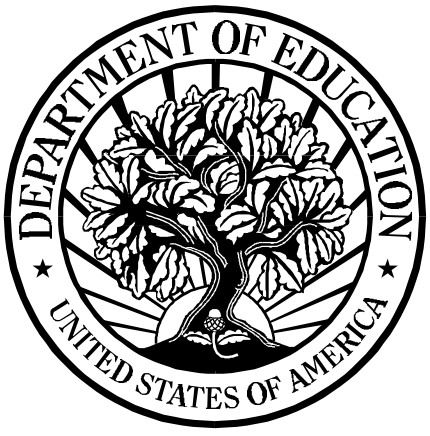
MATHEMATICS EQUALS OPPORTUNITY

White Paper prepared for
U. S. Secretary of Education Richard W. Riley

October 20, 1997



A Letter from the Secretary of Education

Many parents, students, and teachers now understand that mastering mathematics is a gateway to college. A recent analysis by the U.S. Department of Education indicates that high school students who take algebra, geometry, and other rigorous mathematics courses are more likely to go on to college. This is true regardless of their family income. In fact, the benefit of taking rigorous courses is greatest for students from low-income families.

The key to understanding mathematics is taking algebra or courses covering algebraic concepts by the end of the 8th grade. Achievement at that stage gives students an important advantage in taking rigorous high school mathematics and science courses. However, many 8th and 9th graders may already be behind in their course selection to get on to the road to college. Some students do not have access to rigorous mathematics courses -- either because their school does not offer everyone a full selection of challenging courses, or because not all students are prepared for and encouraged to enroll. The results of the recent Third International Mathematics and Science Study (TIMSS) confirm that many students enter high school without a solid grounding in mathematics, closing doors very early for further education and better careers.

Students, parents and educators should review this important report and understand the significance of a solid foundation in mathematics as a key to college and career success.

Yours sincerely,

Richard W. Riley

Table of Contents

Executive Summary

In the United States today, mastering mathematics has become more important than ever. Students with a strong grasp of mathematics have an advantage in academics and in the job market. The 8th grade is a critical point in mathematics education. Achievement at that stage clears the way for students to take rigorous high school mathematics and science courses—keys to college entrance and success in the labor force. However, most 8th and 9th graders lag so far behind in their course taking that getting on the road to college is a long way off.

This report highlights the following findings:

- **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 college within two years of their scheduled high school graduation. Only 36 percent of students who did not take algebra I and geometry courses went to college. While nearly 89 percent of students who took chemistry in high school went to college, only 43 percent of students who did not take chemistry went to college.

- **Algebra is the "gateway" to advanced mathematics and science in high school, yet most students do not take it in middle school.** Students who study algebra in middle school and who plan to take advanced mathematics and science courses in high school have an advantage: approximately 60 percent of the students who took calculus in high school had taken algebra in the 8th grade. However, 1996 NAEP data reveal that only 25 percent of U.S. 8th graders enrolled in algebra, and that low-income and minority students were even less likely to take algebra in the 8th grade.

- **Taking rigorous mathematics and science courses in**

high school 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 take those courses 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. Sixty percent of students from high-income families and 44 percent of students from middle-income families who did not take algebra I and geometry went to college.

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

Other important findings include:

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

- **Students whose parents are involved in their school work are more likely to take challenging mathematics courses early.** Students whose parents were involved in their education 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 middle school mathematics curriculum may be a weak link in the U.S. education system.** While U.S. 4th graders scored above the international average in mathematics and science, U.S. 8th graders scored below average in mathematics, and only slightly above the international average in science. Initial analysis of TIMSS data also shows that the middle school mathematics curriculum in the U.S. is less challenging than in other countries. The curriculum of average 8th-grade mathematics classrooms in the U.S. resembles 7th grade curriculum elsewhere. Although algebra and geometry are integral elements of the middle school curriculum in other countries, only a small fraction of U.S. middle schools offer their students these topics.

Algebra in the Curriculum

Making a successful transition from arithmetic to more advanced mathematics, 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 fundamentals of algebra and geometry into the upper elementary grade curriculum. In these programs, 5th, 6th and 7th grade students are representing and solving equations, characterizing patterns and rates of change among variables, and using other fundamental algebraic concepts.

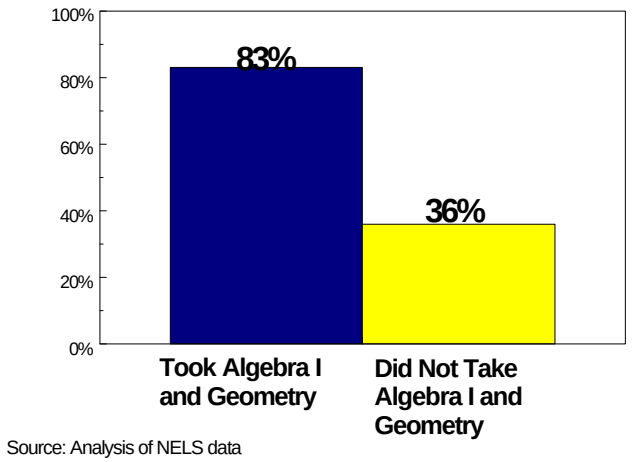
In addition, some middle and high schools are taking a new approach to advanced topics. While many schools offer the traditional model of separate courses for pre-Algebra, Algebra I, Geometry, Algebra II, Trigonometry, pre-Calculus and Calculus, these schools are integrating them. This approach is consistent with practices in other industrialized nations, which integrate algebra, geometry, and other topics throughout the elementary, middle, and high school years and offer a significant component of algebra in the 8th grade. Building a firm foundation in algebra during the elementary and middle school years eases the shift from arithmetic to advanced topics, whatever the format of students' new curriculum. NELS and NAEP, the two sources of national mathematics course-taking data analyzed in this brief, employ traditional courses titles, such as "algebra I" and "geometry." Thus, these titles are used throughout the brief.

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 enrolled in college[1] within two years of their scheduled high school graduation. Only 36 percent of students who did not take algebra I and geometry went to college (Figure 1). Similarly, students who take rigorous science courses in high school are much more likely to go to college. While nearly 89 percent of students who took chemistry entered college, only 43 percent who did not take chemistry went to college.

Figure 1
College Attendance by Course-Taking



Source: Analysis of NELS data

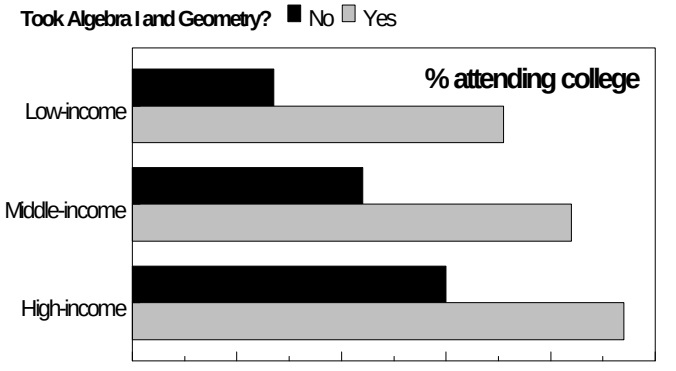
Students who take more rigorous mathematics courses also show higher gains in mathematics achievement (measured by the mathematics achievement test given as part of NELS) than students who take less challenging courses, even when controlling for initial achievement. For example, among students who initially began at the same level of mathematics proficiency in the 8th grade, students who had taken algebra II or geometry by the 10th grade experienced greater gains, on average, than students who had taken no algebra or only algebra I during that 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

[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.

bottom third of the income distribution)[2]***, the difference is particularly dramatic.*** Students 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 went on to college (Figure 2).

Figure 2
College Attendance by Income and Course-Taking



Income divided into thirds
Source: Analysis of NELS data

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 more advantaged 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).

[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 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

Accounting for course-taking patterns dramatically reduces the difference in the rate of college-going between low- and high-income students. 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) when course-taking patterns are not accounted for. However, comparing only students who have taken rigorous courses 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 to college. When low-income students take rigorous courses, income effects on college entrance rates diminish greatly, although they do not disappear.

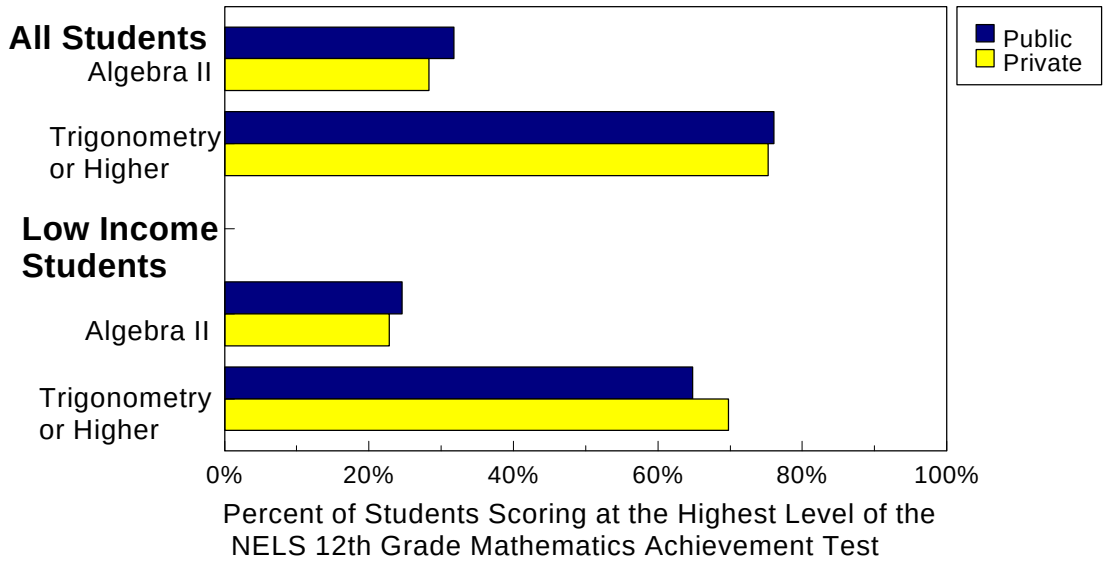
Table 2: College Attendance by High School Course-Taking Patterns of NELS Students

	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 determine achievement more than the type of school they attend . While recognizing that a great deal of diversity exists in 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 [1] school students who took the same mathematics courses were almost equally likely to score at the highest 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

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

The benefits of taking rigorous mathematics and science courses extend to students heading into the job market and to both two- and four-year colleges. As technology becomes prevalent in the workplace, more and more workers will find they need to have strong backgrounds in mathematics and science--backgrounds which will have begun to form even before 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 college and the major that the student wants to pursue. Mathematics- and science-related disciplines typically require that students have taken rigorous mathematics courses. Many other popular courses of study require advanced mathematics as well.

Two-year colleges often require all students to gain an understanding of intermediate algebra prior to graduation, regardless of their course of study. Many two-year colleges require all degree-seeking students to take mathematics placement exams prior to enrollment. High scorers may be exempt from taking certain mathematics courses, while low scorers may have to take remedial mathematics courses. Many of the most popular majors at 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. Most state colleges require students to take mathematics placement exams upon enrollment. Colleges look favorably on Advanced Placement courses and often place students who have taken them out of introductory mathematics courses. While graduation requirements differ depending on the students' 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 strong mathematics and science backgrounds 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 furthered their education but had 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. The unemployment rate was 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.

Mathematics ability will be even more important for well-paying jobs in the future. Some major firms already require job applicants to pass standardized mathematics and reading tests. For example, Diamond-Star Motors, a joint venture of Chrysler and Mitsubishi, tests all applicants for production and maintenance positions on their ability to do high school level mathematics. Authors Richard Murnane and Frank Levy have identified a set of "New Basic Skills," in their book of the same name, that non-college-bound high school graduates should master in order to get well-paying jobs in the modern labor market. The "New Basic Skills" that workers will need in order to earn a good wage include the ability to use mathematics skills and concepts **at least** at the 9th grade level.

Shortages in workers skilled in mathematics and science could affect U.S. performance in global markets. According to a recent report, *America's New Deficit: The Shortage of Information Technology Workers,* from the Office of Technology Policy at the U.S. Department of Commerce, as computer and data processing become more important to the economy, more and more workers skilled in mathematics- and science-related disciplines will be needed to maintain the U.S.'s international competitiveness. The report cites a survey by the Information Technology Association of America indicating that 50 percent of company executives in information technology report a lack of skilled workers as "the most significant barrier" to their companies' growth during the next year. However, the number of bachelor level computer science degrees awarded by U.S. colleges and universities declined more than 40 percent between 1986 and 1994, indicating that these problems are likely to persist.

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 between 1994 to 2005, 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 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

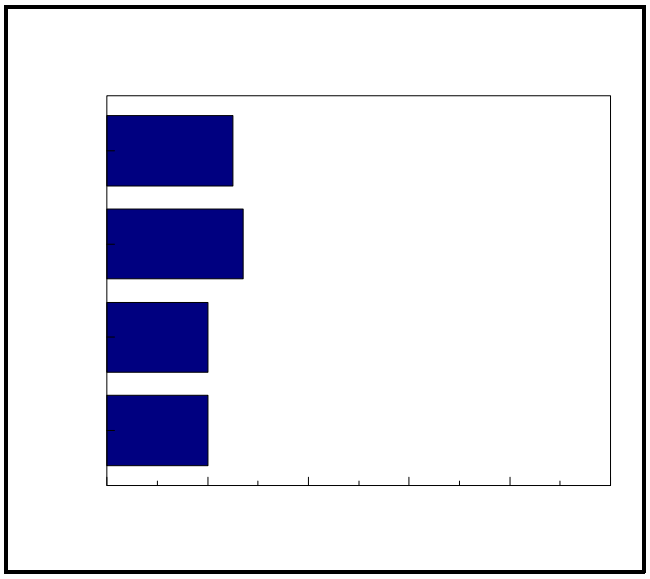
Algebra is the "gateway" to rigorous mathematics courses. Rigorous mathematics courses build upon the skills and concepts that students learn in earlier mathematics courses. Traditionally, students cannot take a rigorous mathematics course in high school until they have successfully completed one or more prerequisite courses. Algebra I, or another course that covers basic algebraic concepts, is the prerequisite for more rigorous mathematics 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 spans several years. The traditional sequence of 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, and then calculus or an Advanced Placement course. Increasingly, schools are covering these rigorous content areas in courses that integrate algebra, geometry and other areas of mathematics such as statistics and probability, rather than teaching each separately. According to NELS, approximately 60 percent of the students who took calculus in high school had taken algebra in the 8th grade. The typical high school sequence of rigorous science courses (biology, chemistry, and physics) also necessitates an early background in algebra and geometry.

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 years, students who have not planned ahead 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 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 including algebraic topics in the middle school curriculum.



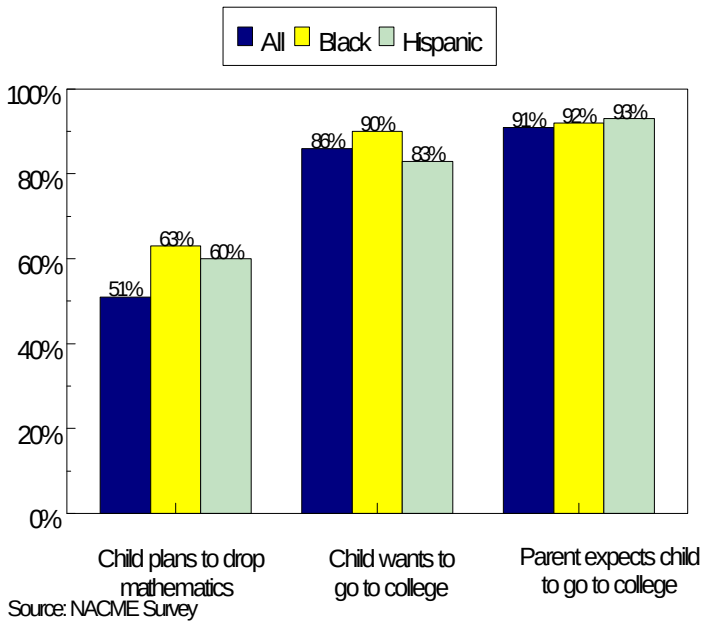
Minority and low-income students continue to be less likely to take challenging mathematics courses in middle school than other students . The 1996 NAEP data reveal that minority students are less likely to report being enrolled in algebra in the 8th-grade (Figure 4). The data also indicate that students 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 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.[3] found that large proportions of students would like to **stop** taking mathematics and science courses as soon as they can. Fifty-one 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 graders 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 say that they would like to stop taking mathematics and science as soon as they could (Figure 5).

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



Source: NACME Survey

However, the same 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

[3]For further information, contact Ronni Denes at NACME Headquarters.

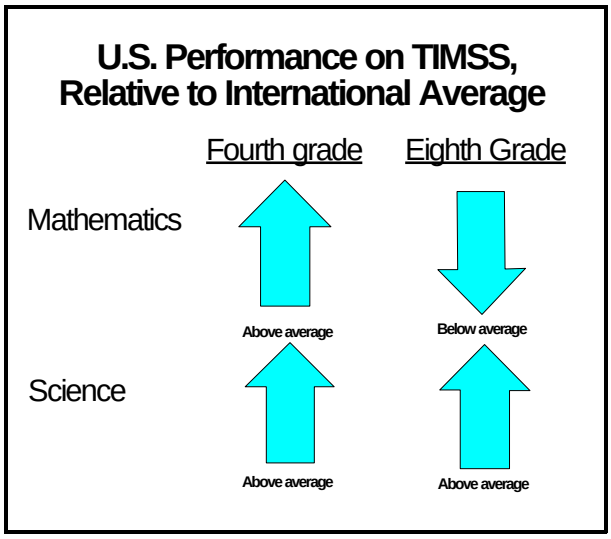
classes in the future.

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 parents' or guardians' 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, 79 percent indicated 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 whose parents or teachers indicated greater levels of parental involvement were also more likely to take advanced courses. Thirty-seven percent of 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 scored 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 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 curricula 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.

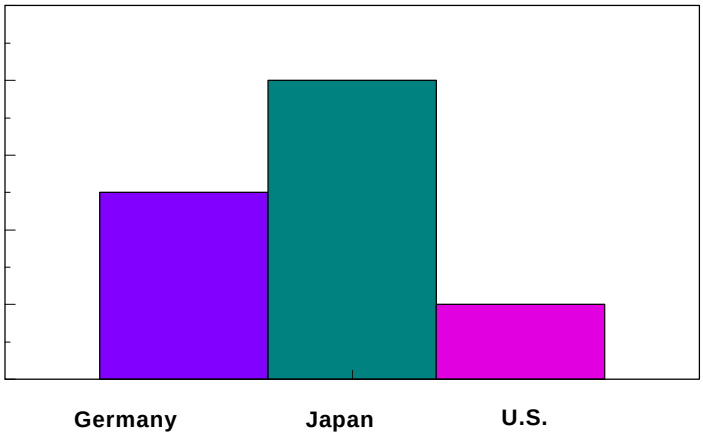
How Does Our Curriculum Compare Internationally?

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

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

- Analyses of curriculum implementation make clear that in the middle school years, the U.S. still focuses on arithmetic. For example, 40 percent of U.S. 8th grade mathematics lessons included arithmetic topics, whereas only 13 percent of Germany's and none 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



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, and 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

Across the country, there are many promising mathematics and science practices underway. Many of these are responsible for increases in the numbers of students taking rigorous courses in mathematics and science. Just as important, many students are finding that they do quite well in these more advanced courses. There is, of course, no one formula to success. Highlighted here are a number of places that demonstrate effective strategies.

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 in favor of all students taking college preparatory curriculum--beginning with algebra and geometry. EQUITY 2000 influences policies, curricula and student academic development at all grade levels, but particularly grades six through nine. These are critical years for mathematics education. During this period, parents, students, and educators make key decisions about which courses students should take and how they should begin planning for education and careers after high school. Equity 2000 provides on-going professional development to help teachers work with mixed-ability classes. It also trains administrators and teachers to use student enrollment and achievement data to drive school-based decision-making, helps schools establish support services for students who need extra time and effort to learn challenging content, and encourages and supports parents to become advocates on behalf of their children.

Increased parental involvement is a priority in Equity 2000. It recognizes the important role that parents play in nurturing and reinforcing their children's desire to attend college. Equity 2000 has sponsored Saturday and summer academies on college campuses for entire families. It also sponsors Family Math nights in which parents and students learn mathematics concepts together.

Results at the six pilot sites indicate 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.

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Advanced Placement Participation and Scores on the Rise. 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. AP courses are widely recognized as setting the standard for high levels of academic achievement in high school. Today more than 500,000 students in about half of the nation's high schools take at least one AP course. Dramatically increased participation in AP courses in Texas and South Carolina illustrate the success of AP-based reform initiatives in two states.

Texas: The Advanced Placement Incentives program was developed in the Dallas, Texas area by O'Donnell Foundation in reaction to low rates of college attendance and poor college preparation. The Advanced Placement Incentives program reward results in AP courses in mathematics, science, English, 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 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). Those who score a three or better (on a five point scale) are given 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:

- The year before the program began in nine typical public high schools, 48 students took AP exams in mathematics, science, and English, and 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.

- In nine high schools in the Dallas Independent School District, the eighth largest inner-city school district in the country, with 85 percent minority enrollment, growth in AP participation has been outstanding. Students took 312 AP in mathematics, science, and English in May 1995, the year before the program started in the Dallas schools. In May 1997, the second year of the Dallas program, this number has grown to 1,750. The number of students scoring three or higher during that time period grew from 139 to 559.

- The Dallas school program has experienced proportional growth among female and minority students. The year before the program started, 94 females took exams in mathematics, computer science, and the sciences. In the program's second year, 452

female students took these exams.

- Minority participation has also grown in Dallas, from 64 7 African-American and Hispanic students taking AP mathematics, science, and English exams the year before the program began, to 734 in the program's second year.

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 student participation in AP classes. The state appropriated funds to train AP teachers and to help pay for AP exams, as well as required 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	430 percent
National	223,888	843,399	380 percent

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

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Strengthening Curriculum and Instruction. Sponsored by the University of Pittsburgh's Learning Research and Development Center, the Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) Project aims to raise low levels of student participation and performance in mathematics. QUASAR is an urban middle school demonstration project that fosters the development and implementation of improved mathematics instructional programs in economically disadvantaged communities. The program revolves around three key principles: (1) all students are able to learn a broad range of mathematical content; (2) all students can acquire a deeper and more meaningful understanding of mathematical ideas; and (3) all students can 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 instruction. All project schools have eliminated most forms of academic tracking, replacing it with the development of deeper student understanding and high-level thinking and reasoning for all students. While curricula, teaching strategies, and approaches to professional development vary, all QUASAR sites include extensive attention to professional development and teacher support. Additionally, the University of Pittsburgh's Learning Research and Development Center provides schools with ongoing support and updated information on their progress.

Data indicate that QUASAR schools build teachers' capacity to improve the quality of their mathematics instruction. Students increase their capacity to think, reason, solve complex problems, and communicate mathematically and they do so while continuing to learn basic skills. QUASAR school students, particularly those who are from minority groups and whose English proficiency is limited, have increased their understandings across a range of important mathematical ideas. Additionally, QUASAR students in grade 8 performed as well as other students on basic and traditional items of the 1992 NAEP Mathematics Assessment. They performed better than their peers on less traditional middle school mathematics content.

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Raising the Standard. 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 over the previous year. The state is now requiring all students take and pass Regents Exams. In addition, Commissioner of Education Richard Mills 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.

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Living Up to Potential. Twenty school districts from Chicago's North Shore joined forces in 1995 to provide their students with a world class education in mathematics and science. Calling themselves the First in the World Consortium, their first challenge was to determine what a "world class" education looked like. They then measured their current performance against that benchmark and developed an improvement strategy.

The Consortium's directed its efforts toward three objectives: (1) benchmarking performance against international standards in mathematics and science, using the Third International Mathematics and Science Study as a guide; (2) creating a forum to clarify world-class education standards for business leaders, policy makers, educators, and community members; and (3) establishing a network of learning communities for educators, parents, and community leaders within the Consortium school districts and beyond.

Students in grades 4, 8, and 12 in First in the World Consortium districts took the TIMSS assessment in Spring 1996. Fourth and eighth graders' results placed them among the top performers in the world, well exceeding U.S. performance generally.

The Consortium attributes its success to the fact that:

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

The First in the World Consortium is not resting on its success. Its "community of learners" approach continues to promote teacher participation and provide a context for long-term commitment to the consortium's goals and to growth in student learning. To this end, it has created teacher learning networks to strengthen curriculum standards, models of instruction, assessment, and use of technology.

The resources of the First in the World Consortium place it at an advantage. Yet, what truly distinguishes it is its willingness to identify its weaknesses and address them. The consortium credits both state and federal support for helping it focus on its goals. Its experiences demonstrate that, when given the opportunity, U.S. students can perform as well as, or better than, students anywhere.

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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.

4. Provide teacher preparation and professional development to teachers of mathematics to increase their knowledge and skills in mathematics and the teaching of mathematics.

5. Support mathematics achievement outside the classroom through math clubs, tutoring, and job shadowing for students who may need extra help.

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 enroll 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 for 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 under the traditional course names (i.e. "geometry," "algebra II") reflective of their content.