.** 1996 NAEP data reveal that only 25 percent of eighth graders in the U.S. were enrolled in algebra, and that low-income and minority students are even less likely to be enrolled in algebra during the eighth grade. Students who do not begin to study algebra during middle school have a distinct disadvantage in taking advanced mathematics and science courses during high school.

•**The effects of taking rigorous mathematics and science courses are most dramatic for low-income students.** Low-income students who took geometry were almost three times as likely to attend college as those who did not: While 71 percent of those who took geometry went to college, only 26 percent who did not went on to college. By way of comparison, 93 percent of students from high income families, and 84 percent of students from middle income families who took geometry in high school went on to college, while 59 percent of students from high income families and 42 percent of students from middle income families who did not take geometry still did go on to college. When course taking is accounted for, differences by income in the rate of college going diminish dramatically, although they do not disappear completely.

•**Despite the dramatic effects of taking rigorous mathematics and science courses for low-income students, they are less likely to take these courses.** Students from high income families are almost twice as likely to take algebra and more than twice as likley to take chemistry than low income students.

Other important findings include:

•**Mathematics achievement depends on course-taking, not the type of school a student attends.** Students at public and private school who had taken the same mathematics courses are equally likely to score at the highest level on the NELS 12th grade mathematics achievement test.

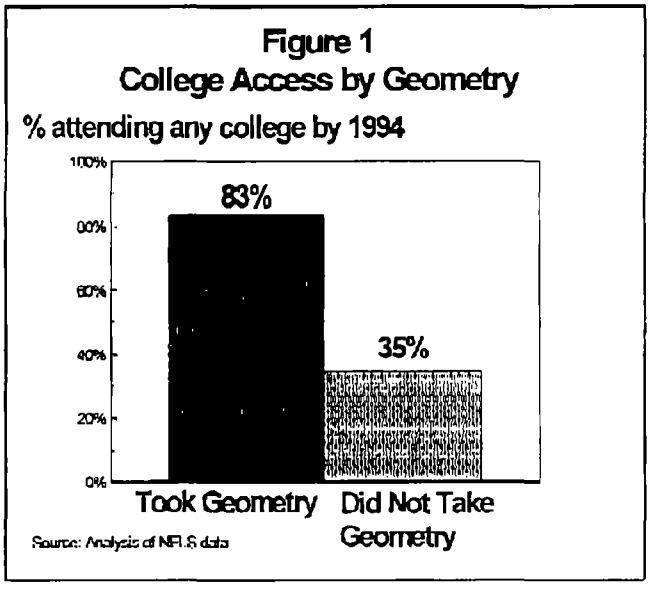
•**Students who have parents who are involved in their school work are more likely to take challenging mathematics courses early.** Regardless of whether the level of parent involvement was reported by the student, the parent, or the student's teacher, students whose parents were involved were more likely to take courses like algebra and geometry in the eighth and ninth grade, than students' whose parents were not involved.

•**The results of the Third International Mathematics and Science Study (TIMSS) reveal that the U.S. middle school mathematics curriculum may be a weak link in the U.S. educational system.** While U.S. fourth graders score above the international average in mathematics and science, U.S. eighth graders score below average in eighth grade mathematics, and only slightly above the international average in science. Initial analysis of the TIMSS data also shows that the U.S. middle school mathematics curriculum is not as challenging as that of other countries. Although algebra and geometry are important elements in the middle school curriculum taught in other countries, only a small fraction of U.S. middle school students are exposed to these topics.

Why Mathematics Matters

The Power of Mathematics for College Entrance

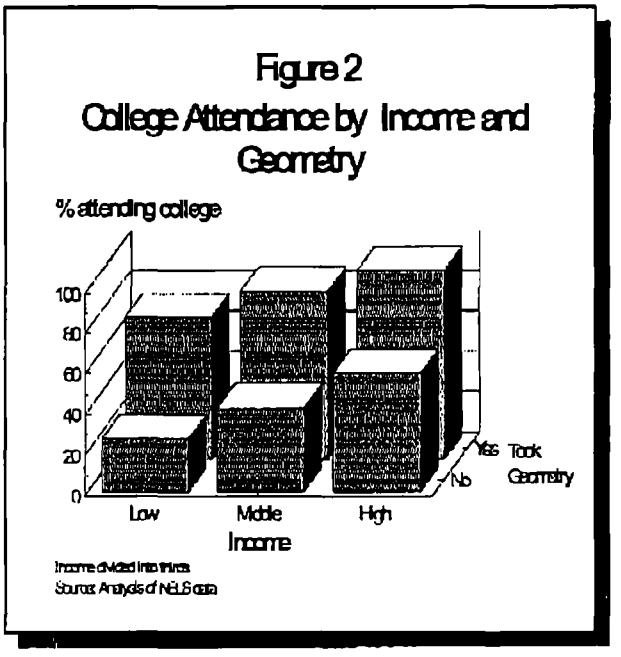
Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not. Data from a longitudinal survey of students who were in the eighth grade in 1988 (National Educational Longitudinal Study or NELS) reveal that 83 percent of students who took geometry in high school--the course that usually follows algebra I in a rigorous mathematics program--went on to attend a two or four year college within two years of their scheduled high school graduation. By way of comparison, only 35 percent of students not taking geometry went to college (Figure 1). Similarly, students who take rigorous science courses in high school are also much more likely to go to college: While nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college. Students who take more rigorous mathematics courses also have higher gains in mathematics achievement (as measured by the NELS mathematics achievement test) than students who take less challenging courses. For example, among students who initially began at the same level of mathematics proficiency in the eighth grade, those students who had taken algebra II or geometry by the tenth grade experienced greater gains, on average, than those students who had taken no algebra or only algebra I during the same period.



Students of all income levels who take rigorous mathematics and science courses in high school are more likely to go to college, and among low-income students (students in the bottom third of the income distribution)[1], the difference is particularly dramatic. Students from low-income families who took geometry were almost three times as likely to attend college as those who did not: While 71 percent of low-income students who took geometry went to college, only 26 percent of low-income students who did not take geometry in high school went on to college. The differences are also dramatic among students from middle- and high-income

[1]Income data are based on total family income reported by parents. Low, middle, and high income groups each contain approximately one-third of the sample. The "all" category includes additional observations with missing income data.

families: 93 percent of students from high income families, and 84 percent of students from middle income families who took geometry in high school went on to college, while 59 percent of students from high income families and 42 percent of students from middle income families who did not take geometry still did go on to college (Figure 2).



Unfortunately, many students, in particular low-income students, do not take these rigorous mathematics and science courses in high school. According to NELS, 63 percent of all students took geometry in high school and 50 percent took chemistry. Students from low-income families, however, were far less likely than their peers to take these rigorous courses. Among students in the bottom third of the income distribution, 46 percent took geometry and only 33 percent took chemistry. By way of comparison, fully 82 percent of students in the top third of the income distribution took geometry, and 72 percent took chemistry. The differences are similar for other rigorous mathematics courses (Table 1).

Table 1: High School Course-Taking Patterns of Students in Eighth Grade in 1988

	Percent of Students Taking Course			
	All	Bottom Income	Middle Income	Top Income
Geometry	63.2	46.2	69.1	81.6
Chemistry	49.5	33.3	52.2	71.6
Algebra II	47.1	34.0	51.3	62.1
Trigonometry	18.1	10.3	19.2	29.5

When high school course-taking patterns are accounted for, the difference in the rate of college-going between low and high income students is dramatically reduced. When course taking patterns are not accounted for, students from high income families are almost twice as likely to attend college as students from low-income families (86 percent compared to 44 percent). However, when only students who have taken rigorous courses in high school are compared to one another, students from low-income families go to college at rates much more similar to students from middle and high income families (Table 2). For example, among

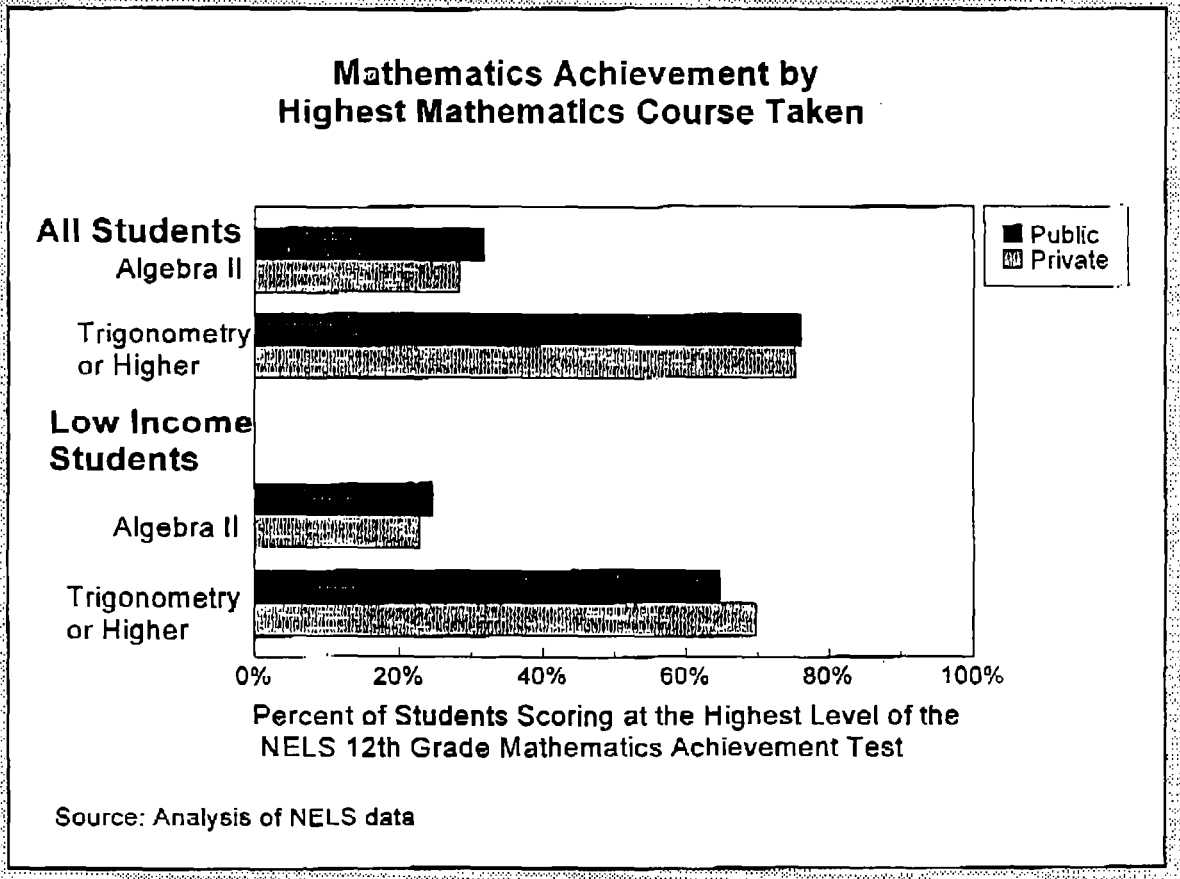
students who took chemistry in high school, 95 percent of high-income students; 89 percent of middle-income students; and 79 percent of low-income students went on to college. When low-income students take rigorous courses in high school, income effects on college-going rates diminish greatly, although they do not disappear.

Table 2: College Attendance by Course-Taking Patterns of Students in Eighth Grade in 1988

	Percent of Students Attending Postsecondary Education				
		All	Bottom Income	Middle Income	Top Income
	All	62.7	43.9	68.8	85.6
Geometry	Yes	83.3	70.7	83.6	93.9
	No	34.8	26.4	41.6	58.5
Chemistry	Yes	88.6	79.2	89.1	95.1
	No	42.7	30.7	50.4	67.8
Algebra II	Yes	85.7	75.9	85.5	94.7
	No	47.4	31.9	54.9	75.3
Trigonometry	Yes	93.5	89.7	91.8	97.9
	No	59.2	41.9	65.6	83.0

Public Versus Private
Achievement Depends on Course-Taking, Not the Type of School

In general, the mathematics courses students take in high school are more important for achievement than the type of school attended. While recognizing that a great deal of diversity exists among public and private schools, it is useful to note that when course-taking patterns are accounted for, the mathematics achievement of students in both categories of school is very similar. Public and private school students who had taken the same mathematics courses were almost equally likely to score at the highest achievement level on the NELS twelfth-grade mathematics achievement test. This was also true for low-income public and private school students. Additionally, among both public and private school students of all incomes, students who had taken more rigorous mathematics courses were much more likely to score at the highest achievement level.



Source: Analysis of NELS data

[1] Private schools include non-religious, Catholic, and other private schools.

Mathematics in College, the Workplace, and the 21st Century

The benefits of taking rigorous mathematics and science courses extend to both two- and four-year colleges, and to the job market. As the prevalence of technology in the workplace steadily increases, workers in more and more jobs will be required to have strong backgrounds in mathematics and science--backgrounds which begin to be formed during high school. Rigorous mathematics and science preparation is also important to students intending to go to a two or four year college or university. The level and number of mathematics courses that a student needs to take before and during college depend on the type of college and the major that the student wants to pursue, and while students who plan to major in mathematics- and science-related disciplines typically need to take a more rigorous mathematics program, many other popular courses of study also require strong mathematics backgrounds.

Two-year colleges often require all students to gain an understanding of intermediate algebra prior to graduation, regardless of their course of study. In many two-year colleges, all entering degree-seeking students are required to take mathematics placement exams prior to enrollment. Students who score high enough may be exempted from taking certain mathematics courses, while students with low scores may be required to enroll in remedial mathematics courses. Many of the most popular majors at typical two-year colleges--including Business, Nursing, and Computer Science--require more rigorous mathematics course work, such as statistics.

Four-year colleges and universities typically require more high school mathematics preparation for admission. Typical state four-year colleges and universities recommend, and in some cases, require, that all students take at least three, and sometimes four, years of mathematics in high school. Data collected by the College Board reveal that in 1997, 68 percent of incoming freshman at four-year colleges and universities had taken four years of mathematics in high school. Furthermore, almost all of these students had taken algebra and geometry, and more than half had taken trigonometry. Upon enrollment, most state colleges require students to take mathematics placement exams. Advanced Placement courses are looked at favorably by colleges and can result in placement out of introductory mathematics courses. While graduation requirements differ depending on the student's major, many popular majors, such as Business and Psychology, require students to take several more rigorous courses in mathematics or science.

In the job market, workers who have a strong background in mathematics and science are more likely to be employed and generally earn more than workers with lower achievement, even if they have not gone on to college. A national survey found that by age 30, high school graduates who had not gone on to further education and had previously scored in the top quartile on the mathematics portion of the Armed Services Vocational Aptitude Battery (ASVAB--administered to civilians for study purposes) earned, on average, 38 percent more per hour than high school graduates who had not gone to college and had scored in the bottom quartile of the mathematic portion of the ASVAB. Similarly, the unemployment rate among high school graduates who scored in the top quartile of the mathematics test was only 4.4 percent, compared to an unemployment rate of 10.3 percent among high school graduates who scored in

the lowest quartile. Workers who scored in the top quartile of the science section of the ASVAB also earned more, on average, and were less likely to be unemployed.

In the future, ability in mathematics will be even more important for middle class employment. Today, some major firms now require that all job applicants pass standardized mathematics and reading tests, so that they may hire only individuals with solid backgrounds in these areas. For example, at Diamond-Star Motors, a joint venture of Chrysler and Mitsubishi, all applicants for production and maintenance positions must pass a standardized test that assesses their ability to do mathematics at a high school level. Authors Richard Murnane and Frank Levy have identified a set of "New Basic Skills," in their book of the same name, that, though fundamental for middle class employment in the modern labor market, are often not mastered by non-college-bound high school graduates. The "New Basic Skills" that workers will need to earn a good wage include the ability to use mathematics skills and concepts **at least** at the ninth grade level, yet currently many non-college bound students looking for work do not possess a sufficient mathematics background to do so.

Mathematics and Science in Tomorrow's Job Market

Many jobs in today's labor market require a mathematics or science background. A number of these are among the fastest growing occupations nationally, and are ones we might not think of as "technical." Projections from the Bureau of Labor Statistics' (BLS) Occupational Outlook Handbook indicate that during the 1994 to 2005 period, jobs requiring the most education and training will be the fastest growing and highest paying. BLS predicts that occupations requiring a bachelor's degree or higher will average 23 percent growth, almost double the 12 percent growth rate projected for occupations that require less education and training.

Many jobs that once required little background in mathematics now call for specific skills in algebra, geometry, measurement, probability, and statistics. According to an industry-wide standard, an entry level automobile worker needs to be able to apply formulas from algebra and physics to properly wire the electrical circuits of any car. The National Coalition for Advanced Manufacturing has defined 25 specific standards of mathematics and measurement among their national skill standards for what a good competent worker should know and be able to do.

Several of the fastest growing job areas will reflect growth in computer technology and health services--fields that can require substantial mathematics and science preparation. Generally speaking, fields requiring a strong science base also require substantial mathematics preparation, as most academic science programs build upon a strong background in mathematics. Below are some of the jobs which BLS indicates require a mathematics or science background; while many of these jobs require mathematics or science course work beyond the high school level, all require at least a high school level background. The occupations that BLS projects will be among the fastest growing during the period from 1994 to 2005 are noted with a star (*).

Computer Scientists (*)
Systems Analysts (*)
Occupational Therapy Assistants and Aides (*)
Chemical Engineers
Civil Engineers
Aerospace Engineers
Medical Assistants (*)
Dentists and Dental Hygienists
Surveyors
Surgical Technologists
Dieticians and Nutritionists
Optometrists
Physical Therapists (*)
Roofers
Tool and Die Makers
Photographers
Financial Managers
Budget Analysts

Middle School: Getting on the Road to Challenging Mathematics and Science Courses

Laying the Foundation

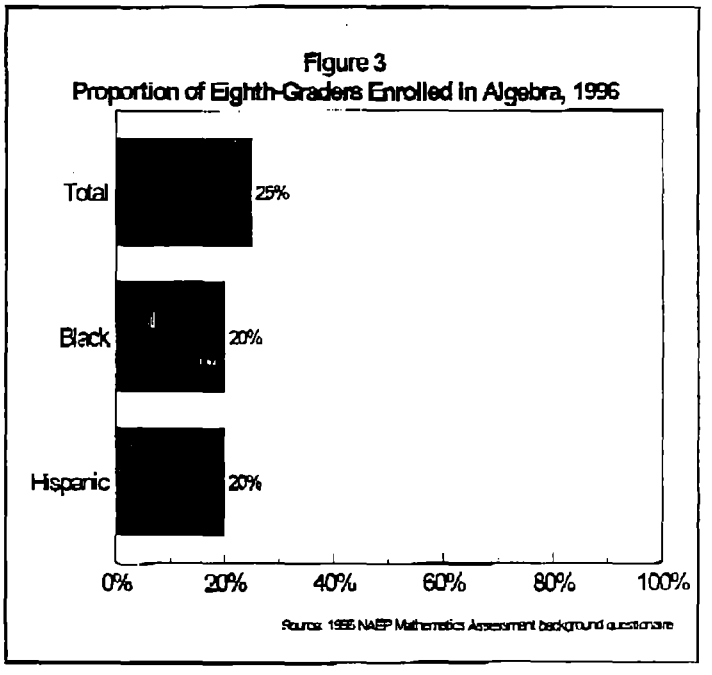
> "Mathematics is the language of science, and algebra is the minimum vocabulary that scientists of every discipline use to describe their work."
>
> --Dr. George Castro, Associate Dean of the College of Science at San Jose State University

Algebra is the "gateway" to rigorous mathematics courses. Rigorous mathematics courses build upon the skills and concepts that students learn in earlier mathematics courses. Traditionally, students cannot take a rigorous mathematics course in high school until they have successfully completed one or more prerequisite courses that provide the foundation for the next course. Algebra I, or another course that covers basic algebraic concepts, is the first prerequisite for all more rigorous mathematics classes in high school.

Students who take algebra early in their educational career have a clear advantage in taking rigorous mathematics courses. A rigorous sequence of mathematics courses spans several years. Although there is some variation from school to school, the sequence of recommended mathematics courses typically involves one year courses in algebra I, geometry, and algebra II. In many high schools this is followed by a half-year course in trigonometry, a full- or half-year course in pre-calculus or calculus, or an Advanced Placement course. (An increasing number of schools use curricula that cover these rigorous content areas, but integrate algebra, geometry and other areas of mathematics such as statistics and probability, rather than teaching each individually.) The typical high school sequence of rigorous science courses (biology, chemistry, and physics) also necessitates an early background in algebra and geometry. Although not all students need to take all of the most rigorous mathematics or science courses that their school offers, most colleges encourage students to take four years of challenging mathematics and science courses during high school.

Students who do not take courses covering algebraic concepts early in their educational career risk closing the door on many important opportunities, including opportunities to take courses outside of mathematics and science. Some high schools require students to complete a specific package of courses, including mathematics and science, in order to graduate. By the junior and senior year, students who have not planned ahead to complete the courses that their school requires have fewer options in choosing which courses they take. Students who do not complete prerequisite and required courses early enough not only risk being unable to take more rigorous courses in those disciplines later, but also may not have time in their schedules to take other courses that can help prepare them for college or a career, including foreign language, art, Advanced Placement, and "tech prep" courses.

Course-Taking Patterns in Middle School

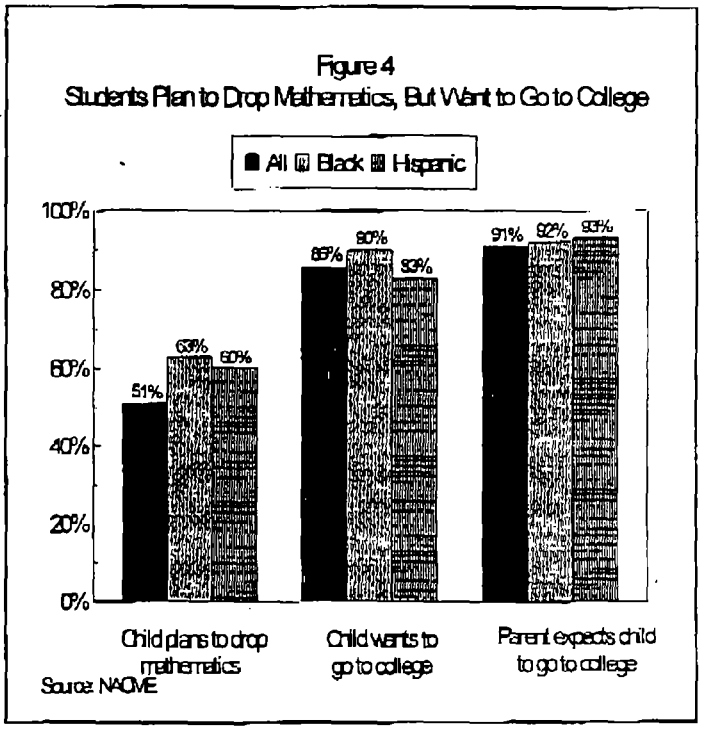


Despite recent increases in the proportion of students taking algebra I in the eighth grade, in 1996, most students were not enrolled in this course. The proportion of eighth-graders taking the National Assessment of Educational Progress (NAEP) mathematics assessment who reported taking algebra has increased in recent years. In 1992, only 20 percent of students reported taking algebra. In 1996, the next year the NAEP mathematics assessment was administered, 25 percent reported taking algebra. This increase may be due to a number of factors, including the National Council of Teachers of Mathematics' (NCTM) call for the inclusion of algebraic topics in the middle school curriculum. However, most students still were not enrolled in courses that include significant amounts of algebra in the eighth grade.

While the number of students taking algebra courses has increased, recent evidence suggests that the content of these courses has remained rigorous. Many states have recently increased mathematics requirements for high school graduation, often requiring that students take more years of mathematics than were required in the past, or mandating that students complete certain courses. A recent study supported by the National Science Foundation (NSF) examined the content of mathematics courses in schools in several of the states making the most substantial changes in mathematics requirements. The study focused on basic courses, such as algebra I, which had experienced large enrollment increases because of the more stringent graduation requirements. Despite the larger numbers of students enrolling in the courses, the study found that the content of these courses was essentially unchanged, indicating that more students were in fact being exposed to rigorous mathematics.

Minority and low-income students continue to be less likely to take challenging mathematics courses in middle school than other students. The 1996 NAEP data reveal that minority students are less likely to report being enrolled in algebra in the eighth-grade (see Figure 3). The data also provide some indication that students from disadvantaged backgrounds are less likely to be enrolled in algebra during the eighth grade: While 29 percent of students who were not eligible for the national school lunch program reported being enrolled in algebra during the eighth grade, only 15 percent of students who were eligible for the national school lunch program were enrolled in algebra.

Parent and Student Attitudes about Mathematics and Science



Large proportions of middle school students indicate that they do not plan to take mathematics and science courses beyond what their schools require. A nationally representative survey of public school students and parents conducted by Louis Harris Associates for the National Action Council for Minorities in Engineering (NACME), Inc. found that large proportions of students would like to **stop** taking mathematics and science courses as soon as they are able to: 51 percent of the fifth through eleventh grade students surveyed indicated that they would take mathematics classes only as long as required, while 47 percent reported they would study science only as long as it is required. Distressingly, young minority students--fifth through eighth grade students who will soon be facing major decisions about which courses to take--were more likely to indicate that they planned to drop mathematics and science as soon as they were able to (61 percent planned to drop mathematics, and 58 percent planned to drop science). Minority students of all ages were more likely than other students to indicate that they would like to stop taking mathematics and science as soon as they were able to (Figure 4).

However, the same group of students indicate that they would be interested in going to college, and taking college-level mathematics courses. Eighty-six percent of all students surveyed said that they would like to go to college. Although fewer than half of the ninth- to eleventh-grade students said that they planned to take trigonometry or algebra II in high school, nearly two-thirds said that they were interested in taking Advanced Placement or college level mathematics courses. African-American students were particularly likely to say that they would be interested in taking Advanced Placement or college-level mathematics courses (78 percent of those surveyed), although they were also less likely to say that they planned to take algebra II or trigonometry in high school. These contrasts signal that many students do not understand the importance of, and requirements for, taking rigorous mathematics and science courses in high school and do not understand the need to take algebra in the 8th grade so they can get the sequence to have taken algebra II, trigonometry, and other rigorous courses before high school graduation: Only 25 percent of minority and 42 percent of non-minority fifth- through eighth-grade students recognized that if they did not take algebra they would not be able to take other mathematics classes in the future.

Parent and teacher involvement may make a large difference in students' decisions about mathematics and science. Ninety-four percent of students indicated that their parent's or guardian's advice was important to them in deciding what they would study in school, and 88 percent indicated their teachers' advice was important. Ninety-one percent of parents want their children to go to college or continue their education beyond high school. Although it is difficult to estimate the effects greater parent involvement has on course-taking, the NACME survey does provide a possible indicator: 50 percent of students who said their parents talked to them about school said that they planned to take algebra II, while only 37 percent of students whose parents did not talk to them about school planned to do so. Students who reported that their parents were involved in their school life were also more likely to plan to take trigonometry and calculus.

Parental Involvement and Course-Taking Behavior

Parental involvement may have a significant effect on the likelihood that students enroll in challenging mathematics courses. Analysis of the NELS data indicates that:

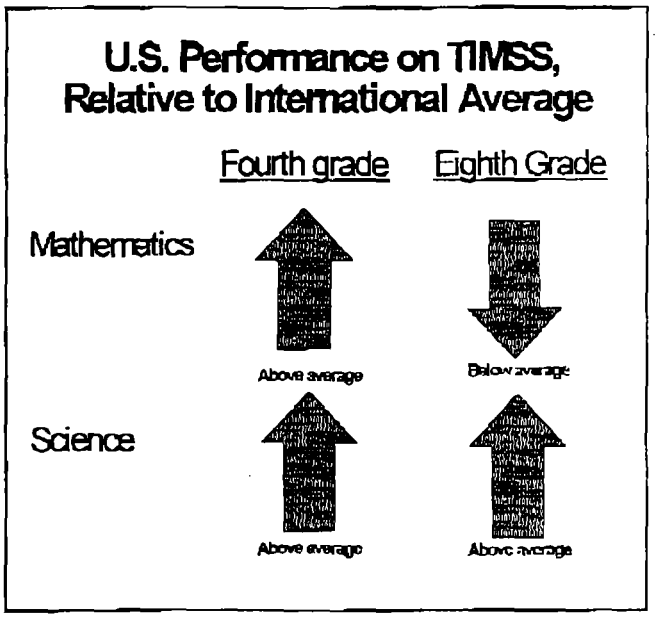
•**Students with greater levels of parental involvement are more likely to take advanced mathematics courses.** While only 8 percent of those students who said that they did not discuss programs at school with their parents took algebra I by the 8th grade, 12 percent of those who said that they discussed school programs one or two times during the past semester, and 17 percent of those who said that they discussed school programs three or more times during the past semester took algebra I by the eighth grade.

•**Students who had parents or teachers who said that there were greater levels of parental involvement were also more likely to take advanced courses.** While 37 percent of those students whose parents said that they rarely talked to their child about high school plans took geometry by the 10th grade, 48 percent of those students whose parents said they regularly spoke to the child about high school plans took geometry by the 10th grade. While 27 percent of students whose teachers said their parents were not involved took geometry by the 10th grade, 63 percent of the students whose teachers said that their parents were very involved took geometry by the 10th grade.

•**Regardless of whether the level of parent involvement is reported by the student, the parent, or the teacher, higher levels of parental involvement are consistently associated with higher likelihoods of taking these courses.**

Mathematics in the U.S. Today

International Comparisons of Middle School Mathematics and Science Proficiency



Recent findings from the Third International Mathematics and Science Study (TIMSS), indicate that the mathematics curriculum from grades five through eight may be a weak link in the U. S. educational system. Newly available data from TIMSS (the most comprehensive international comparison of schools and students ever undertaken) reveal that U.S. fourth graders score above the international average in both mathematics and science. Among 25 other participating nations, only Korea performed better than the U.S. in fourth grade science, and only 7 of the 25 other countries did better than the U.S. in fourth grade mathematics. These findings are in contrast to earlier findings from TIMSS that indicate that U.S. eighth graders perform slightly below the international average in mathematics, and only slightly above the international average in science. In fact, only one country--the U.S. in mathematics--falls from above the international average at fourth grade to below the international average at eighth grade.

The TIMSS data suggest that the middle school mathematics curriculum in the U.S. is significantly less challenging than the curricula used in other countries. Although it is too early to determine definitively why U.S. eighth graders perform relatively poorer in mathematics than U.S. fourth graders, TIMSS curriculum analysis and videotape studies indicate that students in other countries are commonly taught more rigorous material during the middle school years than U.S. students. Eighth-grade mathematics courses in other countries include algebra and geometry, while in the U.S., only students in higher-level classes receive significant exposure to algebra, and very few students study geometry. In fact, the TIMSS findings indicate that in comparison to other countries, the content of mathematics taught in U.S. eighth grade classrooms is generally at a seventh grade level.

Additional research from TIMSS reports the U.S. curriculum to be more concerned with breadth than depth, with quantity than quality, and characterizes U.S. curriculum, textbooks, and teaching as a "mile wide and an inch deep." *A Splintered Vision*, conducted by William Schmidt, Curtis McKnight and Senta Raizen of the U.S. National Research Center for the Third International Mathematics and Science Study, reports findings from the analysis of 491

curriculum guides and 628 textbooks from around the world and presents accompanying data on teacher practices in the U.S. and two other countries: Germany and Japan. This study reports the lack of a single coherent vision of how U.S. mathematics and science educators should teach today's students. It also emphasizes the lack of a single, commonly accepted place to turn to for such visions. Further, Schmidt, McKnight, and Raizen report that our "splintered visions" produce unfocused curricula and textbooks that fail to define clearly what is intended to be taught. The result is influencing teachers to implement diffuse learning goals in their classrooms; emphasizing familiarity with many topics rather than concentrated attention to a few; and lowering the academic performance of students who spend years in such a learning environment.

Promising Practices

Preparing for success: The Algebra Project, supported by the National Science Foundation (NSF) and directed by Robert Moses, addresses equity of opportunity by helping sixth, seventh, and eighth graders in inner city and rural areas gain an understanding of challenging mathematics. Serving over 40,000 traditionally low-income and minority middle school students, the Algebra Project is based on the conviction that all students can learn algebra given the proper context. An essential first step is that all students study algebra as early as possible to ensure their access to a college preparatory high school curriculum.

The project assists students in 22 urban and rural sites in 13 states to succeed in challenging high school mathematics courses by introducing rigorous mathematics concepts in the sixth grade, creating a foundation to build upon throughout the middle school years. The project has been successful in helping traditionally underserved students complete algebra I by the eighth or ninth grades, and either pre-calculus or calculus by the twelfth grade utilizing a variety of strategies. The project places young college-age students in schools to provide extra assistance. In addition, the project provides after-school activities; and provides teacher professional development in examining the curriculum and beliefs about how it should be taught.

The Algebra Project has had important effects for communities. For instance, in the Mississippi Delta and in Jackson, Mississippi, the project showed positive short term effects. Additionally, an external evaluation of these sites found evidence of positive outcomes in teaching, student attitudes about and engagement in mathematical ideas, and community involvement.

Taking the right courses: In 1990, the College Board launched EQUITY 2000 to increase minority enrollment in college preparatory mathematics courses. Originally piloted in six communities, EQUITY 2000 requires participating school districts to phase out lower-level mathematics and require all students to take a college preparatory curriculum--beginning with algebra and geometry. EQUITY 2000 influences policies, curricula and student academic development at all grade levels, with a particular focus on grades six through nine--critical years for mathematics education during which key decisions are made about which courses students should take and how they should begin planning for education and careers beyond high school. The project provides on-going professional development to help teachers work with

heterogeneous ability classes, encourages and supports parents to become advocates on behalf of their children, helps schools establish support services for students who need extra time and effort to learn challenging content, and trains administrators and teachers to use student enrollment and achievement data to drive school-based decision-making.

Finally, EQUITY 2000 has made increased parental involvement a priority because it recognizes the important role that parents play in nurturing and reinforcing their children's desire to attend college. It has sponsored Saturday and summer academies on college campuses for entire families. The program also sponsors Family Math nights in which parents and students learn mathematics concepts together.

An analysis of results at the six pilot sites found that:

•All sites dramatically increased the percentage of students enrolled in algebra I by the ninth grade, and in three pilot districts, all ninth graders enrolled in algebra I.

•The percentage of students passing algebra I did not decline significantly, and in some cases rose, as more students from the discontinued lower tracks began enrolling in algebra classes.

Living Up to Our Potential: The First in the World Consortium, Chicago, Illinois. Twenty school districts from Chicago's North Shore joined forces in 1995 to meet the challenge of providing their students with a world class education in mathematics and science. Their first challenge was to determine what a "world class" education looked like, measure their current performance against that benchmark, and develop an improvement strategy.

The Consortium's efforts were directed toward three objectives: benchmarking performance against international standards in mathematics and science, using the Third International Mathematics and Science Study; creating a forum to clarify world-class education standards for business leaders, policy makers, educators, and community members; and establishing a network of learning communities involving educators, parents, and community leaders within the Consortium school districts and beyond.

The districts in the First in the World Consortium took the TIMSS assessment in Spring 1996 at the fourth, eighth, and twelfth grade level. Their 8th grade results placed them among the top performing countries in the world at the 4th and 8th grades, well exceeding the United States' performance. In addition:

•Fifty percent of their 8th grade students took algebra or geometry compared to 25 percent of students nationally who take algebra;
•The Consortium had high expectations for students and teachers; and
•Gained broad-based community support for improved student performance.

However, the First in the World Consortium is not resting on their success; in fact the findings

from their participation in TIMSS and other studies have caused them to create teacher learning networks to strengthen curriculum standards, models of instruction, assessment, and technology. This "community of learners" approach promotes teacher participation and provides a context for long-term commitment to the consortium's goals and to growth in student learning.

Although the First in the World Consortium is at an advantage in terms of its resources, its willingness to identify its weaknesses and address them has distinguished its efforts. The consortium identifies both state and federal support as helping it focus on its goals. These experiences emphasize that, when given the opportunity, U.S. students can perform as well as, or better than, students in any part of the world.

Advanced Placement Participation and Scores on the Rise in South Carolina. The College Board's Advanced Placement (AP) Program was started nearly four decades ago to enable students to complete college-level studies while still in high school and to obtain college credit or placement. Today more than 500,000 students in about half of the nation's high schools take at least one AP course, and those courses are widely recognized as setting the standard for high levels of academic achievement in high school. Participation and scores in South Carolina illustrate the success of a reform initiative in one state in which 'high standards for all' is seen as the norm and expectation for all schools.

With former-Governor Riley's school reform package of 1984, South Carolina became one of the first states to legislate funding and other actions to boost participation in AP. Actions included state appropriations to train the AP teacher and to help pay for AP exams, as well as a requirement that public colleges accept AP courses if the student scored 3 or higher on the exam. As a result, from 1984 to 1997 South Carolina experienced:

- In increase in the number of students taking AP exams from 2,799 to 9,748.
- An increase in the number of AP exams from 3,595 to 15,286, with the mean grade decreasing only slightly from 2.75 to 2.72.
- An increase in the number of AP science exams (Biology, Chemistry, Physics) from 27 to 2,414.
- An increase in the number of AP math exams (Calculus AB and BC) from 46 to 2,767.
- Nearly all the public high schools in the state participating in AP, 93.4 percent (184 of 197 public high schools).
- AP participation rates above the national average.

AP Exams Taken

(Eleventh and Twelfth Graders)

	1984	1997
South Carolina	3,461	14,890
National	223,888	843,399

Sources: College Board. *Advanced Placement Program, National and South Carolina Summary Reports, 1984 - 1997.*

Incentives to expand AP participation in Texas. The Advanced Placement Incentives program was developed in the Dallas, Texas area by the O'Donnell Foundation in reaction to the low rates of college attendance and poor college preparation of low-income and minority students.

The Advanced Placement Incentives program addresses shortfalls in both the supply and demand for AP courses in math, science, and the arts, by providing performance-based financial incentives to teachers, school and students. Teachers are given financial incentives as well as registration and fees for attending College Board AP teacher training during the summer, and to begin to teach AP courses. Students who complete the Advanced Placement course may take the AP exam at half-cost (the total cost for an AP exam is about $73), and those who score a three or better (on a five point scale) are given a financial incentive and reimbursed for the cost of the exam.

In five years of operation in nine Texas public schools the O'Donnell foundation reports that:

•In the first year of the program 97 students took AP exams, and 52 received a three or better. In the fifth year of operation 1,099 students took AP exams, and 521 received a score of three or better.
•AP participation increased among female students in areas in which females are traditionally under represented, with 19 female students taking AP exams in math, science, or computer science during the program's first year, and 240 female students (compared to 272 male students) doing so in the program's fifth year.
•Minority participation increased, from 7 African-American or Hispanic students taking AP exams during the program's first year, to 116 in the program's fifth year.

Serving disadvantaged and underrepresented students in math-based fields. The purpose of the Mathematics Engineering Science Achievement (MESA) program is to increase the number of students who are eligible for the University of California and prepared to complete degrees in math-based fields at any four-year institution.

Instructional Reform in Mathematics. Sponsored by the University of Pittsburgh's Learning Research and Development Center, the Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) Project is designed to respond to low levels of student participation and the inadequacy of student performance in mathematics.

Standards-based Reform. Both the New York Regents Exam and the Ohio Early Mathematics Placement Testing (EMPT) program have spurred thousands more high school students to take and pass college-preparatory mathematics courses.

Next Steps

Six things educators, policymakers and community members can do:

1. Provide all students the opportunity to take algebra I or a similarly demanding course that includes fundamental algebraic concepts in the eighth grade and more advanced math and science courses in all four years of high school.

2. Build the groundwork for success in algebra by providing a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares students for the transition to algebra.

3. Ensure that all students, parents, teachers, and counselors understand the importance of students' early study of algebra as well as continued study of rigorous mathematics and science in high school to their future college and career opportunities.

4. Prepare teachers of mathematics to teach rigorous mathematics by providing teacher preparation and professional development opportunities that increases teachers knowledge and skills in mathematics and the teaching of mathematics.

5. Support mathematics achievement outside the classroom such as math clubs, tutoring and job shadowing for students who may need extra help to ensure that they can achieve at high levels.

6. Support parent involvement in their children's mathematics education.

Six things parents can do:

1. Discuss your children's mathematics homework with them.

2. Visit your children's mathematics teacher to find out what your children are learning and how you can help.

3. Insist that your children be enrolled in algebra I or a similarly demanding course that includes fundamental algebraic concepts in the eighth grade and more advanced math and science courses in high school so they can keep all of their future options open.

4. Ensure that your children are gaining the groundwork for success in algebra through a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares them for the transition to algebra.

5. Help your children understand the importance of taking challenging mathematics and science courses to their future by visiting colleges, familiarizing them with college requirements, and

exploring financial aid options available to students.

6. Show the importance of mathematics to career choices by talking with your children about the use of mathematics in your work or the work of adults they know.

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Appendix

The NELS:88 data. The National Education Longitudinal Study of 1988 (NELS:88) initially surveyed a nationally representative sample of 26,000 public and private school eighth grade students in 1988. The data collected include responses to student questionnaires, scores on standardized achievement tests, high school transcripts, and interviews with parents and teachers. Since the initial survey in 1988, the students have been resurveyed every two years, with the most recent data available gathered two years after their scheduled high school graduation in 1994. The analyses in this report are based on a sub-sample of over 13,000 individuals from whom data were collected in all three follow-up surveys. The NELS data use traditional names of mathematics courses (i.e. "geometry," "algebra II") to reflect the content of courses. This analysis necessarily employs these titles, but should not be interpreted as implying that courses covering the relevant content (for example, geometric concepts), but employing different titles, would have a different relationship to the data.

U.S. Department of Education
Office of Under Secretary, Planning and Evaluation Service
600 Independence Avenue, SW
Room 4168, FOB10
Washington, DC 20202

FAX COVER SHEET

Fax Number: (202) 401-3036

TO : Bill Kincaid

FAX NO.: 456-7028

(Number of pages, including cover sheet: 2)

FROM: Melissa Chabran

PHONE NO.:401-1265

Message:

Bill,

Attached is the most recent version of the mathematics brief draft.

Melissa

A Letter from the Secretary of Education

Many parents, students, and educators do not realize that within the United States today, mastering mathematics has become a gateway to the road to college--and taking algebra or courses covering algebraic concepts by the end of the 8th grade is a key to the "gate." Although almost all parents want their children to go on to college or some advanced training, many 8th and 9th graders may be behind in their course taking to get on the road to college, and not realize it.

Recent analyses conducted by the U.S. Department of Education indicate that students with strong mathematics backgrounds--those who take algebra and geometry and more rigorous mathematics courses during high school--are more likely to go on to college. This is true regardless of their family's level of income. In fact, the positive impact of taking rigorous courses is most dramatic for students from low-income families. In addition, students who took chemistry, a subject which requires a strong background in mathematics, were also more likely to go to college. Other research tells us that the benefits of a strong background in mathematics are not limited to college-going, and workers with high levels of mathematics achievement earn more and are less likely to be unemployed than workers who are less proficient in mathematics.

However, not all students have access to rigorous mathematics courses--either because their school may not offer a full selection of challenging courses to all students, or because students are not prepared for and encouraged to take them. The results of the recently completed Third International Mathematics and Science Study (TIMSS) confirm that many students enter high school without a solid grounding in mathematics, closing doors very early to opportunities for further education and better career opportunities.

The implications are clear: The 8th grade is a critical point in mathematics education. Achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses important for later success. As a nation, we must ensure that all our students develop the necessary mathematics background by the end of the 8th grade--and build on that foundation throughout high school. We challenge parents, schools, community groups, colleges, universities, and employers to ensure that all children have access to rigorous mathematics courses and encourage them to go to college. To assist in that effort, the U.S. Department of Education stands ready to assist states, local communities, and individual students by providing federal student financial aid for college, by supplementing Advanced Placement Exam fees for students' who demonstrate need by providing funding through Title I of the Elementary and Secondary Education Act (ESEA) and other programs to assist schools in upgrading mathematics teaching and learning, and by providing a voluntary national test in 8th grade in mathematics to help ensure that all students are given the opportunity to excel.

Sincerely,

Richard Riley

Executive Summary

Within the United States today, mastering mathematics has become more important than ever. Students with strong mathematics backgrounds have advantages in academics and in the job market. The 8th grade is a critical point in mathematics education, and achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses that are keys to college entrance and success in the labor force. However, although most parents want their children to go on to college or some advanced training, most 8th and 9th graders are behind in their course taking to get on the road to college. Findings highlighted in this report include:

- **Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not.** Data from the National Educational Longitudinal Study (NELS) reveal that 83 percent of students who took algebra I and geometry went on to attend a two or four year college within two years of their scheduled high school graduation, compared to a college attendance rate of only 36 percent among students not taking algebra I and geometry; while nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college.

- **Algebra is the "gateway" to advanced mathematics and science in high school--yet most students currently do not take algebra during middle school.** Students who plan to take advanced mathematics and science courses during high school and study algebra during middle school are at an advantage; Forty-six percent of students who took algebra I in the 8th grade took calculus in high school, compared to only eight percent of students who took algebra I in the 9th grade. However, 1996 NAEP data reveal that only 25 percent of 8th graders in the U.S. were enrolled in algebra, and that low-income and minority students are even less likely to be enrolled in algebra during the 8th grade.

- **Taking rigorous mathematics and science courses in high schools appears to be especially important for low-income students.** Low-income students who took algebra I and geometry were almost three times as likely to attend college as those who did not: While 71 percent of those who took algebra I and geometry went to college, only 27 percent who did not went on to college. By way of comparison, 94 percent of students from high income families, and 84 percent of students from middle income families who took algebra I and geometry in high school went on to college, while 60 percent of students from high income families and 44 percent of students from middle income families who did not take algebra I and geometry still did go on to college.

- **Despite the importance of taking rigorous mathematics and science courses for low-income students, they are less likely to take these courses.** Students from higher income families are almost twice as likely to take algebra in middle school and geometry in high school and more than twice as likely to take chemistry than lower income students.

Other important findings include:

- **Mathematics achievement depends on course-taking, not the type of school a student attends.** Students at public and private school who had taken the same rigorous mathematics courses were equally likely to score at the highest level on the NELS 12th grade mathematics achievement test.

- **Students who have parents who are involved in their school work are more likely to take challenging mathematics courses early.** Students whose parents were involved in their educations were more likely to take courses like algebra and geometry in the 8th and 9th grade, than students' whose parents were not involved.

- **The results of the Third International Mathematics and Science Study (TIMSS) reveal that the U.S. middle school mathematics curriculum may be a weak link in the U.S. educational system.** While U.S. 4th graders score above the international average in mathematics and science, U.S. 8th graders score below average in 8th grade mathematics, and only slightly above the international average in science. Initial analysis of the TIMSS data also shows that the U.S. middle school mathematics curriculum is not as challenging as that of other countries. The curriculum of average 8th-grade mathematics classrooms in the U.S. resembles 7th grade mathematics elsewhere. Although algebra and geometry are important elements in the middle school curriculum taught in other countries, only a small fraction of U.S. middle school students are exposed to these topics.

Algebra in the Curriculum

Making a successful transition from arithmetic to more advanced topics, including algebra and geometry, has often been difficult for students. As a result, many mathematics programs in the U.S. are now systematically incorporating some of the fundamental ideas from algebra and geometry into the upper elementary grades. In these programs, 5th, 6th and 7th grade students are learning about representing and solving equations, characterizing patterns and rates of change among variables, and other fundamental algebraic concepts.

In addition, the approach middle and high schools take to presenting advanced topics differs. Many schools offer the traditional model of pre-Algebra, Algebra I, Geometry, Algebra II, Trigonometry, pre-Calculus and Calculus. However, an increasing number of schools offer courses in which algebra, geometry and other advanced topics are more integrated. This approach is consistent with the practice in other industrialized nations which integrate algebra, geometry and other topics through out the elementary, middle and high school years and offer a significant component of algebra in the 8th grade. Building a firm foundation in algebra in the elementary and middle school years makes the shift from arithmetic to advanced topics more successful, regardless of the format of the middle and high school curriculum. NELS and NAEP, the two sources of national course-taking data which are analyzed in this brief, employ traditional courses titles, such as "algebra I" and "geometry" for mathematics courses. Thus, these traditional titles are used throughout the brief.

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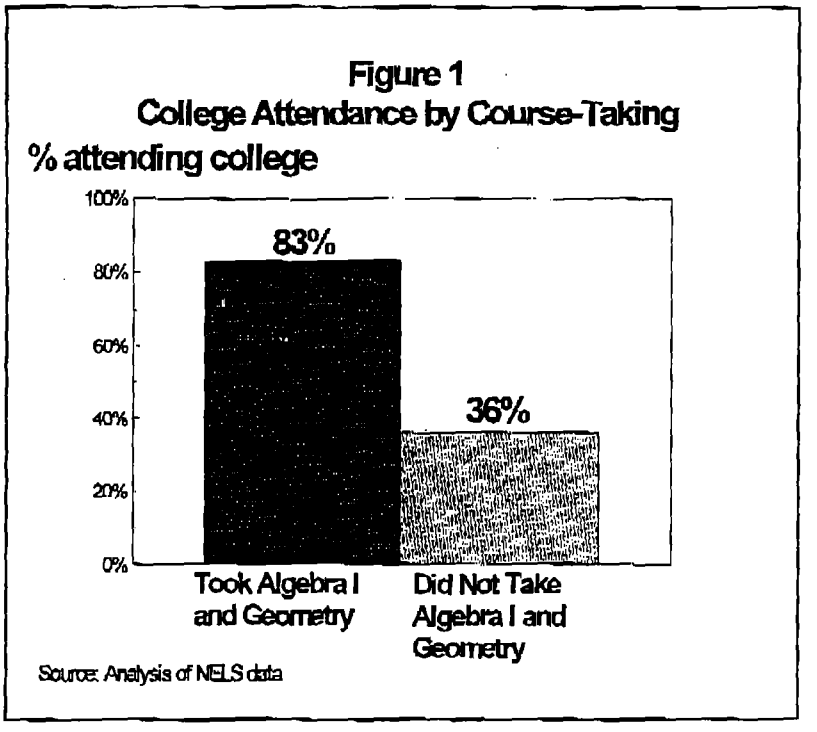
Mathematics and Future Opportunities

The Importance of Mathematics for College Entrance

Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not. Data from a longitudinal survey of students who were in the 8th grade in 1988 (National Educational Longitudinal Study or NELS) reveal that 83 percent of students who took algebra I and geometry went on to attend college[1] within two years of their scheduled high school graduation. By way of comparison, only 36 percent of students not taking algebra I and geometry went to college (Figure 1). Similarly, students who take rigorous science courses in high school are also much more likely to go to college: While nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college. Students who take more rigorous mathematics courses also have higher gains in mathematics achievement (measured by the mathematics achievement test given as part of NELS) than students who take less challenging courses, even when controlling for achievement. For example, among students who initially began at the same level of mathematics proficiency in the 8th grade, those students who had taken algebra II or geometry by the 10th grade experienced greater gains, on average, than those students who had taken no algebra or only algebra I during the same period.

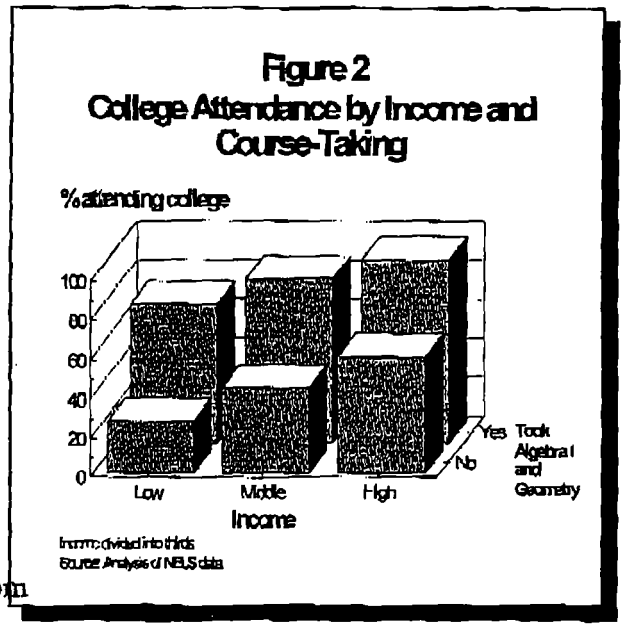


Students of all income levels who take rigorous mathematics and science courses in high school are more likely to go to college, and among low-income students (students in the bottom third of the income distribution)[2], the difference is particularly dramatic. Students

[1]Throughout this report, the term "college" is used to refer to any postsecondary education taken at a public, private not-for-profit, or private for-profit institution.

[2]Income data are based on total family income reported by parents. Low, middle, and high income groups each contain approximately one-third of the sample. The "all" category includes additional observations with

from low-income families who took algebra I and geometry were almost three times as likely to attend college as those who did not: While 71 percent of low-income students who took algebra I and geometry went to college, only 27 percent of low-income students who did not take algebra I and geometry went on to college. The differences are also dramatic among students from middle- and high-income families: 94 percent of students from high-income families, and 84 percent of students from middle-income families who took algebra I and geometry went on to college, while 60 percent of students from high-income families and 44 percent of students from middle-income families who did not take geometry still did go on to college (Figure 2).



Unfortunately, many students, in particular low-income students, do not take these rigorous mathematics and science courses. According to NELS, 63 percent of all students took algebra I and geometry and 50 percent took chemistry. Students from low-income families, however, were far less likely than their peers to take these rigorous courses. Among students in the bottom third of the income distribution, 46 percent took algebra I and geometry and only 33 percent took chemistry. By way of comparison, fully 81 percent of students in the top third of the income distribution took algebra I and geometry, and 72 percent took chemistry. The differences are similar for other rigorous mathematics courses (Table 1).

missing income data.

Table 1: Course-Taking Patterns of NELS Students

	Percent of Students Taking Course			
	All	Bottom Income	Middle Income	Top Income
Algebra I and Geometry	**63**	**46**	**68**	**81**
Trigonometry	18	10	19	30
Chemistry	50	33	52	72

When course-taking patterns are accounted for, the difference in the rate of college-going between low and high income students is dramatically reduced. When course taking patterns are not accounted for, students from high-income families are almost twice as likely to attend college as students from low-income families (86 percent compared to 44 percent). However, when only students who have taken rigorous courses are compared to one another, students from low-income families go to college at rates much more similar to students from middle- and high-income families (Table 2). For example, among students who took chemistry in high school, 95 percent of high-income students; 89 percent of middle-income students; and 79 percent of low-income students went on to college. When low-income students take rigorous courses, income effects on college-going rates diminish greatly, although they do not disappear.

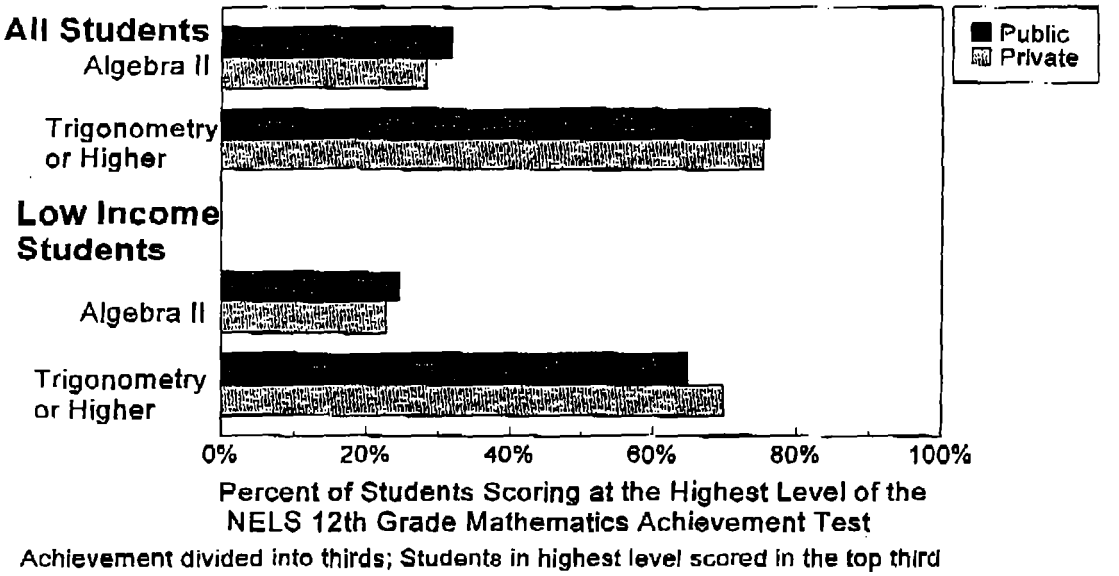
Table 2: College Attendance by High School Course-Taking Patterns of NELS Students

	Percent of Students Attending Postsecondary Education				
		All	Bottom Income	Middle Income	Top Income
	All	63	44	69	86
Algebra I and Geometry	**Yes**	**83**	**71**	**84**	**94**
	No	**36**	**27**	**44**	**60**
Trigonometry	Yes	94	90	92	98
	No	59	42	66	83
Chemistry	Yes	89	79	89	95
	No	43	31	50	68

Public Versus Private Achievement Depends on Course-Taking, Not the Type of School

In general, the mathematics courses students take in high school are more important for achievement than the type of school attended. While recognizing that a great deal of diversity exists among public and private schools, it is useful to note that when course-taking patterns are accounted for, the mathematics achievement of students in both categories of school is very similar. Public and private school students who had taken the same mathematics courses were almost equally likely to score at the highest achievement level on the NELS 12th grade mathematics achievement test. This was also true for low-income public and private school students. Additionally, among both public and private school students of all incomes, students who had taken more rigorous mathematics courses were much more likely to score at the highest achievement level (Figure 3).

Figure 3
Mathematics Achievement by Highest Mathematics Course Taken



Achievement divided into thirds; Students in highest level scored in the top third
Source: Analysis of NELS data

1 Private schools include non-religious, Catholic, and other private schools

1

Mathematics in College, the Workplace, and the 21st Century

The benefits of taking rigorous mathematics and science courses extend to both two- and four-year colleges, and to the job market. As the prevalence of technology in the workplace steadily increases, workers in more and more jobs will be required to have strong backgrounds in mathematics and science--backgrounds which begin to be formed during high school. Rigorous mathematics and science preparation is also important to students intending to go to a two or four year college or university. The level and number of mathematics courses that a student needs to take before and during college depend on the type of college and the major that the student wants to pursue, and while students who plan to major in mathematics- and science-related disciplines typically need to take a more rigorous mathematics program, many other popular courses of study also require strong mathematics backgrounds.

Two-year colleges often require all students to gain an understanding of intermediate algebra prior to graduation, regardless of their course of study. In many two-year colleges, all entering degree-seeking students are required to take mathematics placement exams prior to enrollment. Students who score high enough may be exempted from taking certain mathematics courses, while students with low scores may be required to enroll in remedial mathematics courses. Many of the most popular majors at typical two-year colleges--including Business, Nursing, and Computer Science--require more rigorous mathematics course work, such as statistics.

Four-year colleges and universities typically require more high school mathematics preparation for admission. Typical state four-year colleges and universities recommend, and in some cases, require, that all students take at least three, and sometimes four, years of mathematics in high school. Data collected by the College Board reveal that in 1997, 68 percent of incoming freshmen at four-year colleges and universities had taken four years of mathematics in high school. Furthermore, almost all of these students had taken algebra and geometry, and more than half had taken trigonometry. Upon enrollment, most state colleges require students to take mathematics placement exams. Advanced Placement courses are looked at favorably by colleges and can result in placement out of introductory mathematics courses. While graduation requirements differ depending on the student's major, many popular majors, such as Business and Psychology, require students to take several more rigorous courses in mathematics or science.

In the job market, workers who have a strong background in mathematics and science are more likely to be employed and generally earn more than workers with lower achievement, even if they have not gone on to college. A national survey found that by age 30, high school graduates who had not gone on to further education and had previously scored in the top quartile on the mathematics portion of the Armed Services Vocational Aptitude Battery (ASVAB--administered to civilians for study purposes) earned, on average, 38 percent more per hour than high school graduates who had not gone to college and had scored in the bottom quartile of the mathematic portion of the ASVAB. Similarly, the unemployment rate among high school graduates who scored in the top quartile of the mathematics test was only 4.4 percent, compared to an unemployment rate of 10.3 percent among high school graduates who scored in

the lowest quartile. Workers who scored in the top quartile of the science section of the ASVAB also earned more, on average, and were less likely to be unemployed.

In the future, ability in mathematics will be even more important for good-paying jobs. Today, some major firms now require that all job applicants pass standardized mathematics and reading tests, so that they may hire only individuals with solid backgrounds in these areas. For example, at Diamond-Star Motors, a joint venture of Chrysler and Mitsubishi, all applicants for production and maintenance positions must pass a standardized test that assesses their ability to do mathematics at a high school level. Authors Richard Murnane and Frank Levy have identified a set of "New Basic Skills," in their book of the same name, that, though fundamental for good-paying jobs in the modern labor market, are often not mastered by non-college-bound high school graduates. The "New Basic Skills" that workers will need to earn a good wage include the ability to use mathematics skills and concepts **at least** at the 9th grade level, yet currently many non-college bound students looking for work do not possess a sufficient mathematics background to do so.

Mathematics and Science in the Modern Job Market

Many jobs in today's labor market require a mathematics or science background. A number of these are among the fastest growing occupations nationally, and are not ones ordinarily thought of as "technical." Projections from the Bureau of Labor Statistics' (BLS) Occupational Outlook Handbook indicate that during the 1994 to 2005 period, jobs requiring the most education and training will be the fastest growing and highest paying. BLS predicts that occupations requiring a bachelor's degree or higher will average 23 percent growth, almost double the 12 percent growth rate projected for occupations that require less education and training.

Many jobs that once required little background in mathematics now call for specific skills in algebra, geometry, measurement, probability, and statistics. According to an industry-wide standard, an entry level automobile worker needs to be able to apply formulas from algebra and physics to properly wire the electrical circuits of any car. The National Coalition for Advanced Manufacturing has defined 25 specific standards of mathematics and measurement among their national skill standards for what a good competent worker should know and be able to do.

Several of the fastest growing job areas will reflect growth in computer technology and health services--fields that can require substantial mathematics and science preparation. Generally speaking, fields requiring a strong science base also require substantial mathematics preparation, as most academic science programs build upon a strong background in mathematics. Below are some of the jobs which BLS indicates require a mathematics or science background; while many of these jobs require mathematics or science course work beyond the high school level, all require at least a high school level background. The occupations that BLS projects will be among the fastest growing during the period from 1994 to 2005 are noted with a star (*).

Computer Scientists (*)
Systems Analysts (*)
Occupational Therapy Assistants and Aides (*)
Chemical Engineers
Civil Engineers
Aerospace Engineers
Medical Assistants (*)
Dentists and Dental Hygienists
Surveyors
Surgical Technologists
Dieticians and Nutritionists
Optometrists
Physical Therapists (*)
Roofers
Tool and Die Makers
Photographers
Financial Managers
Budget Analysts

Middle School: Getting on the Road to Challenging Mathematics and Science Courses

Laying the Foundation

> "Mathematics is the language of science, and algebra is the minimum vocabulary that scientists of every discipline use to describe their work."
>
> —Dr. George Castro, Associate Dean of the College of Science at San Jose State University

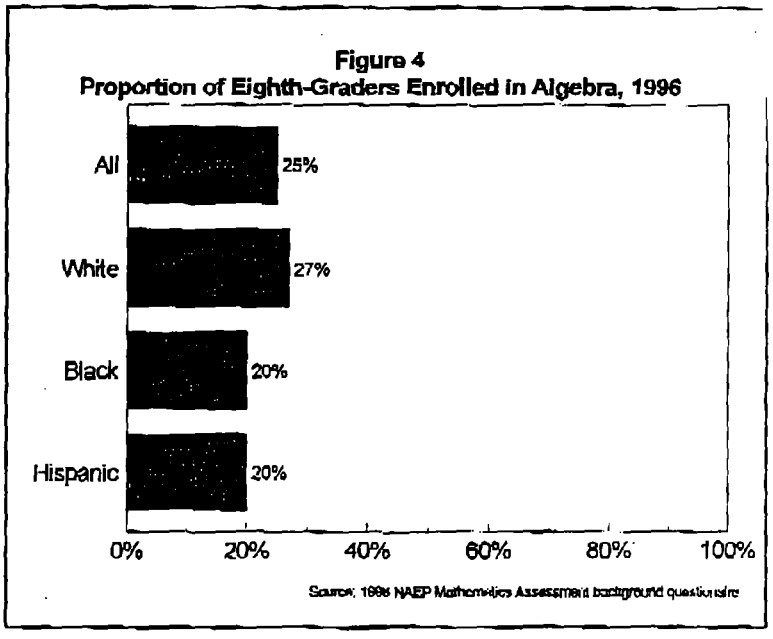
Algebra is the "gateway" to rigorous mathematics courses. Rigorous mathematics courses build upon the skills and concepts that students learn in earlier mathematics courses. Traditionally, students cannot take a rigorous mathematics course in high school until they have successfully completed one or more prerequisite courses that provide the foundation for the next course. Algebra I, or another course that covers basic algebraic concepts, is the prerequisite for more rigorous mathematics classes in high school.

Students who plan to take advanced mathematics and science courses during high school and begin to study algebra during middle school are at a clear advantage. A rigorous sequence of mathematics courses spans several years. The traditional sequence of recommended mathematics courses involves one year courses in algebra I, geometry, and algebra II, followed by a half-year course in trigonometry, a full- or half-year course in pre-calculus then calculus, or an Advanced Placement course. In addition, an increasing number of schools use curricula that cover these rigorous content areas, but integrate algebra, geometry and other areas of mathematics such as statistics and probability, rather than teaching each in a separate course. According to NELS, forty-six percent of students who took algebra I in the 8th grade took calculus in high school, compared to only eight percent of students who took algebra I in the 9th grade. The typical high school sequence of rigorous science courses (biology, chemistry, and physics) also necessitates an early background in algebra and geometry. Although not all students need to take all of the most rigorous mathematics or science courses that their school offers, most colleges encourage students to take four years of challenging mathematics and science courses during high school.

Students who do not take courses covering algebraic concepts early in their educational career risk closing the door on many important opportunities, including opportunities to take courses outside of mathematics and science. Some high schools require students to complete a specific package of courses, including mathematics and science, in order to graduate. By the junior and senior year, students who have not planned ahead to complete the courses that their school requires have fewer options in choosing which courses they take. Students who do not complete prerequisite and required courses early enough not only risk being unable to take more rigorous courses in those disciplines later, but also may not have time in their schedules to take other courses that can help prepare them for college or a career, including foreign language, art,

Advanced Placement, and "tech prep" courses.

Course-Taking Patterns in Middle School



Despite recent increases in the proportion of students taking algebra I in the 8th grade, in 1996, most students were not enrolled in this course. The proportion of 8th-graders taking the National Assessment of Educational Progress (NAEP) mathematics assessment who reported taking algebra has increased in recent years. In 1992, only 20 percent of students reported taking algebra. In 1996, the next year the NAEP mathematics assessment was administered, 25 percent reported taking algebra. This increase may be due to a number of factors, including the National Council of Teachers of Mathematics' (NCTM) call for the inclusion of algebraic topics in the middle school curriculum. However, most students still were not enrolled in courses that include significant amounts of algebra in the 8th grade.

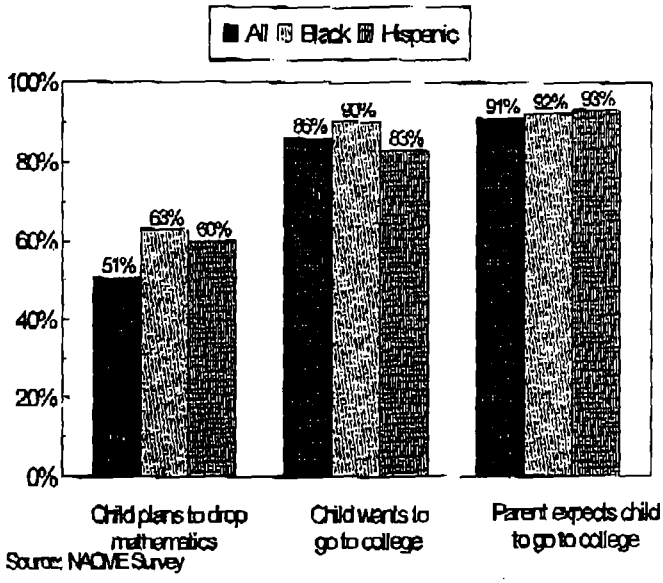
Minority and low-income students continue to be less likely to take challenging mathematics courses in middle school than other students. The 1996 NAEP data reveal that minority students are less likely to report being enrolled in algebra in the 8th-grade (Figure 4). The data also provide some indication that students from disadvantaged backgrounds are less likely to be enrolled in algebra during the 8th grade: While 29 percent of students who were not eligible for the national school lunch program reported being enrolled in algebra during the 8th grade, only 15 percent of students who were eligible for the national school lunch program were enrolled in algebra.

While the number of students taking algebra courses has increased, recent evidence suggests that the content of these courses has remained rigorous. Many states have recently increased mathematics requirements for high school graduation, often requiring that students take more years of mathematics than were required in the past, or mandating that students complete certain courses. A recent study supported by the National Science Foundation (NSF) examined the content of mathematics courses in schools in several of the states making the most substantial changes in mathematics requirements. The study focused on basic courses, such as algebra I, which had experienced large enrollment increases because of the more stringent graduation requirements. Despite the larger numbers of students enrolling in the courses, the study found that the content of these courses was essentially unchanged, indicating that more students were in fact being exposed to rigorous mathematics.

Parent and Student Attitudes about Mathematics and Science

Large proportions of middle school students indicate that they do not plan to take mathematics and science courses beyond what their schools require. A nationally representative survey of public school students and parents conducted by Louis Harris Associates for the National Action Council for Minorities in Engineering (NACME), Inc. found that large proportions of students would like to **stop** taking mathematics and science courses as soon as they are able to: 51 percent of the 5th through 11th grade students surveyed indicated that they would take mathematics classes only as long as required, while 47 percent reported they would study science only as long as it is required. Distressingly, young minority students--5th through 8th grade students who will soon be facing major decisions about which courses to take--were more likely to indicate that they planned to drop mathematics and science as soon as they were able to (61 percent planned to drop mathematics, and 58 percent planned to drop science). Minority students of all ages were more likely than other students to indicate that they would like to stop taking mathematics and science as soon as they were able to (Figure 5).

Figure 5
Students Plan to Drop Mathematics, But Want to Go to College



However, the same group of students indicate that they would be interested in going to college, and taking college-level mathematics courses. Eighty-six percent of all students surveyed said that they would like to go to college. Although less than half of the 9th- to 11th-grade students said that they planned to take trigonometry or algebra II in high school, nearly two-thirds said that they were interested in taking Advanced Placement courses. These contrasts signal that many students do not understand the importance of, and requirements for, taking rigorous mathematics and science courses in high school, including the need to take algebra by the 8th grade. In fact, only 25 percent of minority and 42 percent of non-minority 5th- through 8th-grade students recognized that if they did not take algebra they would not be able to take other mathematics classes in the future.

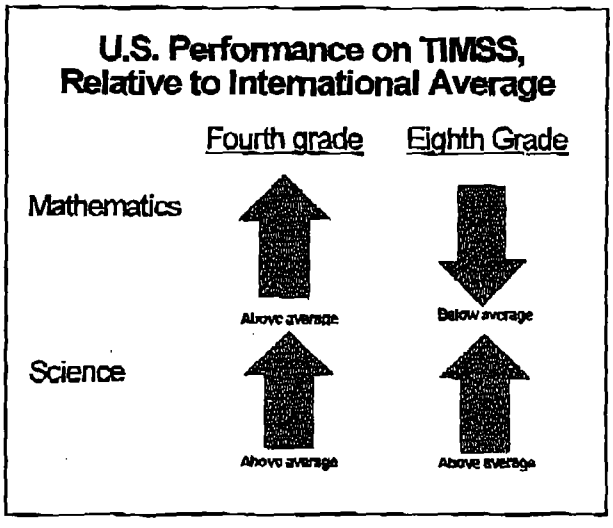
Parent and teacher involvement may make a large difference in students' decisions about mathematics and science. According to the NACME survey, ninety-four percent of students indicated that their parent's or guardian's advice was important to them in deciding what they

would study in school, and 88 percent indicated their teachers' advice was important. Ninety-one percent of parents want their children to continue their education beyond high school. However, when 9th- through eleventh-graders were asked who decided which mathematics classes they would take, seventy-nine percent indicate that they had made the decision by themselves.

Analysis of the NELS data indicates that students with greater levels of parental involvement are more likely to take advanced mathematics courses. Analysis of the course-taking patterns of the NELS students who were in 8th-grade in 1988 reveals that regardless of whether the level of parent involvement was reported by the student, the parent, or the teacher, higher levels of parental involvement were consistently associated with higher likelihoods of taking rigorous mathematics courses. While only 8 percent of those students who said that they did not discuss programs at school with their parents took algebra I by the 8th grade, 17 percent of those who said that they discussed school programs three or more times during the previous semester took algebra I by the 8th grade. Students who had parents or teachers who said that there were greater levels of parental involvement were also more likely to take advanced courses. Thirty-seven percent of those students whose parents said that they rarely talked to their child about high school plans took geometry by the 10th grade, while 48 percent of those students whose parents said they regularly spoke to the child about high school plans took geometry by the 10th grade. While 27 percent of students whose teachers said their parents were not involved took geometry by the 10th grade, a full 63 percent of the students whose teachers said that their parents were very involved took geometry by the 10th grade.

Mathematics in the U.S. Today

International Comparisons of Middle School Mathematics and Science Proficiency



Recent findings from the Third International Mathematics and Science Study (TIMSS), indicate that the mathematics curriculum from grades five through eight may be a weak link in the U. S. educational system. Newly available data from TIMSS (the most comprehensive international comparison of schools and students ever undertaken) reveal that U.S. 4th graders score above the international average in both mathematics and science. Among 25 other participating nations, only Korea performed better than the U.S. in 4th grade science, and only 7 of the 25 other countries did better than the U.S. in 4th grade mathematics. These findings are in contrast to earlier findings from TIMSS that indicate that U.S. 8th graders perform slightly below the international average in mathematics, and only slightly above the international average in science. In fact, only one country--the U.S. in mathematics--falls from above the international average at 4th grade to below the international average at 8th grade.

The U.S. expects less of its middle school and junior high students compared to high performing nations. TIMSS data suggest that one reason U.S. students do less well at 8th grade is that the middle school mathematics curriculum in the U.S. is significantly less challenging than the curricula used in other countries. In Germany and Japan, virtually all students in grades 5 through 8 move beyond arithmetic to the foundations of algebra and geometry. By 8th grade, mathematics courses in virtually all other countries participating in TIMSS include significant algebra and geometry, while in the U.S., only students in college-preparatory classes receive significant exposure to algebra, and very few students study geometry. As a result, the content taught in U.S. 8th grade mathematics classrooms is usually at a 7th-grade level compared to the 40 other nations in the TIMSS study.

TIMSS also found that U.S. mathematics classes require students to engage in less high-level mathematical thought and solve fewer multi-step problems than classes in Germany and Japan. A U.S. mathematics teacher's typical goal is to teach students the mechanics of solving a problem versus understanding the concepts behind it, while a Japanese teacher's goal is to help them learn the basics as well as understand the relevant mathematical concepts. In a typical U.S. classroom, students follow the teacher as he or she leads them through solutions to mathematics

problems. In Japan, students are asked to solve problems, present them to the class, and describe how they approached the problem to increase their own understanding.

How Does Our Curriculum Compare Internationally?

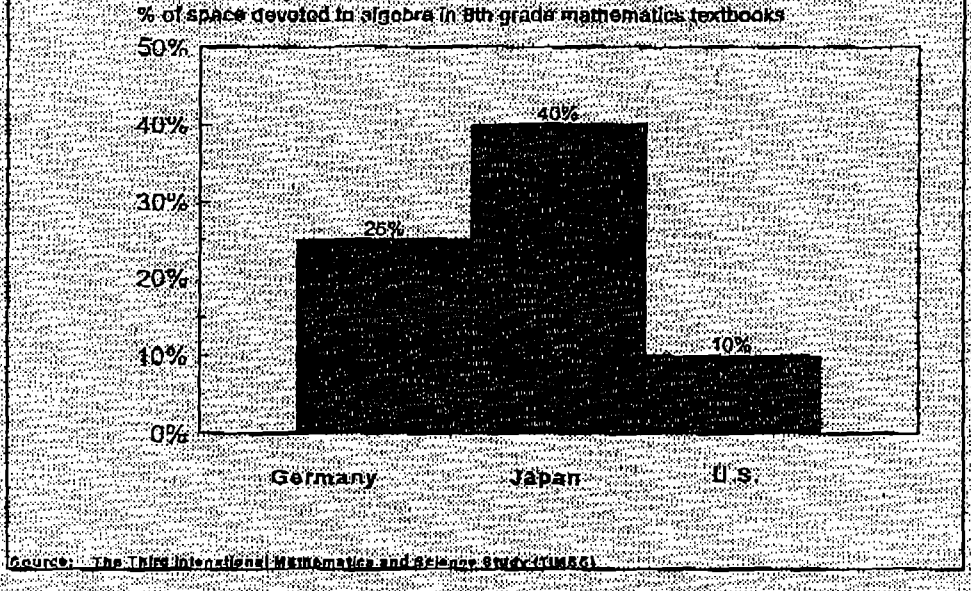
The 8th grade mathematics curriculum in both Germany and Japan is more advanced than in the United States. The TIMSS analysis of U.S. curricula examined both what is in textbooks and how it is implemented in classrooms.

- An analysis of curriculum in the U.S. and other countries, found that algebra and geometry occupy more space[1] in German and Japanese textbooks than do the textbooks used by a majority of U.S. 8th graders (Figure 6).

- Analyses of implementation of curriculum make clear that in the middle school years, the U.S. stays focused on arithmetic. For example, 40 percent of U.S. 8th grade mathematics lessons included arithmetic topics, whereas only 13 percent of Germany's and 0 percent of Japan's lessons at the 8th grade level included these topics. The major focus of curriculum taught in these countries is on algebra and geometry.

Figure 6

Algebra in 8th Grade Textbooks



Source: The Third International Mathematics and Science Study (TIMSS)

[1]Space is defined in terms of the percentage of a textbook or guidebook that is devoted to particular topics/blocks. Topics include such items as formulas, geometry, numbers, estimation. Blocks are sub-units of topics that are parts of a textbook and which might include individual pedagogical suggestions, individual examples, individual testing, narrative blocks, graphic blocks, suggested activities, and mathematical problems.

Promising Practices

In many places across the country, there are promising programs underway that focus on improving student achievement in mathematics in science. Many of these are greatly expanding the numbers of students taking rigorous courses in mathematics and science, and are finding that students are doing quite well. While recognizing that there is no one formula to success, we have highlighted a number of places that demonstrate effective strategies. We hope that these examples will be useful to you as you plan efforts to improve mathematics and science education for students in your community and across the nation.

Preparing for success: The Algebra Project, supported by the National Science Foundation (NSF) and directed by Robert Moses, addresses equity of opportunity by helping 6th, 7th, and 8th graders in inner city and rural areas gain an understanding of challenging mathematics. Serving over 40,000 traditionally low-income and minority middle school students, the Algebra Project is based on the conviction that all students can learn algebra given the proper context. An essential first step is that all students study algebra as early as possible to ensure their access to a college preparatory high school curriculum.

The project assists students in 22 urban and rural sites in 13 states to succeed in challenging high school mathematics courses by introducing rigorous mathematics concepts in the 6th grade, creating a foundation to build upon throughout the middle school years. The project has been successful in helping traditionally underserved students complete algebra I by the 8th or 9th grades, and either pre-calculus or calculus by the 12th grade utilizing a variety of strategies. The project places young college-age students in schools to provide extra assistance. In addition, the project provides after-school activities; and provides teacher professional development in examining the curriculum and beliefs about how it should be taught.

The Algebra Project has had important effects for communities. For instance, in the Mississippi Delta and in Jackson, Mississippi, the project showed positive short term effects. Additionally, an evaluation team, comprised of education experts from across the country, found evidence of positive outcomes in teaching, student attitudes about and engagement in mathematical ideas, and community involvement.

Taking the right courses: In 1990, the College Board launched EQUITY 2000 to increase minority enrollment in college preparatory mathematics courses. Originally piloted in six communities, EQUITY 2000 requires participating school districts to phase out lower-level mathematics and require all students to take a college preparatory curriculum--beginning with algebra and geometry. EQUITY 2000 influences policies, curricula and student academic development at all grade levels, with a particular focus on grades six through nine--critical years for mathematics education during which key decisions are made about which courses students should take and how they should begin planning for education and careers beyond high school.

The project provides on-going professional development to help teachers work with heterogeneous ability classes, encourages and supports parents to become advocates on behalf of their children, helps schools establish support services for students who need extra time and effort to learn challenging content, and trains administrators and teachers to use student enrollment and achievement data to drive school-based decision-making.

Finally, EQUITY 2000 has made increased parental involvement a priority because it recognizes the important role that parents play in nurturing and reinforcing their children's desire to attend college. It has sponsored Saturday and summer academics on college campuses for entire families. The program also sponsors Family Math nights in which parents and students learn mathematics concepts together.

An analysis of results at the six pilot sites found that:

- All sites dramatically increased the percentage of students enrolled in algebra I by the 9th grade, and in three pilot districts, all 9th graders enrolled in algebra I.

- The percentage of students passing algebra I did not decline significantly, and in some cases rose, as more students from the discontinued lower tracks began enrolling in algebra classes.

Advanced Placement Participation Rising in South Carolina and Texas. The College Board's Advanced Placement (AP) Program was started nearly four decades ago to enable students to complete college-level studies while still in high school and to obtain college credit or placement. Today more than 500,000 students in about half of the nation's high schools take at least one AP course, and those courses are widely recognized as setting the standard for high levels of academic achievement in high school. Dramatically increased participation in Advanced Placement courses in South Carolina and Texas illustrate the success of AP-based reform initiatives in two states.

South Carolina: With former-Governor Riley's school reform package of 1984, South Carolina became one of the first states to legislate funding and other actions to boost participation in AP. Actions included state appropriations to train AP teachers and to help pay for AP exams, as well as a requirement that public colleges accept AP courses if the student scored 3 or higher on the exam. As a result, from 1984 to 1997 South Carolina experienced:

- An increase in the number of students taking AP exams from 2,799 to 9,748.
- An increase in the number of AP exams from 3,461 to 14,890, with the mean grade remaining stable at approximately 2.7 - 2.8.
- An increase in the number of AP science exams (Biology, Chemistry, Physics) from 27 to 2,414.
- An increase in the number of AP math exams (Calculus AB and BC) from 46 to 2,767.

- Ninety-three percent of all the public high schools in the state participating in AP(184 of 197 public high schools).
- AP participation rates above the national average.

AP Exams Taken
(Eleventh and Twelfth Graders)

	1984	1997	Percent increase
South Carolina	3,461	14,890	77 percent
National	223,888	843,399	73 percent

Sources: College Board. *Advanced Placement Program, National and South Carolina Summary Reports, 1984 - 1997.*

Texas: The Advanced Placement Incentives program was developed in the Dallas, Texas area by the O'Donnell Foundation in reaction to the low rates of college attendance and poor college preparation of low-income and minority students. The Advanced Placement Incentives program addresses shortfalls in both the supply and demand for AP courses in math, science, and the arts, by providing performance-based financial incentives to teachers, school and students. Teachers are given financial incentives as well as registration and fees for attending College Board AP teacher training during the summer, and to begin to teach AP courses. Students who complete the Advanced Placement course may take the AP exam at half-cost (the total cost for an AP exam is about $73), and those who score a three or better (on a five point scale) are given a financial incentive and reimbursed for the cost of the exam.

In five years of operation in nine Texas public schools the O'Donnell foundation reports that:

- In the first year of the program 97 students took AP exams, and 52 received a three or better. In the fifth year of operation 1,099 students took AP exams, and 521 received a score of three or better.
- AP participation increased among female students in areas in which females are traditionally under represented, with 19 female students taking AP exams in math, science, or computer science during the program's first year, and 240 female students (compared to 272 male students) doing so in the program's fifth year.
- Minority participation increased, from 7 African-American or Hispanic students taking AP exams during the program's first year, to 116 in the program's fifth year.

Instructional Reform in Mathematics. Sponsored by the University of Pittsburgh's Learning Research and Development Center, the Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) Project is designed to respond to low levels of student participation and the inadequacy of student performance in mathematics. QUASAR is a practical school demonstration project for urban middles schools that fosters the development and implementation of enhanced mathematics instructional programs in economically disadvantaged communities. The program's key principles are that all students are able to learn a broad range of mathematical content, acquire a deeper and more meaningful understanding of mathematical ideas,

and demonstrate proficiency in mathematical reasoning and complex problem solving.

IN QUASAR schools, teams of mathematics teachers, school administrators and "resource partners"-- generally mathematics educators from local universities-- collaborate to develop, implement, and refine mathematics instructional programs. All project schools have eliminated most forms of academic tracking, and have emphasized deeper student understanding and high-level thinking and reasoning for all students. While there is variation across the sites in curricula, teaching strategies, and approaches to professional development, all QUASAR sites included extensive attention to professional development and teacher support. Additionally, the University of Pittsburgh's Learning Research and Development Center provides the schools with ongoing support and updated information on progress.

Program data indicate that QUASAR schools build the capacity of teachers to improve the quality of their mathematics instruction and to increase the capacity of students to think, reason, solve complex problems, and communicate mathematically. Students in QUASAR schools, particularly those who are from minority groups and those with limited English proficiency, have increased their understandings of important mathematical ideas across a range of content topic areas. Additionally, QUASAR students in grade 8 performed as well as students on basic and traditional items of the 1992 NAEP Mathematics Assessment, and above their peers on less traditional middle school mathematics content.

Standards-based Reform. The New York Regents Exam has spurred thousands more high school students to take and pass college-preparatory mathematics courses. In 1993 then-New York-Chancellor Ramon Cortines required all students to take tougher Regents-level mathematics and science courses traditionally reserved for college-bound students. Beginning in 1995, the state required that all students take Regents-level classes. The number of Hispanic and black students who passed the science portion of the Regents Exam more than doubled from the previous year. Since then, the state has decided to require that all students take and pass the Regents Exams . In addition, Commissioner of Education Richard Mills has recently called for an increase in the rigor of the state's requirements for graduation from high school, including adding another year of both mathematics and science to the current two years required in each.

Living Up to Our Potential: The First in the World Consortium, Chicago, Illinois. Twenty school districts from Chicago's North Shore joined forces in 1995 to meet the challenge of providing their students with a world class education in mathematics and science. Their first challenge was to determine what a "world class" education looked like, measure their current performance against that benchmark, and develop an improvement strategy.

The Consortium's efforts were directed toward three objectives: benchmarking performance against international standards in mathematics and science, using the Third International Mathematics and Science Study; creating a forum to clarify world-class education standards for business leaders, policy makers, educators, and community members; and establishing a network of learning communities involving educators, parents, and community leaders within the Consortium school

districts and beyond.

The districts in the First in the World Consortium took the TIMSS assessment in Spring 1996 at the 4th, 8th, and 12th grade level. Their 8th grade results placed them among the top performing countries in the world at the 4th and 8th grades, well exceeding the United States' performance. In addition:

- Fifty percent of their 8th grade students took algebra or geometry compared to 25 percent of students nationally who take algebra;
- The Consortium had high expectations for students and teachers; and
- Gained broad-based community support for improved student performance.

However, the First in the World Consortium is not resting on their success; in fact they have created teacher learning networks to strengthen curriculum standards, models of instruction, assessment, and use of technology. This "community of learners" approach promotes teacher participation and provides a context for long-term commitment to the consortium's goals and to growth in student learning.

Although the First in the World Consortium is at an advantage in terms of its resources, its willingness to identify its weaknesses and address them has distinguished its efforts. The consortium identifies both state and federal support as helping it focus on its goals. These experiences emphasize that, when given the opportunity, U.S. students can perform as well as, or better than, students in any part of the world.

Next Steps

Six things educators, policymakers and community members can do:

1. Provide all students the opportunity to take algebra I or a similarly demanding course that includes fundamental algebraic concepts in the 8th grade and more advanced math and science courses in all four years of high school.

2. Build the groundwork for success in algebra by providing a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares students for the transition to algebra.

3. Ensure that all students, parents, teachers, and counselors understand the importance of students' early study of algebra as well as continued study of rigorous mathematics and science in high school to their future college and career opportunities.

4. Prepare teachers of mathematics to teach rigorous mathematics by providing teacher preparation and professional development opportunities that increases teachers knowledge and skills in mathematics and the teaching of mathematics.

5. Support mathematics achievement outside the classroom such as math clubs, tutoring and job shadowing for students who may need extra help to ensure that they can achieve at high levels.

6. Support parent involvement in their children's mathematics education.

Six things parents can do:

1. Discuss your children's mathematics homework with them.

2. Visit your children's mathematics teacher to find out what your children are learning and how you can help.

3. Insist that your children be enrolled in algebra I or a similarly demanding course that includes fundamental algebraic concepts in the 8th grade and more advanced math and science courses in high school so they can keep all of their future options open.

4. Ensure that your children are gaining the groundwork for success in algebra through a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares them for the transition to algebra.

5. Help your children understand the importance of taking challenging mathematics and science courses to their future by visiting colleges, familiarizing them with college requirements, and

exploring financial aid options available to students.

6. Show the importance of mathematics to career choices by talking with your children about the use of mathematics in your work or the work of adults they know.

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Appendix

The NELS:88 data. The National Education Longitudinal Study of 1988 (NELS:88) initially surveyed a nationally representative sample of 26,000 public and private school 8th grade students in 1988. The data collected include responses to student questionnaires, scores on standardized achievement tests, high school transcripts, and interviews with parents and teachers. Since the initial survey in 1988, the students have been resurveyed every two years, with the most recent data available gathered two years after their scheduled high school graduation in 1994. The analyses in this report are based on a sub-sample of over 13,000 individuals from whom data were collected in all three follow-up surveys. Analysis of course-taking patterns is based on student reports of 8th-grade course-taking and high school transcript data. The actual titles of mathematics courses as they appear on the transcripts may vary, despite covering similar content (for example, geometric concepts); accordingly, we have attempted to include all courses covering similar content under traditional course names (i.e. "geometry," "algebra II") reflective of their content.

A Letter from the Secretary

Within the United States today, mastering mathematics has become a gateway to the road to college, and taking algebra in the 8th grade is a key to the "gate." Even though almost all parents want their children to go on to college or some advanced training, most 8th and 9th graders are behind in their course taking to get on the road to college.

Recent analyses conducted by the U.S. Department of Education indicate that students with strong mathematics backgrounds--namely those who take geometry and more rigorous mathematics courses during high school-- are much more likely to go to college. This is true regardless of their family's level of income. In addition, these more rigorous mathematics courses allow students to take and succeed in chemistry and physics in high school--also helpful for college acceptance and success.

We also know from other research that the benefits of a strong background in mathematics are not limited to college-going. Workers with high levels of mathematics achievement earn more and are less likely to be unemployed than workers who are less proficient in mathematics. As the prevalence of technology in the workplace steadily increases, it is easy to recognize that more and more jobs will require a solid background in mathematics.

However, not all students have access to rigorous mathematics courses in high school--either because their school does not offer a full selection of challenging courses to all students, or because students are not prepared for and encouraged to take them. Although algebra I is considered the primary "gateway" course for other important mathematics courses, many students do not take it early enough to enroll in higher level mathematics courses and science courses in high school.

Furthermore, the results of the recently completed Third International Mathematics and Science Study (TIMSS)--the most comprehensive international comparison of education ever undertaken--indicate that while our fourth graders are developing a strong foundation in mathematics and science, and score above average among twenty-five other participating nations, U.S. eighth graders score below the international average in eighth grade mathematics. Early analysis of the TIMSS data shows that our middle school mathematics curriculum is not as challenging as that of other countries. In fact, in comparison to many other countries, which commonly cover some algebra and geometry during the eighth grade, the U.S. eighth grade mathematics curriculum is at a seventh grade level.

The implications are clear: The eighth grade is a critical point in mathematics education, and achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses that are keys to college entrance and success in the labor force. Yet, too many students today enter high school without a solid grounding in mathematics, closing doors very early to opportunities for further education and better career opportunities.

Success in challenging mathematics is important for long-term academic and labor market success; it is critical that we, as a nation, ensure that all children master more rigorous mathematics by the end of the eighth grade--and build on that foundation throughout high school. I encourage teachers, parents, policy makers and all others who are concerned with the well-being of our children, to work together to ensure that all children have the opportunity to take--and master--the most challenging mathematics courses our schools have to offer.

Sincerely,

Richard Riley
U.S. Secretary of Education

Executive Summary

Within the United States today, mastering mathematics has become more important than ever. Students with strong mathematics backgrounds have advantages in academics and in the job market. The eighth grade is a critical point in mathematics education, and achievement at that stage opens opportunities for students to take rigorous high school mathematics and science courses that are keys to college entrance and success in the labor force. However, although most parents want their children to go on to college or some advanced training, most 8th and 9th graders are behind in their course taking to get on the road to college. Findings highlighted in this report include:

- **The results of the Third International Mathematics and Science Study (TIMSS) reveal that the U.S. middle school mathematics curriculum may be a weak link in the U.S. educational system.** While U.S. fourth graders score above the international average in mathematics and science, U.S. eighth graders score below average in eighth grade mathematics, and only slightly above the international average in science. Early analysis of the TIMSS data also shows that the U.S. middle school mathematics curriculum is not as challenging as that of other countries. Although algebra and geometry are commonly featured in the middle school curriculum taught in other countries, only a small fraction of U.S. middle school students are exposed to these topics.

- **Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not.** Data from the National Educational Longitudinal Study (NELS) reveal that 83 percent of students who took geometry in high school went on to attend a two or four year college within two years of their scheduled high school graduation, compared to a college attendance rate of only 35 percent among students not taking geometry; while nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college.

- **The effects of taking rigorous mathematics and science courses are most dramatic for low income students.** Low income students who took geometry were almost three times as likely to attend college as those who did not: While 71 percent of those who took geometry went to college, only 26 percent of low income students who did not take geometry in high school went on to college. By way of comparison, 93 percent of students from high income families, and 84 percent of students from middle income families who took geometry in high school went on to college, while 59 percent of students from high income families and 42 percent of students from middle income families who did not take geometry still did go on to college. When course taking is accounted for, income differences in the rate of going to college diminish dramatically, although they do not disappear completely.

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- **As the first prerequisite for geometry and other rigorous mathematics courses, algebra is the "gateway" to advanced mathematics and science in high school--yet most students currently do not take algebra or a course covering algebraic concepts during middle school.** 1996 NAEP data reveal that only 25 percent of eighth graders in the U.S. were enrolled in algebra, and that low income and minority students are even less likely to be enrolled in algebra during the eighth grade. Students who do not begin to study algebra during middle school have a distinct disadvantage in taking advanced mathematics courses during high school.

Other important findings include:

- **Mathematics achievement depends on course-taking, not the type of school a student attends.** Students at public and private school who had taken the same mathematics courses are equally likely to score at the highest level on the NELS 12th grade mathematics achievement test.

- **Students who have parents that are involved in their school work are more likley to take challenging mathematics courses early.** Regardless of whether the level of parent involvement was reported by the student, the parent, or the student's teacher, students whose parents were involved were more likley to take courses like algebra and geometry in the eighth and ninth grade, than students whose parents were not involved.

Do we know how many 8th graders were enrolled in 7th grade or who had taken by the end of 8th grade. (7th grade / 8th grade together).

Mathematics in the U.S. Today

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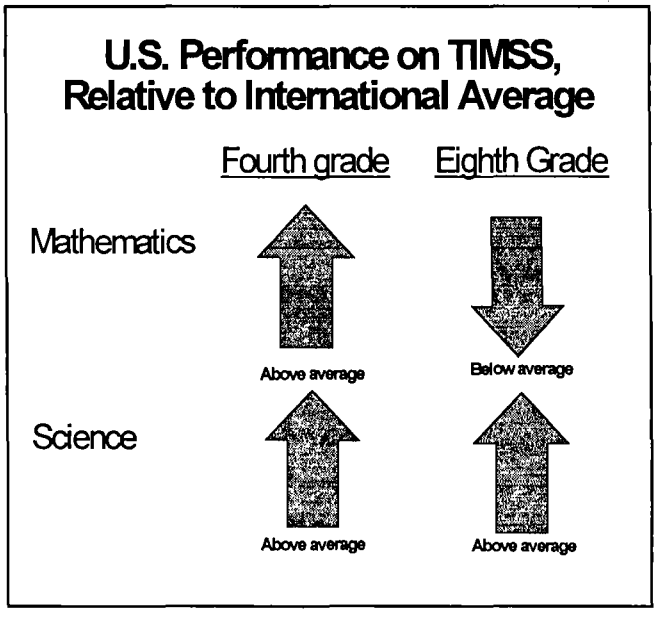
International Comparisons of Middle School Mathematics and Science Proficiency



Recent findings from the Third International Mathematics and Science Study (TIMSS), indicate that the mathematics curriculum from grades five through eight may be a weak link in the U. S. educational system. Newly available data from TIMSS (the most comprehensive international comparison of schools and students ever undertaken) reveal that U.S. fourth graders score above the international average in both mathematics and science. Among twenty-five other participating nations, only Korea performed better than the U.S. in fourth grade science, and only seven of the twenty five other countries did better than the U.S. in fourth grade mathematics. These findings are in contrast to earlier findings from TIMSS that indicate that U.S. eighth graders perform slightly below the international average in mathematics, and only slightly above the international average in science. In fact, only one country--the U.S. in mathematics--falls from above the international average at fourth grade to below the international average at eighth grade.

The TIMSS data suggest that the middle school mathematics curriculum in the U.S. is significantly less challenging than the curricula used in other countries. Although it is too early to determine definitively why U.S. eighth graders perform relatively poorer in mathematics than U.S. fourth graders, TIMSS curriculum analysis and videotape studies indicate that students in other countries are commonly taught more rigorous material during the middle school years than U.S. students. Eighth-grade mathematics courses in other countries often include algebra and geometry, while in the U.S., only students in higher-level classes receive significant exposure to algebra, and very few students study geometry. In fact, the TIMSS findings indicate that in comparison to other countries, the content of mathematics taught in U.S. eighth grade classrooms is generally at a seventh grade level.

Bake

This section is a little thin.

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Living Up to Our Potential
The First in the World Consortium, Chicago, Illinois

Twenty school districts from Chicago's North Shore joined forces in 1995 to meet the challenge of providing their students with a world class education in mathematics and science. Their first challenge was to determine what a "world class" education looked like, measure their current performance against that benchmark, and develop an improvement strategy.

The Consortium's efforts were directed toward three objectives: benchmarking performance against international standards in mathematics and science, using the Third International Mathematics and Science Study (TIMSS); creating a forum to clarify world-class education standards for business leaders, policy makers, educators, and community members; and establishing a network of learning communities involving educators, parents, and community leaders within the Consortium school districts and beyond.

The districts in the First in the World Consortium took the TIMSS assessment in Spring 1996 at the fourth, eighth, and twelfth grade level. Their 8th grade results placed them among the top performing countries in the world at the 4th and 8th grades, well exceeding the United States' performance. In addition:

- Fifty percent of their 8th grade students took algebra or geometry compared to 20 percent of students nationally;
- The Consortium had high expectations for students and teachers; and
- Gained broad-based community support for improved student performance.

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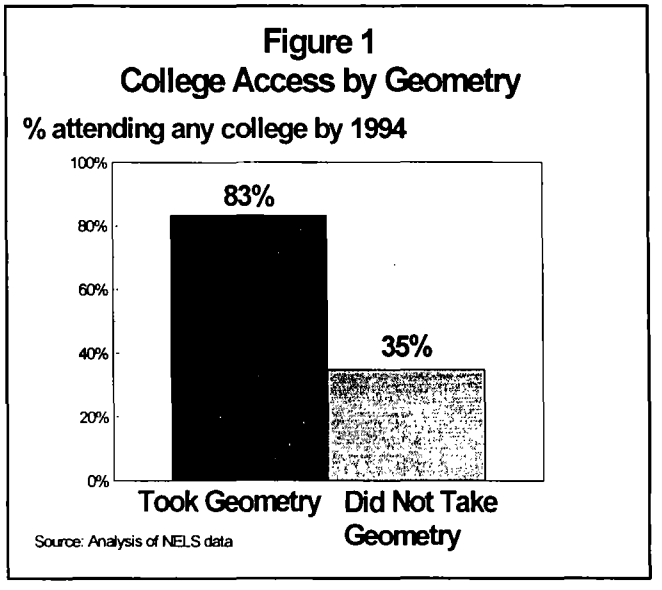
However, the First in the World Consortium is not resting on their success; in fact the findings from their participation in TIMSS and other studies have caused them to create teams of XX to strengthen XX.

The First in the World Consortium's experiences emphasize that, when given the opportunity, U.S. students can perform as well as students in any part of the world.

The Power of Mathematics for College Entrance

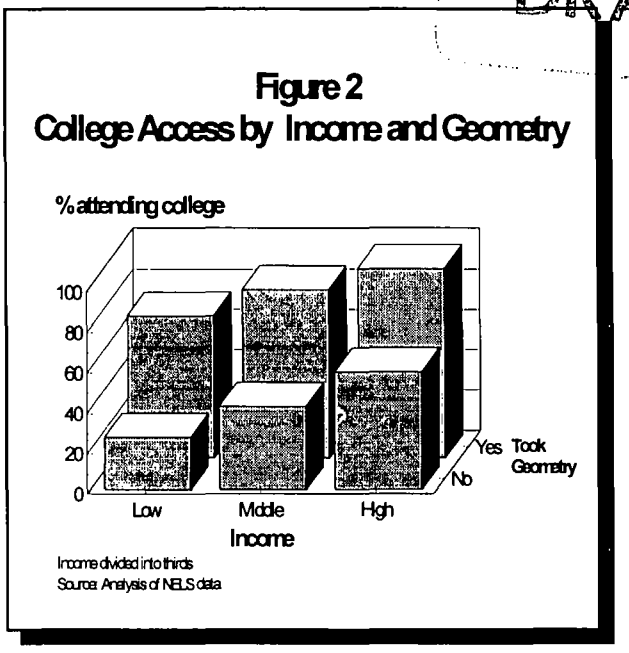
Students who take rigorous mathematics and science courses are much more likely to go to college than those who do not. Data from a longitudinal survey of students who were in the eighth grade in 1988 (National Educational Longitudinal Study or NELS) reveal that 83 percent of students who took geometry in high school--the course that usually follows algebra I in a rigorous mathematics program--went on to attend a two or four year college within two years of their scheduled high school graduation, compared to a college attendance rate of only 35 percent among students not taking geometry (Figure 1). Similarly, students who take rigorous science courses in high school are also much more likely to go to college: While nearly 89 percent of students who took chemistry went to college, only 43 percent of students who did not take chemistry in high school went to college. Earlier analysis of the NELS data reveal that students who take more rigorous mathematics courses also have higher gains in mathematics achievement (as measured by the NELS mathematics achievement test) than students who take less challenging courses. For example, among students who initially began at the same level of mathematics proficiency in the eighth grade, those students who had taken algebra II or geometry by the tenth grade experienced greater gains, on average, than those students who had taken no algebra or only algebra I during the same period.



Although students of all income levels who take rigorous mathematics and science courses in high school are more likely to go to college, for students from low income families (students in the bottom third of the income distribution)[1], the difference is even more dramatic. Low income students who took geometry were almost three times as likely to attend college as those who did not: While 71 percent of those who took geometry went to college, only 26 percent of low income students who did not take geometry in high school went on to college. By way of

[1]Income data are based on total family income reported by parents. Low, middle, and high income groups each contain approximately a third of the sample. The "all" category includes additional observations with missing income data.

comparison, 93 percent of students from high income families, and 84 percent of students from middle income families who took geometry in high school went on to college, while 59 percent of students from high income families and 42 percent of students from middle income families who did not take geometry still did go on to college (Figure 2).



Unfortunately, many students, in particular low income students, do not take these rigorous mathematics and science courses in high school. According to NELS, 63 percent of all students took geometry in high school and 50 percent took chemistry. Low income students, however, were far less likely than their peers to take these rigorous courses. Among students in the bottom third of the income distribution, 46 percent took geometry and only 33 percent took chemistry. By way of comparison, fully 82 percent of students in the top third of the income distribution took geometry, and 72 percent took chemistry. The differences are similar for other rigorous mathematics courses (Table 1).

Table 1: High School Course-Taking Patterns of Eighth Graders from 1988

	Percent of Students Taking Course			
	All	Bottom Income	Middle Income	Top Income
Geometry	**63.2**	**46.2**	**69.1**	**81.6**
Chemistry	49.5	33.3	52.2	71.6
Algebra II	47.1	34.0	51.3	62.1
Trigonometry	18.1	10.3	19.2	29.5

When high school course-taking patterns are accounted for, the difference in the rate of college-going between low and high income students is dramatically reduced. When course taking patterns are not accounted for, students from high income families are almost twice as likely to attend college as students from low income families (86 percent compared to 44 percent). However, when only students who have taken rigorous courses in high school are compared to one another, students from low income families go to college at rates much more

similar to students from middle and high income families (Table 2). For example, among students who took chemistry in high school, 95 percent of high-income students; 89 percent of middle-income students; and 79 percent of low-income students went on to college. When low income students take rigorous courses in high school, income effects on college-going rates diminish greatly, although they do not disappear.

Table 2: College Attendance by Course-Taking Patterns of Eighth Graders from 1988

	Percent of Students Attending Postsecondary Education				
		All	Bottom Income	Middle Income	Top Income
	All	62.7	43.9	68.8	85.6
Geometry	**Yes**	**83.3**	**70.7**	**83.6**	**93.9**
	No	**34.8**	**26.4**	**41.6**	**58.5**
Chemistry	Yes	88.6	79.2	89.1	95.1
	No	42.7	30.7	50.4	67.8
Algebra II	Yes	85.7	75.9	85.5	94.7
	No	47.4	31.9	54.9	75.3
Trigonometry	Yes	93.5	89.7	91.8	97.9
	No	59.2	41.9	65.6	83.0

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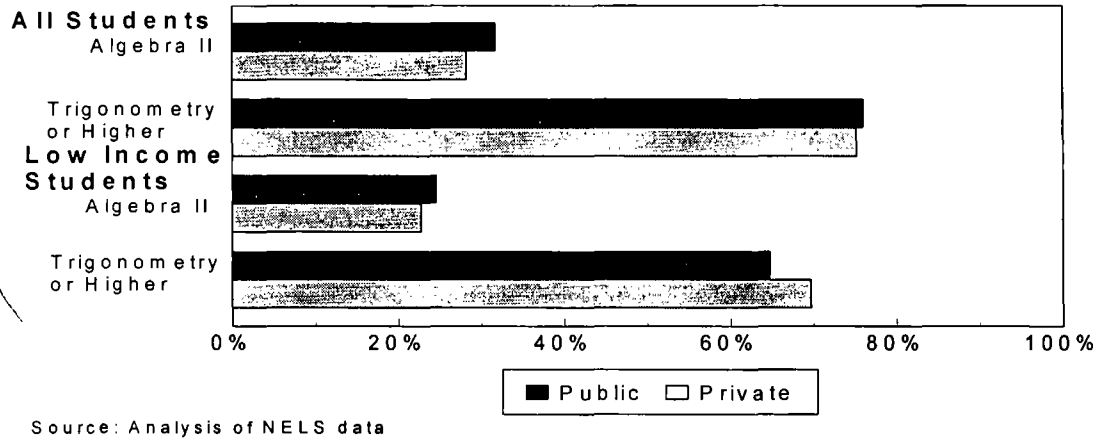
Public Versus Private
Achievement Depends on Course-Taking, Not the Type of School

In general, the mathematics courses students take in high school are more important for achievement than the type of school attended. While recognizing that there exists great diversity among public and private schools, course-taking patterns provide some insight. Public and private school students who had taken the same level of mathematics courses were almost equally likely to score at the highest achievement level on the NELS twelfth-grade mathematics achievement test. This was also true for low income public and private school students. Additionally, among both public and private school students of all incomes, students who had taken more rigorous mathematics courses were much more likely to score at the highest achievement level.

Percent of Students Scoring at the Highest Level of the NELS 12th Grade Mathematics Achievement Test by Highest Mathematics Course Taken



Source: Analysis of NELS data

Private schools include non-religious, Catholic, and other private schools

What Do Colleges and Universities Require?

The level and number of mathematics courses that a student needs to take before and during college depend on the type of college and the major the student intends to pursue. Although students who intend to major in mathematics- and science-related disciplines typically need to take a rigorous mathematics program, many other popular courses of study also require solid mathematics backgrounds.

Two-year colleges

Two-year colleges often require all entering degree-seeking students to take mathematics placement exams prior to enrollment; students who score high enough may be exempted from taking certain mathematics courses, while students with low scores may be required to enroll in remedial mathematics courses. Many two-year colleges require all students to master intermediate algebra prior to graduation, regardless of their course of study. Many of the most popular majors at typical two-year colleges--such as Business, Nursing, and Computer Science--require more rigorous mathematics course work, such as statistics.

Four-year colleges and universities

Four-year colleges and universities typically require more high school mathematics preparation for admission. Typical state four-year colleges and universities recommend, and in some cases, require, that all students take at least three, and sometimes four, years of mathematics in high school, generally including at least algebra I, geometry, and algebra II. Most state colleges require students to take mathematics placement exams. Advanced Placement courses are looked at favorably by colleges and can result in placement out of introductary mathematics courses. Graduation requirements differ depending on the student's major, though. Many popular majors, such as Business and Psychology, require students to take several more rigorous courses in mathematics or science.

What Did the Class of 1996 Take?
High School Course-Taking Patterns of College-Bound Seniors, 1996

Years of Mathematics	Percent of Students
4 or More Years	68
3 Years	28
1 or 2 Years	3
Course Work	
Algebra	96
Geometry	94
Trigonometry	53

Source: The College Board

Working in the 21st Century

Students who have strong backgrounds in mathematics have significant advantages in today's job market. Workers who have a record of high academic achievement in mathematics and science, as measured by achievement test scores, are more likely to be employed and generally earn more than workers with lower achievement, even if they have not gone on to college. A national survey found that by age 30, high school graduates who had not gone on to further education who had previously scored in the top quartile on the mathematics portion of the Armed Services Vocational Aptitude Battery (ASVAB--administered to civilians for study purposes) earned, on average, 38 percent more per hour than high school graduates who had not gone to college who had scored in the bottom quartile of the mathematic portion of the ASVAB. Similarly, the unemployment rate among high school graduates who scored in the top quartile of the mathematics test was only 4.4 percent, compared to an unemployment rate of 10.3 percent among high school graduates who scored in the lowest quartile.

In the future, ability in mathematics will be even more important for middle class employment. Today, some major firms now require that all job applicants pass standardized mathematics and reading tests, so that they may hire only individuals with solid backgrounds in these areas. For example, at Diamond-Star Motors, a joint venture of Chrysler and Mitsubishi, all applicants for production and maintenance positions must pass a standardized test that assesses their ability to do mathematics on a high school level. Authors Richard Murnane and Frank Levy have identified a set of "New Basic Skills," in their book of the same name, that, though fundamental

for middle class employment in the modern labor market, are often not mastered by non-college-bound high school graduates. The "New Basic Skills" that workers will need to earn a good wage include the ability to use mathematics skills and concepts **at least** at the ninth grade level, yet currently many non-college bound students looking for work do not possess a sufficient mathematics background to do so.

Mathematics and Science in Tomorrow's Job Market

Many jobs in today's labor market require a mathematics or science background. A number of these are among the fastest growing occupations nationally, and are ones we might not think of as "technical." Projections from the Bureau of Labor Statistics' (BLS) Occupational Outlook Handbook indicate that during the 1994 to 2005 period, jobs requiring the most education and training will be the fastest growing and highest paying. BLS predicts that occupations requiring a bachelor's degree or higher will average 23 percent growth, almost double the 12 percent growth rate projected for occupations that require less education and training.

Many of the fastest growing job areas will reflect growth in computer technology and health services--fields that can require substantial mathematics and science preparation. Generally speaking, fields requiring a strong science base also require substantial mathematics preparation, as most academic science programs build upon a strong background in mathematics. Below are some of the jobs which BLS indicates require a mathematics or science background; while many of these jobs require mathematics or science course work beyond the high school level, all require at least a high school level background. The occupations that BLS projects will be among the fastest growing during the period from 1994 to 2005 are noted with a star (*).

Computer Scientists (*)
Systems Analysts (*)
Occupational Therapy Assistants and Aides (*)
Chemical Engineers
Civil Engineers
Aerospace Engineers
Medical Assistants (*)
Dentists and Dental Hygienists
Surveyors
Surgical Technologists
Dieticians and Nutritionists
Optometrists
Physical Therapists (*)
Roofers
Tool and Die Makers
Photographers
Financial Managers
Budget Analysts

Getting on the Road to Challenging Mathematics and Science Courses

Laying the Foundation

As the prerequisite for all rigorous mathematics courses, algebra is the "gateway" course that all students must master. Rigorous mathematics courses build upon the skills and concepts that students master in earlier mathematics courses. Traditionally, students cannot take a rigorous mathematics course in high school until they have successfully completed one or more prerequisite courses that provide the foundation for the next course. Algebra I, or another course that covers basic algebraic concepts, is the first prerequisite for all more rigorous mathematics classes in high school, from geometry to calculus. As the first course that students must master, algebra I acts as the "gateway" course to rigorous work later in the student's education not only in mathematics, but in science as well.

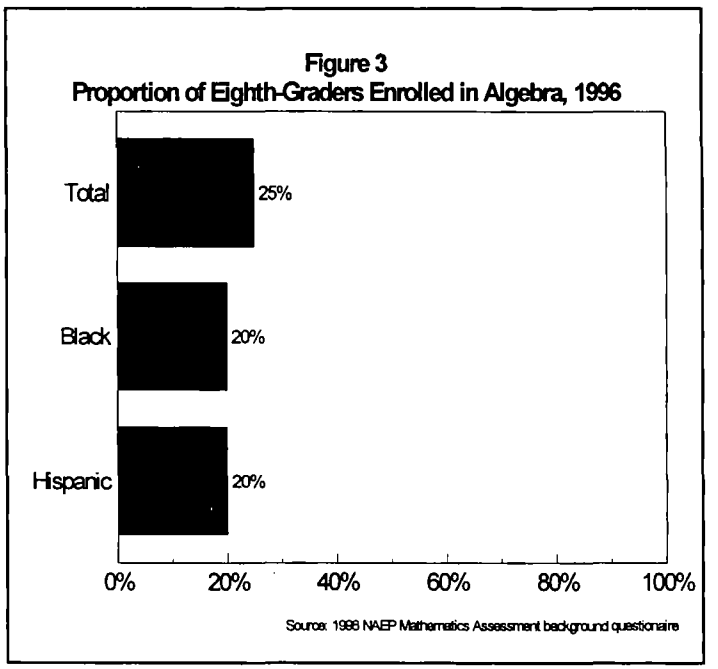
Algebra and the Changing Middle School Curriculum

To succeed in rigorous mathematics courses, students in middle school must make a critical transition between arithmetic, the basis of much of the foundational mathematics taught in elementary school, and algebra, the basis of more challenging high school mathematics. In the past, algebra has traditionally been taught as a separate subject--generally in a course called "algebra". However, many middle schools have begun to integrate algebraic concepts into other mathematics courses, sometimes under course names other than "algebra." While this document refers to taking "algebra," it is important to note that some schools may offer algebra within a course of a different name. Parents should contact their child's middle and high schools for more information about their child's opportunities to study algebra and other challenging mathematics courses.

Students who take algebra early in their educational career have a clear advantage in taking rigorous mathematics courses. The series of prerequisites for more rigorous mathematics courses can span several years. Although there is some variation from school to school, the sequence of recommended mathematics courses typically involves one year courses in algebra I, geometry, and algebra II; in some high schools a half year course in trigonometry; and in many high schools, a full or half-year course in pre-calculus or calculus and even one to two Advanced Placement courses. Similarly, the sequence of rigorous science courses (engineering, chemistry, and physics) necessitates an early background in algebra and geometry. Other models incorporating concepts from these courses provide an integrated approach to studying challenging mathematics. Although not all students need to take all of the most rigorous mathematics or science courses that their school offers, most colleges encourage students to take four years of challenging mathematics and science courses during high school. Students who take algebra I early in their educational careers increase greatly their ability to take rigorous mathematics and science courses later in high school.

Students who do not take algebra early in their educational career risk closing the door on many

important opportunities, including opportunities to take courses outside of mathematics and science. Some high schools require students to complete a specific package of courses, including mathematics and science, in order to graduate. By the junior and senior year, students who have not planned ahead to complete the courses that their school requires have fewer options in choosing which courses they take. Students who do not complete prerequisite and required courses early enough not only risk being unable to take more rigorous courses in those disciplines later, but also may not have time in their schedules to take other courses that can help prepare them for college or a career, including foreign language, art, Advanced Placement, and "tech prep" courses.

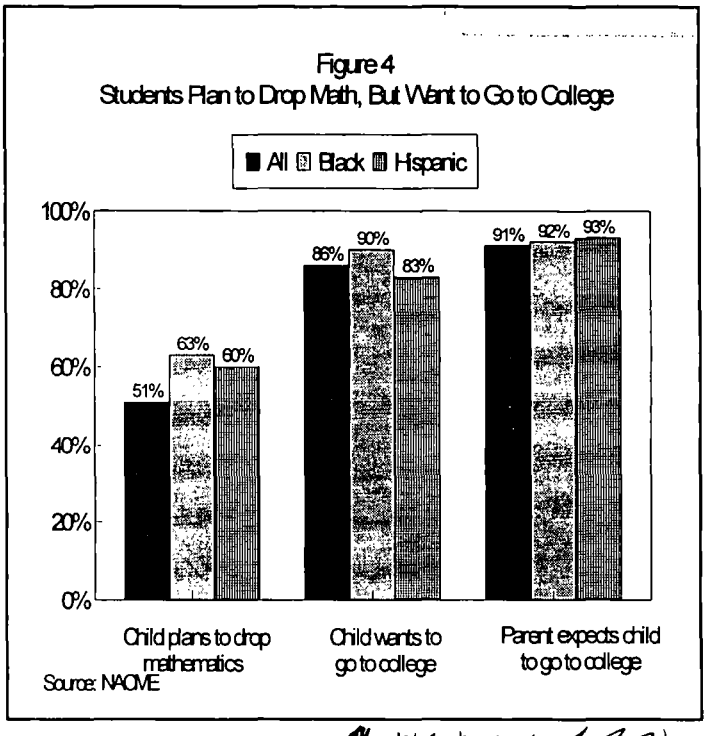


Course-Taking Patterns in Middle School

Despite recent increases in the proportion of students taking algebra I in the eighth grade, in 1996, most students were not enrolled in this course. The proportion of eighth-graders taking the National Assessment of Educational Progress (NAEP) mathematics assessment who reported taking algebra on the accompanying background questionnaire has increased in recent years. In 1992, only 20 percent of students reported taking algebra. In 1996, the next year the NAEP mathematics assessment was administered, 25 percent reported taking algebra. This increase may be due to a number of factors, including the National Council of Teachers of Mathematics' (NCTM) call for the inclusion of algebra in the middle school curriculum. However, most students still were not enrolled in this course.

While the number of students taking algebra courses has increased, recent evidence suggests that the content of these courses has remained rigorous. Many states have recently increased mathematics requirements for high school graduation, often requiring that students take more years of mathematics than were required in the past, or mandating that students complete certain courses. A recent study supported by the National Science Foundation (NSF) examined the content of mathematics courses in schools in several of the states making the most substantial changes in mathematics requirements. The study focused on basic courses, such as algebra I, which had experienced large enrollment increases because of the more stringent graduation requirements. Despite the larger numbers of students enrolling in the courses, the study found that the content of these courses was essentially unchanged, indicating that more students were in

fact being exposed to rigorous mathematics.



Minority and low-income students continue to be less likely to take challenging mathematics courses in middle school than other students. 1996 NAEP data reveal that minority students are less likely to report being enrolled in either algebra in the eighth-grade (see Figure 3). The data also provides some indication that students from disadvantaged backgrounds are less likely to be enrolled in algebra during the eighth grade: While 29 percent of students who were not eligible for the national school lunch program reported being enrolled in algebra during the eighth grade, only 15 percent of students who were eligible for the national school lunch program were enrolled in algebra.

Hard to Read

Parent and Student Attitudes about Mathematics and Science

Large proportions of middle school students indicate that they do not plan to take mathematics and science courses beyond what their schools require. A nationally representative survey of students and parents conducted by Louis Harris Associates for the National Action Council for Minorities in Engineering (NACME), Inc. found that large proportions of students would like to **stop** taking mathematics and science courses as soon as they are able to: 51 percent of the fifth through eleventh grade students surveyed indicated that they would take mathematics classes only as long as required, while 47 percent reported they would study science only as long as it is required. Distressingly, the younger students--fifth through eighth grade students who will soon be facing major decisions about which courses to take--were more likely to indicate that they planned to drop mathematics or science as soon as they were able to. Furthermore, minority students of all ages were more likely than other students to indicate that they would like to stop taking mathematics and science as soon as they were able to.

However, the same group of students indicate that they would be interested in going to college, and taking college-level mathematics courses. Eighty-six percent of all students surveyed said that they would like to go to college. Although fewer than half of the ninth to eleventh grade students said that they planned to take trigonometry or algebra II in high school, nearly two-thirds said that they were interested in taking Advanced Placement or college level

mathematics courses. African-American students were particularly likely to say that they would be interested in taking Advanced Placement or college-level mathematics courses (78 percent of those surveyed), although they were also less likely to say that they planned to take algebra II or trigonometry in high school. These contrasts signal that many students do not understand the importance of, and requirements for, taking rigorous mathematics and science courses in high school and do not understand the need to take algebra in the 8th grade so they can get the sequence to have taken algebra II, trigonometry, and other rigorous courses before high school graduation: Only 25 percent of minority and 42 percent of non-minority fifth through eighth grade students recognized that if they did not take algebra they would not be able to take other mathematics classes in the future.

Parent and teacher involvement may make a large difference in students' decisions about mathematics and science. Ninety-four percent of students indicated that their parent or guardian's advice was important to them in deciding what they would study in school, and 88 percent indicated their teachers' advice was important. Ninety-one percent want their children to go to college or continue their education beyond high school. Although it is difficult to estimate the effects greater parent involvement would have on course-taking, the NACME survey does provide a possible indicator: fifty percent of students who said their parents talked to them about school said that they planned to take algebra II, while only 37 percent of students whose parents did not talk to them about school planned to do so. Students who reported that their parents were involved in their school life were also more likely to plan to take trigonometry and calculus.

Parental Involvement and Course-Taking Behavior

Parental involvement may have a significant effect on the likelihood that students enroll in challenging mathematics courses. Analysis of the NELS data indicates that:

- **Students with greater levels of parental involvement are more likely to take advanced mathematics courses.** While only 8 percent of those students who said that they did not discuss programs at school with their parents took algebra I by the 8th grade, 12 percent of those who said that they discussed school programs one or two times during the past semester, and 17 percent of those who said that they discussed school programs three or more times during the past semester took algebra I by the eighth grade.

- **Students who had parents or teachers who said that there were greater levels of parental involvement were also more likely to take advanced courses.** While 37 percent of those students whose parents said that they rarely talked to their child about high school plans took geometry by the 10th grade, 48 percent of those students whose parents said they regularly spoke to the child about high school plans took geometry by the 10th grade. While 27 percent of students whose teachers said their parents were not involved took geometry by the 10th grade, 63 percent of the students whose teachers said that their parents were very involved took geometry by the 10th grade.

- **Regardless of whether the level of parent involvement is reported by the student, the parent, or the teacher, higher levels of parental involvement are consistently associated with higher likelihoods of taking these courses.**

Promising Practices

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Preparing for success: The Algebra Project, supported by the National Science Foundation (NSF) and directed by Robert Moses, addresses equity of opportunity by helping sixth, seventh, and eighth graders in inner city and rural areas gain mastery of challenging mathematics. An essential first step is that all students complete algebra as early as possible to ensure their access to a college preparatory high school curriculum. The Algebra Project's underlying conviction is that all children can learn algebra. The Project is based on the expectation that virtually all middle school students can learn algebra given the proper context. The Project assists ~~that~~ students to succeed in challenging high school mathematics courses by introducing rigorous mathematics concepts in the sixth grade, creating a foundation to build upon throughout the middle school years. Through the infusion of young college-age students into the school, the work of individuals to provide after-school activities, and the connection of the Algebra Project to ~~other~~ avenues that give students a chance to pursue other interests (for example, theater), the project has been successful in helping traditionally underserved students complete algebra I by the eighth or ninth grades, and either pre-calculus or calculus by the twelfth grade. The Project serves over 40,000 traditionally low-income and minority middle school students in 22 urban and rural sites in 13 states.

Taking the right courses: In 1990, the College Board launched Equity 2000 to increase minority enrollment in college preparatory mathematics courses. Originally piloted in six communities, Equity 2000 ~~requires participating school districts to~~ agree to phase out lower-level mathematics and require all students to take a college preparatory curriculum--beginning with algebra and geometry. The project provides on-going professional development to help teachers work with heterogeneous classes, encourages and supports parents to become advocates on behalf of their children, helps schools establish support services for students who need extra time and effort to master challenging content, and trains administrators and teachers to use student enrollment and achievement data to drive school-based decision-making. An analysis of results at the six pilot sites found that:

- All sites dramatically increased the percentage of students enrolled in algebra I by the ninth grade, and in three pilot districts, all ninth graders enrolled in algebra I.
- The total number of students taking and passing algebra I increased, as more students from the discontinued lower tracks began enrolling in algebra classes.

Finally, Equity 2000 has made increased parental involvement a priority because it recognizes the important role that parents play in kindling and reinforcing their children's desire to attend college. It has sponsored Saturday and summer academies on college campuses for entire families. The program also sponsors Family Math nights in which parents and students learn mathematics concepts together.

Advanced Placement Participation and Scores on the Rise in South Carolina

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Next Steps: What We Can Do

- Ensure that all students, parents, teachers, and counselors recognize the importance of students' early enrollment in algebra to their future opportunities.
- Ensure that all children have access to algebra I or a similarly challenging class that includes fundamental algebraic concepts in the eighth grade.
- Ensure that all children have access to rigorous mathematics and science courses.
- Ensure that all students are taught by well-prepared teachers.

Parents:

- Insist that your children be enrolled in challenging mathematics and science courses in the middle and high school years so they can keep all of their future options open.
- Visit your children's mathematics teacher to find out what your children are learning and how you can help.
- Discuss your children's mathematics homework with them.
- Take the opportunity to talk with your children about applications of mathematics that you use in your job or in your everyday life. Articles in the newspaper containing scientific, statistical, business data, or graphs and charts make especially good examples. Helping your child to budget for expenses and plan ahead for needed items is also important. Work on household improvements or repairs offers interesting uses of measurement of scaling. Planning trips can involve consulting maps and planning for travel time and expenses.

Administrators and Policymakers:

- Eliminate dead-end middle and high school courses that shortchange students; provide all children with access to rigorous mathematics and science courses beginning with algebra I in the 8th grade.
- Encourage stiffer and more explicit college mathematics and science entry requirements.

- Encourage states to offer special diplomas and scholarships to students who have taken college-prep mathematics courses and have done well.

- Develop and make readily available instructional materials and assessments which support the kind of curriculum that needs to be taught in the early and middle grades.

What about teachers?

Resources

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Appendix

The NELS:88 data. The National Education Longitudinal Study of 1988 (NELS:88) initially surveyed a nationally representative sample of 26,000 public and private school eighth grade students in 1988. The data collected include responses to student questionnaires, scores on standardized achievement tests, high school transcripts, and interviews with parents and teachers. Since the initial survey in 1988, the students have been resurveyed every two years, with the most recent data available gathered two years after their scheduled high school graduation in 1994. The analyses in this report are based on a sub-sample of over 13,000 individuals from whom data were collected in all three follow-up surveys. The NELS data use traditional names of mathematics courses (i.e. "geometry," "algebra II") to reflect the content of courses. This analysis necessarily employs these titles, but should not be interpreted as implying that courses covering the relevant content (for example, geometric concepts), but employing different titles, would have a different relationship to the data.

But could this analysis underestimate the number of students who appear to study such concepts?