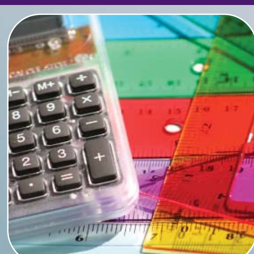
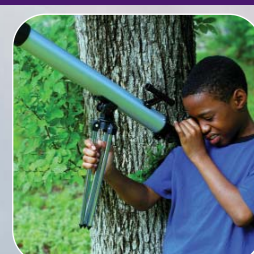
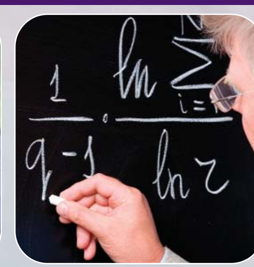
# The Gateway to Student Success in Mathematics and Science

**A call for middle school reform—the research and its implications**





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# A Message from the Microsoft Corporation and the American Institutes for Research

The Microsoft Corporation and the American Institutes for Research (AIR) are pleased to have partnered in the development of this document. Our two organizations are deeply committed to assisting schools and school districts in transforming themselves to better prepare students to meet the great challenges and the great opportunities of the 21st century. We share a common concern regarding the critical need for dramatic improvement in our K–12 school systems, particularly in the area of mathematics and science education.

Microsoft, as a major player in the global software industry, is acutely aware of the increasingly important role that advanced mathematics and science skills play in today's global, digital economy. Our company has a long history of supporting educational initiatives in Washington State, throughout America and around the world. Microsoft's support for this report reflects its deep concern for the growing gap between the demands of the increasingly sophisticated workplace and the performance of the American K–12 school system in producing students with high levels of mathematics and science skills.

AIR, as one of America's leading educational research, evaluation, and consulting organizations, has been a long-time advocate for increasing academic rigor in America's K–12 school systems. AIR sees the significant improvement in student literacy achievement over the last decade as a direct outgrowth of a concerted nationwide strategy for educational reform. Our organization hopes that this report will encourage educators, both in Washington State and across the country, to place a similar focus on reforming their mathematics and science practices to improve student achievement.

The original purpose of this report was to assist Microsoft in developing a strategy for focusing its philanthropic efforts in its home state of Washington. As this report has developed, however, we now realize that its contents can have significant value and applicability in the larger educational community throughout the country.

Microsoft and AIR hope this report brings some clarity to the complex issues of mathematics and science education. Our intent is that it serve as a platform and catalyst for a public discussion about educational reform in mathematics and science as well as the development of strategies for improving mathematics and science outcomes for <u>all</u> students.

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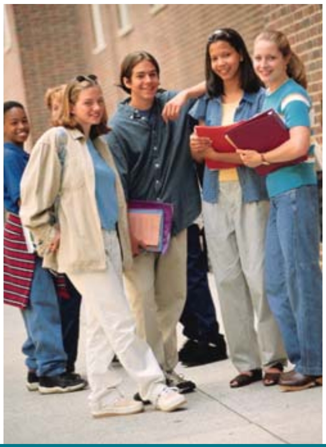

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# Overview

The No Child Left Behind Act and state standards-based educational reform efforts have placed enormous pressure on schools and school districts to dramatically increase the academic performance of all of their students. Throughout the United States, educators have responded to this challenge by setting high standards, increasing the rigor of their curriculum, and improving the quality of instruction. Over the last several years, these efforts have begun to generate genuine gains in student achievement, particularly in our elementary schools and with student literacy skills. However, student achievement in middle and high schools continues to lag, particularly in the areas of mathematics and science.

The weakness in student performance in mathematics and science is evident in the low performance of U.S. students on nationally benchmarked assessments. For example, the National Assessment of Educational Progress (NAEP) reports that in 2005 only one in three 8th-grade students had the mathematics and science knowledge and skills expected by 8th grade. In 2000, fewer than 20% of 12th-grade students could perform at a 12th-grade level of proficiency on NAEP in mathematics and science.[1]

Backed by these dire statistics regarding U.S. students' performance in mathematics and science, the National Commission on Mathematics and Science (NCMS) mirrored the urgency begun in *A Nation at Risk*[2] by imploring policymakers, educators, and superintendents to up the ante for students on mathematics and science requirements. Increasing the percentage of students who are academically proficient in mathematics, science, and technology, NCMS argued, has become a critical imperative of our nation's K–12 school system:[3]

> *"Globalization has occurred . . . goods, services, ideas, communication, businesses, industries, finance, investment and jobs*—the good jobs—*are increasingly the competitive currency of the international marketplace."*[4]

Without the skills that a rigorous education provides, our young people will not be able to compete in the global market. Our highly technological society has called for academic preparation for college and the workforce to be one and the same. The need for a "college track" and a "vocational track" are now obsolete.[5]

The American Institutes for Research, with the support of the Microsoft Corporation, has reviewed the research that has been completed over the last few decades regarding the growing need for increased rigor in mathematics and science education as well as strategies for raising student achievement in mathematics and science. The purpose of this review was to identify key findings from research regarding mathematics and science educational reform that could inform Microsoft's philanthropic investments in the

Washington State/Puget Sound K–12 educational arena as well as the reform agendas of school districts interested in increasing student performance in mathematics and science.

Several key themes emerged from this research review that should inform school district reform strategies in mathematics and science:

- The mathematics and science performance of students in the American K–12 system lags substantially behind their international peers, even though the 21st century economy is increasingly demanding greater skills in mathematics and science. This weakness in American student performance exists across all student groups, even among our highest performing students.
- Algebra is the key "gatekeeper" for student access to the upper-level high school courses in mathematics and science that are drivers of high school graduation, college readiness, and college completion.
- Preparing *all* students for rigorous mathematics and science coursework in middle school and early in high school helps to close the achievement gap among students from differing ethnic and socioeconomic groups.
- Student performance in Washington State in mathematics and science parallels the weak performance seen nationally. While the state is above the national average in student performance, it lags in the quality of its standards, the rigor of its graduation requirements, and the college-readiness of its high school graduates.

A synthesis of these research findings suggests a number of powerful implications for K–12 educators as they consider ways of improving student performance in mathematics and science. However, more than any other, the most compelling implication is this:

> If we want to dramatically increase the proportion of students graduating from high school with high-level, globally-competitive skills, then we must dramatically increase the number of students who achieve proficiency in Algebra in their middle school or early high school years as a gateway to the advanced high school coursework that is the driver of high school graduation, college readiness, and post-secondary completion rates.

Because the trajectory for taking advanced high school coursework is set prior to 9th grade, it is imperative that students begin their academic preparation for advanced mathematics and science coursework in middle school. The middle school years are when students decide which academic path they will take, so that broad-based, rigorous middle school coursework in mathematics and science can be a turning point for future student performance over the long term.

# Review of the Research[6]

## Primary Themes

1. The mathematics and science performance of students in the American K–12 system lags substantially behind their international peers, even though the 21st century economy is increasingly demanding greater skills in mathematics and science. This weakness in American student performance exists across all student groups, even among our highest performing students.
2. Algebra is the key "gatekeeper" for student access to the upper-level high school courses in mathematics and science that are drivers of high school graduation, college readiness, and college completion.
3. Preparing all students for rigorous mathematics and science coursework in middle school and early in high school helps to close the achievement gap among students from differing ethnic and socioeconomic groups.
4. Student performance in Washington State in mathematics and science parallels the weak performance seen nationally. While the state is above the national average in student performance, it lags in the quality of its standards, the rigor of its graduation requirements, and the college-readiness of its high school graduates.

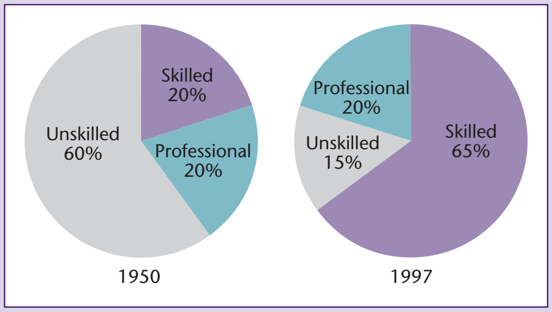
**The mathematics and science performance of students in the American K–12 system lags substantially behind their international peers, even though the 21st century economy is increasingly demanding greater skills in mathematics and science. This weakness in American student performance exists across all student groups, even among our highest performing students.**

## The Demand for 21st Century Skills

The demands of the American workplace have been changing rapidly and dramatically over the last several decades. Not too long ago, young people could enter the workforce with only limited skills and still be assured of having access to a good job and their share of the American Dream. This reality is quickly fading as our technologically driven society increasingly demands much higher levels of skill and competency from our citizens of the 21st century (see Figure 1).

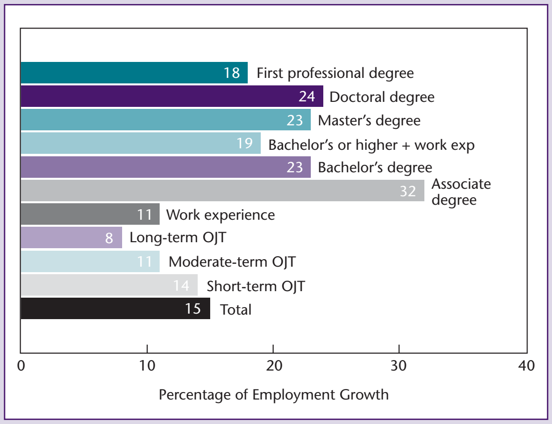
As our society becomes more technological in nature, the skill sets needed for the workforce are becoming more complex and requiring more education. The fastest growing sector of jobs—as indicated in Figure 2 below—require additional schooling after high school. Yet even jobs that do not require a bachelor's degree necessitate higher levels of mathematics and science skills from high school graduates. Over two thirds of new jobs will demand a solid high school education and some postsecondary education (from on-the-job training [OJT] to further degree attainment after high school), while less than 20% of new jobs will be available to workers without a high school diploma.[7]

**Figure 1.** Skill-Level Changes, 1950 and 1997




*Source:* Meeder, H. K., *Preparing America's future: High school initiative.*

**Figure 2.** Fastest Growing Jobs Require Some Education Beyond High School




*Source:* Meeder, H. K., *Preparing America's future: High school initiative.*

It is clear that this trend is continuing and gaining strength. The U.S. Department of Labor (DOL) predicts that between 1998 and 2008, jobs requiring science, engineering, and technical training will have increased by 51%, a rate four times faster than overall job growth. The DOL predicts that by 2008 there will be 6 million job openings for scientists, engineers, and technicians.[8]

## U.S. Students Lagging in 21st Century Skills

***"The ultimate challenge for America—and for Americans—is whether we are prepared for this flat world . . . Are we conducting ourselves in a way that will succeed in this new atmosphere? Or will it turn out that, having globalized the world, the United States had forgotten to globalize itself?"***

*—Fareed Zakaria editor of Newsweek*

At a time when the demand for mathematics and science skills is soaring, American elementary and secondary students are not achieving the level of skills and knowledge required for an internationally competitive scientific and technological workforce. While every student's future depends on high-level competence in mathematics and science, the vast majority of American K–12 students (even our highest performing students) are falling well below expected levels of performance in these subjects.

## U.S. Student Performance Results

The National Assessment of Educational Progress (NAEP)—commonly known as "the nation's report card"—is a test given on a regular basis to K–12 students throughout the country in a number of grade levels and content areas. NAEP data is an excellent source for assessing the student outcomes of our K–12 system on a nationwide and state-by-state basis.

**Table 1:** Percentage of Students At or Above Proficiency on 2005 NAEP in Math and Science

| | Math | Science |
|---|---|---|
| 4th | 36% | 29% |
| 8th | 30% | 29% |
| 12th | 17%* | 18% |

*Represents assessments results for 2000. Mathematics NAEP results for 2005 were not available at time of publication.

*Sources:* National Center for Education Statistics, *The nation's report card: Mathematics 2000*; National Center for Education Statistics, *The nation's report card: Mathematics 2005*, and National Center for Education Statistics, *The nation's report card: Science 2005*.

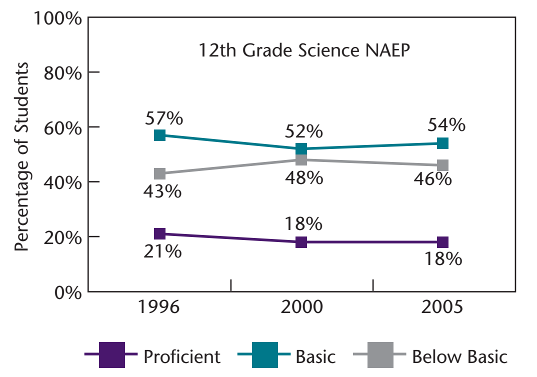
NAEP data paints a sobering picture regarding the abilities of American students to handle the rigors of mathematics and science, as indicated in Table 1. On the 2005 NAEP, only 30% of 8th graders knew the content and had the skills necessary to meet the 8th-grade NAEP mathematics proficiency standards. The science results were equally weak: less than 30% of 8th graders knew the content and had the skills necessary to meet the 8th- grade NAEP science proficiency standards. By 12th grade, a dismal 18% of 12th graders were proficient in science, while even fewer were proficient in mathematics (17%). Close to half of students were performing below the basic benchmark in science, while over one third of 12th-grade students were below the basic benchmark in mathematics.

## International Comparisons

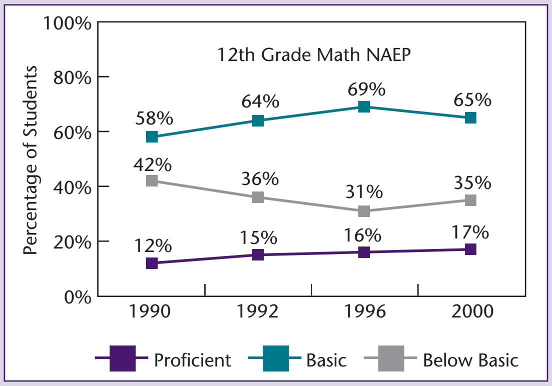
The Trends in International Mathematics and Science Study (TIMSS) exam is administered on a regular basis to students in many countries throughout the world in a number of grade levels and content areas. TIMSS data is an excellent source for assessing the student outcomes of the U.S. K–12 system as compared to the performance of students in a variety of countries throughout the globe.

The National Assessment of Educational Progress (NAEP)—"the nation's report card"—assesses K–12 students throughout the country in a number of grade levels and content areas. It appears that there is not a strong trend for improvement in the NAEP results over the long term. As indicated in Figure 3, there was only a modest increase in proficiency levels of 12th graders in mathematics through the 1990s, while science performance actually declined during the decade.

**Figure 3.** Percentage of 12th-Grade Students at Each NAEP Achievement Level in Science (1996–2005) and Mathematics (1990–2000)



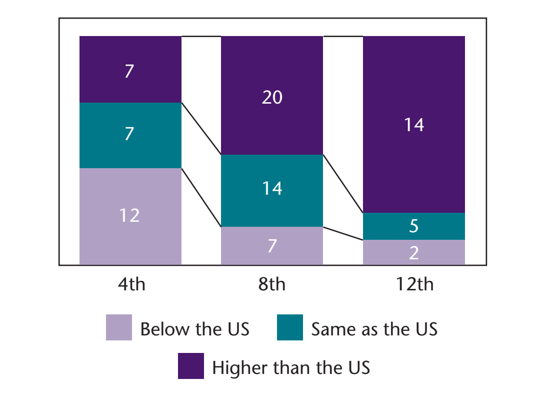

*Source:* National Center for Education Statistics, *The nation's report card: Science 2005*.




*Source:* National Center for Education Statistics, *The nation's report card: Mathematics 2000*.

On the TIMSS, U.S. student performance substantially lags behind many of our international peers (see Figure 4). In a troubling trend, U.S. performance declines the longer our students stay in our K–12 system: for example, U.S. students are above the international average in mathematics in elementary school, they slip to near the middle by 8th grade, and then plunge to near the bottom by 12th grade.

**Figure 4.** TIMSS Nations' Average Mathematics Performance Compared With the United States (1999)




*Source:* U.S. Department of Education, *Highlights from TIMSS: Overview and key findings across grade levels*.

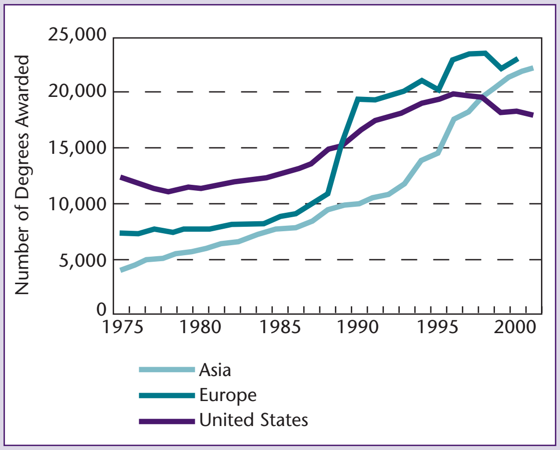
Even America's best and brightest are not near the top. U.S. students with Advanced Placement Calculus were only average in the international arena. Those with Advanced Placement Physics finished below the international average when compared to all advanced science students in the other nations tested.[9]

## The Achievement Gap

The poor performance of American students in mathematics and science is even more pronounced when the student results are disaggregated by race, ethnicity and income level. The achievement gap for African American, Hispanic, and low-income students is particularly broad in the areas of mathematics and science. For example, on NAEP, a 20–25 point difference in NAEP mathematics scores is already evident by 4th grade between students at low and high income levels as well as White and African American and White and Hispanic students. By 8th grade, the gap in scores increases to 27 and 34 points. By 12th grade, the scores of African American and/or Hispanic students are at about the same level as a typical 8th-grade White student.

Closing the achievement gap is more than just a moral responsibility. The Census Bureau offers a critical forecast to America's changing population and the consequences these achievement discrepancies have on our future. The non-Hispanic White percentage of the American population will fall from 74% in 1995 to 64% in 2020 and to 53% in 2050.[10] As a result, for America continue to be a major player in the global economy, it will need to eliminate these achievement gaps and have more students from African American and Hispanic populations reach high levels of performance in mathematics and science.

**Figure 5.** Natural Science and Engineering Doctoral Degrees in United States, Europe, and Asia: 1975–2001




*Source:* National Science Foundation, *Science and Engineering Indicators—2002*.

## Post-Secondary Student Performance

Once students graduate from the K–12 system and continue onto post-secondary education, their skill deficiencies in mathematics and science become a significant barrier to their achievement in a college setting. Nationally, 22% of all college freshmen fail to meet the performance levels required for entry-level mathematics courses and must begin their college experience in remedial courses. The problem of remediation is a widespread and costly phenomenon: in the fall of 2000, 71% of America's higher education institutions were required to offer remedial courses in mathematics in order to adequately prepare students for college level coursework.[11] Students taking remedial coursework in college are much less likely to finish their studies by earning an associate or bachelor's degree and almost two-thirds of students taking post-secondary remedial mathematics classes do not finish college.[12]

From an international standpoint, U.S. student deficiencies in mathematics and science have a dramatic impact on their ability to seek advanced technical degrees. Once the leader in science and engineering degree attainees, in 1999 the United States earned less than 10% of the bachelor-level engineering degrees granted worldwide.[13] In China, three-quarters of all Chinese students earn bachelor's degrees in mathematics, science, and engineering fields, compared to only about one third of American students. The attainment of doctoral degrees in these subject areas mirrors the bachelor's degree attainment as noted in Figure 5.

Even when U.S. students aspire to a degree in a technical field, their mathematics and science skill deficiencies limit their success in achieving their goal. Slightly more than one third of the students who begin college majoring in science or engineering actually obtain a degree in that field.[14] Minority populations fare worse yet. Less than 25% of African Americans, Hispanics, and Native Americans majoring in these areas graduate with a degree in science or engineering.[15] Overall minorities received less than 20% of the undergraduate degrees in engineering, mathematics, and computer science.[16]

**Algebra is the key "gatekeeper" for student access to the upper-level high school courses in mathematics and science that are drivers of high school graduation, college readiness, and college completion.**

Research conducted over the last three decades and replicated recently concludes one critical observation regarding student readiness to pursue upper-level mathematics and science coursework in high school: successfully passing Algebra early in a student's academic career—no later than 9th grade—greatly improves the chances of the student graduating from high school, going to college, and graduating from college.[17]

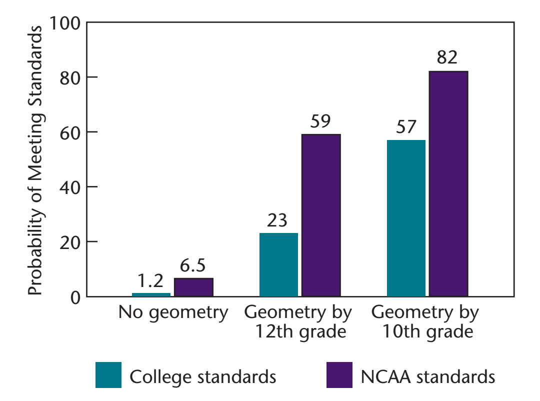
However, Algebra is not simply a means to an end; it is a "gatekeeper," serving as a foundation and language system on which higher-order mathematics, science, technology, and engineering courses are built. For this reason, Algebra has traditionally served as a gatekeeper course in the pipeline to higher-level courses, college enrollment, and better career options.[18] While Algebra should be considered a gateway to the college-going pipeline, continuing through this pipeline is key to later student achievement in upper-level coursework, high school graduation, and college enrollment.

In most high schools, Algebra is a prerequisite for a student to have access to the higher-level courses required for college, so that early proficiency in Algebra is a necessary condition for students to be in the college-ready pipeline.[19] Students are encouraged to take Algebra no later than 9th grade so that they can continue through the pipeline of higher-order coursework and be prepared for college-going.

A U.S. Department of Education report found that students who successfully completed Algebra by 9th grade received substantially

A study of student course taking records conducted as part of the American Institutes for Research's evaluation of the well-known district-wide reform initiative, Equity 2000, found that students taking Algebra by 9th grade and continuing on with Geometry in 10th grade had the highest chance of meeting the college and National Collegiate Athletic Association (NCAA) curricular requirements for entrance. Students who did not continue through the pipeline—did not take at least one upper-level mathematics class (in this case Geometry), or stalled along the pipeline and took Geometry by the 12th grade (as opposed to by 10th grade)—were, on average, half as likely to meet the requirements for entrance into a postsecondary institution, as shown in Figure 6 below.

**Figure 6:** Probability of Meeting In-State College and NCAA Standards by Time Component of Taking Upper-Level Mathematics (Geometry) in High School (2002)



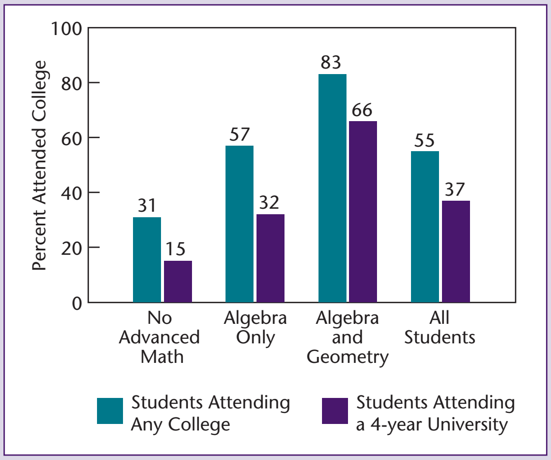

*Source:* Rodriguez, C., Borhnstedt, G., Miller, B., & Stapleton, J., *Closing the gap report: Equity 2000.*

higher mathematics grades in their first years of high school than those who did not take Algebra. This early success translated into substantially higher mathematics achievement—and the taking of many more upper-level mathematics classes—in their final years of high school. Students who started 9th grade by passing Algebra were more likely to take and pass more mathematics classes.[20]

Passing more than one upper-level mathematics class is also a powerful motivator for getting students to actually enroll in post-secondary education, as noted in Figure 7. Researchers from the National Educational Longitudinal Study (NELS), using a nationally representative dataset, found that students who passed only Algebra in 9th grade attended college at almost double the rate of students not taking or not passing Algebra, and more than 80% of students who passed both Algebra in 9th grade and Geometry in 10th grade went on to attend college. Passing Algebra in 9th grade and Geometry in 10th more than tripled the odds of a student's college attendance.[21]

Building on these findings, Adelman (1999; 2006) analyzed how academic preparation in high school influenced the odds of bachelor's degree completion. Adelman observed the range of courses taken by high school students in relation to college completion (see Figure 7). He found that taking a full slate of academically intense courses in high school—including mathematics beyond Algebra 2 and at least 3 years of laboratory science—had the strongest effect on college completion. However, for a student to have access to any of these higher-order classes, one must master Algebra by 9th grade, if not earlier. Taken together, these results indicate that solid training, starting with Algebra by the 9th grade, is critical for success in life after donning the robe and walking across the stage to obtain a high school diploma.

**Figure 7.** Percentage of High School Graduates Attending College—By Algebra and Geometry Courses versus Only Algebra Courses (1999)




Source: Adelman, C., *Answers in the toolbox: Academic intensity, attendance patterns, and bachelor's degree attainment.*

## Preparing all students for rigorous mathematics and science coursework in middle school and high school helps to close the achievement gap among students from differing ethnic and socioeconomic groups.

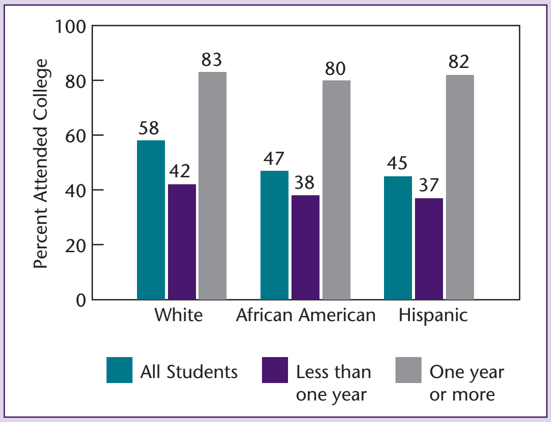
Several important studies completed over the last 20 years point to the observation that the achievement gap between students of differing ethnic and socioeconomic groups can be significantly reduced or even eliminated if low-income and minority students increase their success in high school mathematics and science courses. In 1990, Pelavin and Kane found that college enrollment rates were equal across race and socioeconomic status when students successfully passed upper-level mathematics coursework (see sidebar below). A more recent study (2006) confirmed such results and also found that students taking mathematics beyond Algebra 2 and 3 years of laboratory science were going to college and earning a degree at the same rate regardless of race or socioeconomic status.

Unfortunately, researchers in 1990 and 2006 also found that minority and poor students were taking these upper-level classes at a rate less than half that of White and upper-income students. In fact, minority students reported that many upper-level classes were not even offered at their high schools, as shown in Figure 9.[22]

Several important studies have observed that all students are likely to perform better in high-level courses than in low-level courses,

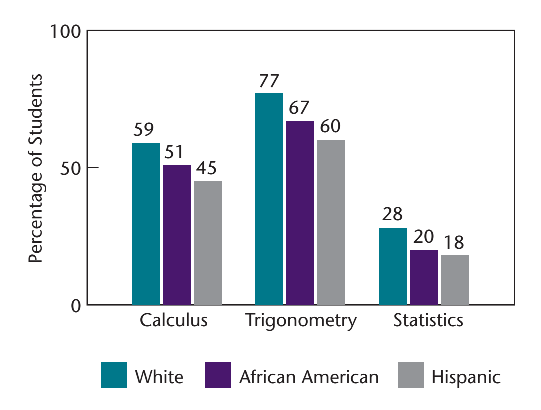
In a landmark study in 1990 regarding the characteristics of college-going students, researchers found that for high school graduates, taking upper-level coursework in mathematics and science greatly increased the likelihood of going to college. Approximately 58% of the graduating White students in the class of 1982 went to college. White students taking one year or more of upper-level mathematics coursework (Geometry) attended college 83% of the time. In this study, about 47% of African American students in general attended college within 4 years of graduating high school. African American students who took 1 year or more of upper-level mathematics course (Geometry) attended college at a rate of 80%. Roughly 45% of Hispanic students attended college. However, Hispanic students who took 1 year or more of upper-level coursework in high school nearly doubled their college attendance rate. College attendance rates of all students taking less than 1 year of upper-level coursework are drastically lower.

**Figure 8.** Percentage of Students from Graduating Class of 1982 Attending College Within Four Years of High School—By Race/Ethnicity and Duration of Upper-Level Coursework (1990)




*Source:* Pelavin, S., & Kane, M., *Changing the odds Factors increasing access to college.*

**Figure 9.** Percentage of 1992 12th Graders Who Attended High Schools that Offered Courses in Calculus, Trigonometry, and Statistics, by Race/Ethnicity (2006)



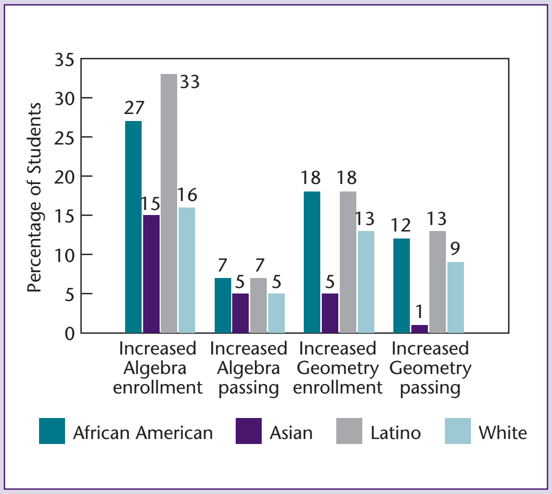

*Source:* Adelman, C. *The toolbox revisited: Paths to degree completion from high school through college.*

and that students who are the farthest behind at the outset will make the greatest gains.[23] For example, Education Trust recently studied the characteristics and practices of a group of "high-impact" schools—i.e. schools that are especially effective at improving the academic achievement of previously low-performing students. The researchers found that these schools opened rigorous courses to all students, regardless of prior achievement. Struggling students in these high impact schools spent more time in academic, rather than "support," courses compared to their peers in high schools that did not demonstrate the same academic gains.[24]

Given these research observations, the role of Algebra as a gatekeeper for student access to upper-level mathematics and science coursework becomes all the more compelling. That

Equity 2000 found that by requiring that all students take Algebra and Geometry, and instituting several programmatic supports to make this happen, a higher percentage of students—especially students of color and low socioeconomic status—were in fact taking Algebra and Geometry. However, with more students taking these classes, many more students were also *failing* them, as shown in Figure 10, below. While Equity 2000 increased the percentage of all ethnic groups taking Algebra and Geometry from 1991 to 1996, the program was not as successful in getting all students to pass these classes. Many students simply were not prepared academically to take Algebra in the 9th grade.[25]

**Figure 10.** Equity 2000: Increase in Enrollment and Passing Rates in Algebra and Geometry, 1991–1996, by Race/Ethnicity (2002)




*Source: Rodriguez, C., Borhnstedt, G., Miller, B., & Stapleton, J., Closing the gap report: Equity 2000.*

is, by not successfully preparing minority and low-income students for the rigors of Algebra early in their high school years, school districts have foreclosed these students' access to upper-level mathematics and science courses, thereby dramatically reducing their prospects for future college success.

Or, to say this same observation in another way, Algebra's traditional gateway function has played a central role in maintaining and institutionalizing the achievement gap by systematically reducing the access of minority and low-income students to the upper-level mathematics and science coursework that is a pre-condition for college success. So, by dramatically increasing the number of minority and low-income students who achieve Algebra proficiency early in their high school careers, a school district can increase these students' participation in upper-level mathematics and science coursework, thereby increasing their college readiness and dramatically reducing the achievement gap.

**Student performance in Washington State in mathematics and science parallels the weak performance seen nationally. While the state is above the national average in student performance, it lags in the quality of its standards, the rigor of its graduation requirements, and the college readiness of its high school graduates.**

Despite the efforts of many dedicated educators throughout the state, the mathematics and science performance of Washington State students in many ways parallels the weak mathematics and science performance of students nationwide. This performance weakness can be measured across a number of important metrics, including the WASL, NAEP, and other post-secondary performance measures.

## Student Performance on the WASL

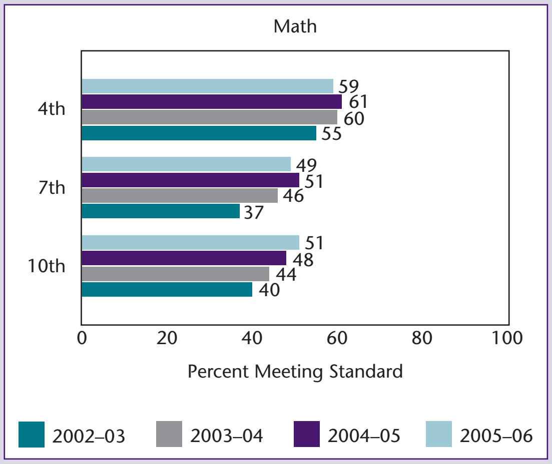
Since the outset of the WASL, mathematics and science performance have been the weakest areas of student performance across all grade levels. As you can see in Table 2, the percentage of students at or above standard on the 2006 WASL in mathematics and science is significantly below the percentage of students at or above standard in reading and writing (with the partial exception of 4th-grade mathematics).

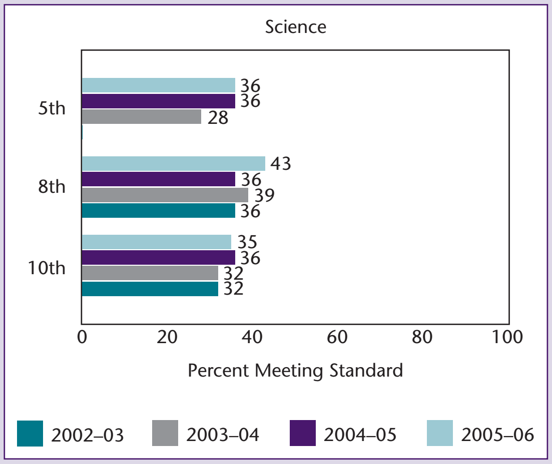
**Table 2:** Percentage of Students At or Above Standard on the 2006 WASL

| Grade Level | Math | Science | Reading | Writing |
|---|---|---|---|---|
| 4th/5th | 58.9% | 35.7% | 81.1% | 60.3% |
| 7th/8th | 48.5% | 42.9% | 61.5% | 64.5% |
| 10th | 51.0% | 34.9% | 81.9% | 79.7% |

*Source:* Office of Superintendent for Public Instruction, *Office of Superintendent of Public Instruction Washington state report card: 2005–06.*

**Figure 11.** Percentage of Students Meeting Mathematics and Science WASL Standards in Elementary, Middle, and High School for School Years 2002–03, 2003–04, 2004–05, and 2005–06




*Source:* Office of Superintendent for Public Instruction, *Office of Superintendent of Public Instruction Washington state report card: 2005–06.*

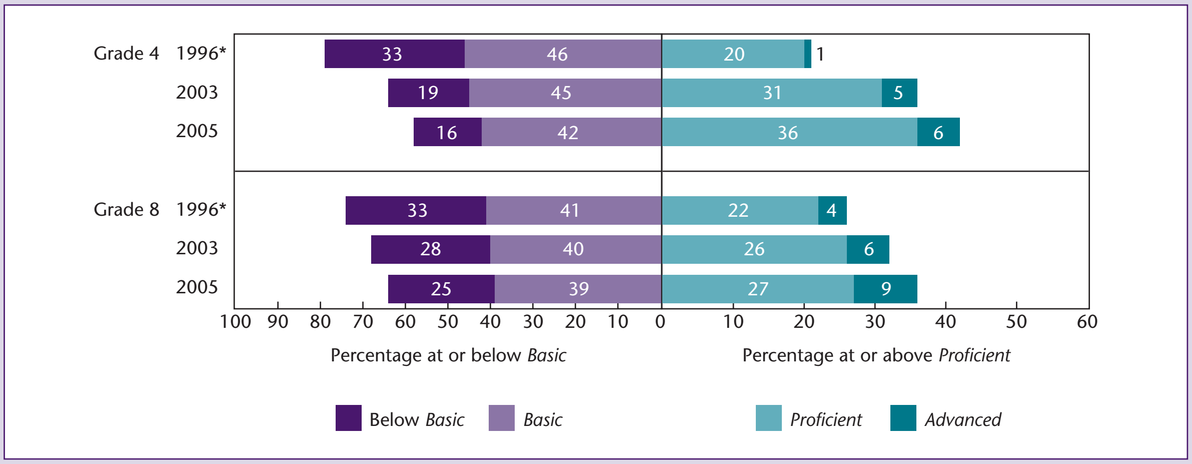
In addition, the rate of improvement in mathematics and science scores over the last few years has been fairly modest. As shown in Figure 11, with the exception of 7th-grade mathematics, the upward trends in student mathematics and science achievement have not been steep. The recently announced 2006 WASL results, continued such trends of low performance in math and science.

This WASL performance is even more troubling in light of the observation that the standards against which student performance is measured on the WASL are considered significantly less rigorous than the standards applied to students in other states. Recent analyses by national organizations, such as the Fordham Foundation and Achieve, Inc. have called into question the quality and rigor of Washington State's standards. In particular, Achieve, Inc. found the mathematics WASL at 10th grade was not overly demanding and noted that it was reasonable to expect high school graduates to pass the test. In particular, Achieve noted that the 10th-grade mathematics WASL assessed students on concepts typically taught between 7th and the latter portion of 8th grade.[27]

## National Comparisons

When compared to other states on NAEP, Washington State students' performance in mathematics is somewhat stronger than the national average. Mirroring the WASL gains, as shown in Figure 12, the percentage of 4th-grade students proficient on NAEP's mathematics test has shown strong improvement since 1996 (21% at or above proficient in 1996 compared to 42% at or above proficient in 2005). While improvement in 4th grade has been strong, 8th grade proficiency scores have realized more modest gains (26% at or above proficient in 1996 compared to 36% proficient in 2005).

**Figure 12.** NAEP Achievement Levels for Grades 4 and 8 in Mathematics, State of Washington (1996–2005)




*Accommodations were not permitted for this assessment.
NOTE: Percentages may not add to 100 due to rounding.
*Source:* Institute of Education Sciences. *State profiles: Washington*.

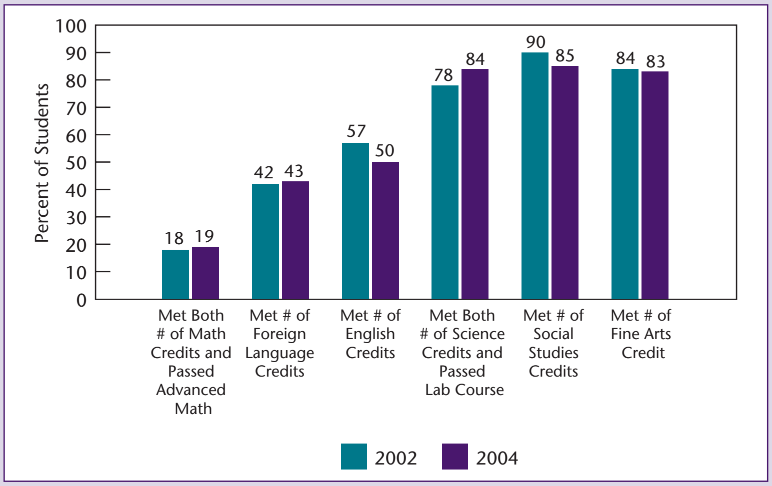
Washington's mathematics performance places it in the upper half (but not near the top) of all the states and territories measured by NAEP.

**Table 3:** Graduation Course Requirements in Washington State versus an Average of Requirements from Other States

| | Course Credits Required to Earn a Standard Diploma | Number of Credits Required by Average State |
|---|---|---|
| Mathematics | 2 | 2.7 |
| English/ Language Arts | 3 | 3.9 |
| Science | 2 | 2.5 |
| History/Social Studies | 2.5 | 2.8 |
| Other Credits | 9.5 | 8.6 |
| Total Credits Required: | 19 | 20.5 |

*Source:* Education Commission of the States, *Standard high school graduation requirements (50-state reports).*

**Figure 13.** Course-Taking Patterns of Students *not* Meeting High School Course Requirements (2005)




*Source:* Baker, D. B., Gratama, C. A., Stroh, H. R., Fouts, J. T., & Bachtler, S. D., *The Bill and Melinda Gates Foundation's Washington state achievers high schools: Year 3 evaluation summary*.

## College Readiness

Many students in Washington State are not graduating from high school ready to be productive citizens. Many Washington students who complete all of the requirements of graduation are leaving high school without the necessary content skills in mathematics, science, and other rigorous coursework. When compared to other states, Washington State graduation requirements are far less rigorous and more "elective-heavy" than other states, as noted in Table 3.

Even with these light graduation requirements, Washington State's graduation rate is well below the national average (65.8% vs. 69.4%).[28] Only 24% of Washington State students graduate with the coursework requisite for college admission or work-force readiness and (according to the 2006 Quality Counts Report conducted for Washington State) there has been a downward trend in the percentage of students graduating Washington high schools academically ready for post-secondary education.[29]

Among those students who are not graduating, the primary gap in their coursework—by a large margin—is their lack of credits in mathematics. Figure 13 indicates that more than 4 out of 5 students who did not meet graduation requirements did not take the requisite years of mathematics coursework in order to qualify for a diploma.

# A Call for Middle School Reform in Mathematics and Science

A synthesis of all of these research findings suggests a number of powerful implications for K–12 educators as they consider ways of improving student performance in mathematics and science. However, more than any other, the most compelling implication is this:

> If we want to dramatically increase the proportion of students graduating from high school with high-level, globally-competitive skills, then we must dramatically increase the number of students who achieve proficiency in Algebra in their middle school or early high school years as a gateway to the advanced high school coursework that is the driver of high school graduation, college readiness and post-secondary completion rates.

Because the trajectory for taking advanced high school coursework is set prior to 9th grade, it is imperative that students begin their academic preparation for advanced mathematics and science coursework in middle school. The middle school years are when students decide which academic path they will take, so that broad-based, rigorous middle school coursework in mathematics and science can be a turning point for future student performance over the long term.

The National Science Board (NSB) came to the following conclusion in its 2004 Science & Engineering Indicators report regarding "an emerging and critical problem of the science and engineering labor force":

***"We have observed a troubling decline in the number of U.S. citizens who are training to become scientists and engineers, whereas the number of jobs requiring science and engineering (S&E) training continues to grow . . . These trends threaten the economic welfare and security of our country . . .***

***The United States has always depended on the inventiveness of its people in order to compete in the world marketplace. Now, preparation of the S&E workforce is a vital arena for national competitiveness. Even if action is taken today to change these trends, the reversal is 10 to 20 years away. The students entering the science and engineering workforce in 2004 with advanced degrees decided to take the necessary mathematic courses to enable this career path when they were in middle school, up to 14 years ago. The students making that same decision in middle school today won't complete advanced training for science and engineering occupations until 2018 or 2020. If action is not taken now to change these trends, we could reach 2020 and find that the ability of U.S. research and education institutions to regenerate has been damaged and that their preeminence has been lost to other areas of the world."***[30]

## A Policy Framework for a Middle School Reform Agenda Focused on Mathematics and Science

Educators in Washington State and around the country need to develop a reform agenda that will significantly increase the rigor of the middle school experience for all of our students. A policy framework for this reform agenda should be based on the following key elements:

- **Establish a fundamental goal that all students pass Algebra 1 by 9th grade—**Preparing all students to pass the critical gateway course of Algebra 1 by the 9th grade is a pivotal step in preparing students for continued success through the advanced high school coursework pipeline. In addition, because more advanced-level coursework is highly correlated with college-going, getting through the Algebra gateway is a powerful driver of student access to post-secondary education. The research clearly shows that waiting until later in high school to prepare students for advanced coursework will not result in the magnitude of student performance gains that are driven by success through the Algebra gateway.

- **Require that all students take rigorous "college prep" mathematics and science courses in middle school—**It is critical for middle school coursework to be structured so that all students are prepared for the rigors of advanced high school coursework in mathematics and science. Beginning rigorous mathematics and science coursework for all students in middle school will help ensure that more students will be proficient in Algebra and prepared for advanced mathematics and science pipeline classes as they enter high school. Encouraging and requiring rigorous mathematics and science preparation for all students is vital in raising student achievement and eliminating the achievement gap.

- **Reframe the central mission of middle schools around a goal of mathematics and science "numeracy"—**Many educators have observed that middle schools do not have the clear articulation of a central academic mission as do elementary and high schools. Middle schools are seen as being "betwixt and between" the two levels, but without any central organizing idea of their own. A focus on mathematics and science would provide middle schools with a sharp academic mission that is clearly more advanced than the literacy-

**A policy framework for a middle school reform agenda focused on mathematics and science**

- Establish a fundamental goal that all students pass Algebra 1 by 9th grade.
- Require that all students take rigorous "college prep" mathematics and science courses in middle school.
- Reframe the central mission of middle schools around a goal of mathematics and science "numeracy."
- Significantly improve middle school instructional skills in mathematics and science.
- Establish a set of widely reported outcome measures that will track the performance of the K–12 system in improving student performance in mathematics and science.

oriented mission of elementary school, while also being preparatory to the more advanced coursework of high school. By reframing the middle school mission around mathematics and science "numeracy," school districts would provide a focus to their middle school reform efforts that could set a platform for systemwide improvement.

- **Significantly improve middle school instructional skills in mathematics and science—**Many middle school teachers do not have strong academic backgrounds in mathematics or science. Close to one-third of all secondary (7–12) math classes and over half of physical science classes are taught by teachers who neither majored nor minored in the subjects.[31] Like many adults of their generation, these teachers did not receive advanced training in mathematics or science as part of their own schooling, so they have a degree of mathematics and science "phobia" that limits their orientation toward technical fields and dampens their effectiveness in teaching advanced mathematics and science courses.

  As a result, it will be critical to dramatically improve both the confidence and the capabilities of middle school teachers to handle sophisticated mathematics and science content in order for them to raise student achievement significantly for all students. Teachers need a skill set and content knowledge that enables them to be comfortable in challenging all levels of students. This will be particularly true for mathematics and science teachers, but also holds true for all middle school teachers, even those who do not teach mathematics or science.

- **Establish a set of widely reported outcome measures that will track the performance of the K–12 system in improving student performance in mathematics and science—**For each of the elements of this framework, it will be important to define and report a set of clear metrics that will track our collective progress in accomplishing our goals. Many of these metrics are already in existence, although some may need to be developed over time. Measurements of progress could include the percentage of students passing the mathematics and science WASL, the number of mathematics and science teachers graduating from universities and colleges, the number of students taking and passing Advanced Placement classes, and the number of students pursuing technical degrees from Washington State colleges. In addition, some states have developed a common end-of-course exam for Algebra (and other subjects) as a means of monitoring student performance through the critical Algebra gateway.

## Parallels to Other Instructional Reform Efforts

In many ways, this call for dramatic improvement in middle school mathematics and science education can be seen in parallel to other instructional reform efforts in K–12 education over the last decade.

**The elementary literacy movement—**In the mid-1990's a broad coalition of educators and researchers strongly advocated for the central role of literacy in the development of student learning. Their argument, in essence, was that by getting to the key "gateway" of being able to read proficiently in their early grades, students would have access to a far wider array of concepts and content in the other disciplines such as mathematics, science, and social studies. Without reaching this gateway, students were effectively foreclosed from the rigors of these other disciplines in their later academic careers.

Out of this effort, the literacy movement was born and proceeded to generate dramatic changes in schools, school districts and homes throughout the country. There was a widespread expansion of teacher professional development focused on the techniques of teaching reading and writing, particularly in the early grades. All-day kindergarten was dramatically expanded and became the norm in many states and school districts. Colleges of education expanded their offerings and requirements regarding the teaching of literacy skills, both for new and experienced teachers. School districts sought to adopt more sophisticated elementary curriculum that placed literacy at the center of the schools' academic mission. Elementary schools dramatically increased the portion of the school day devoted to reading and writing, particularly for kindergarten to 2nd-grade students. Finally, parents responded to the challenge of reading more to their kids and taking a more active role in continuing literacy education at home.

School districts all across America began promoting the idea of "every child a reader by 3rd grade" as the mantra to crystallize parent and teacher attention on this critical academic goal. Today, one can visit literally thousands of elementary schools in every state in which some variation on this mantra serves as the school's central goal. To a large degree, student literacy has come to be seen as the core mission of elementary schools above all other academic goals.

As a result of all the reform energy generated by this literacy movement, we are now witnessing a sustained and significant increase in student performance in reading and writing at the elementary school level. In state after state, in test after test, elementary school students are becoming proficient at reading and writing at much higher levels than we could have imagined only 5 or 10 years ago.

**The high school reform movement—**In the early 2000's, a set of leading educators and social advocates began calling for the widespread reform of our country's comprehensive high schools. Citing dismal graduation rates and a staggering achievement gap, these advocates declared the obsolescence of the traditional American high school and the urgent need to dramatically increase the percentage of our teenagers being prepared for rigorous post-secondary education. Led by the Bill & Melinda Gates Foundation, these advocates argued that without significant reform of our high schools, U.S. high school students were not being adequately prepared for the challenges of a 21st century, globally competitive society.

Out of this energy came the beginnings of the high school reform movement that we see gaining strength throughout the country. While it has not yet expanded and matured to the level of the elementary literacy movement, evidence of the momentum of the high school reform movement can be seen across a wide swath of schools and school districts across the country. Graduation exams, increasing graduation requirements, Advanced

Placement, small schools, small learning communities, career academies, early college course-taking, and teacher content training, among others, have become elements of the high school reform strategies in many leading school districts.

For many school districts, the slogan (or some variation) of "every student college ready" has become the mantra at the core of their high school reform efforts. Even in highly challenged school districts with very low graduation rates, we are seeing the core mission of the high school being recast as preparing all students for the rigors of post-secondary education.

It remains to be seen whether or not the high school reform movement can have the same success in raising student achievement that the elementary literacy movement has had. While the early results are mixed, it is still too early in the evolution of the high school reform movement to definitively declare the success or failure of the movement in achieving its ambitious academic goals.

## A "Movement" for Middle School Mathematics and Science

The success of the elementary literacy movement and the high school reform movement in focusing the attention of educators and the public on critical educational issues provides us with clear direction on how best to organize a middle school reform agenda focused on mathematics and science. Clearly, there are challenges and opportunities in middle schools that are specific to this arena, but the energy and the traction these other two movements have generated provides us with a roadmap for crafting a new movement for middle school reform focused on mathematics and science.

Some key elements of this roadmap include the following:

- **Define and communicate a powerful central goal—**The other two successful educational movements were able to take the complexities of a broad reform agenda and distill them into a simple yet powerful mantra which captures the overall goals of the movement. The mantras of "every child a reader" and "every student college ready" serve to focus the entire educational system—both inside and outside of the school walls—on a goal that demands dramatic change across a wide array of activities, while still being understandable and compelling to a non-educator public audience.

  For middle school mathematics and science, we need to frame a similar mantra that captures the essence of our goals

**A "movement" for middle school mathematics and science:**

- Define and communicate a powerful central goal.
- Do not confuse the mantra with the larger goals.
- Realize that change needs to be broad and long term.
- Maintain a central focus on instructional improvement.
- Acknowledge that more resources will be needed.

without over-complicating the message to the larger public. "Every student Algebra proficient" or "every student mathematics literate" may not have the public resonance of these other mantras, but a slogan along these lines will be critical to galvanize broader support for the difficult reform work that lies ahead. The public and, most importantly, parents need to be informed of the repercussions of their children not entering into and continuing through the mathematics and science pipeline.

- **Do not confuse the mantra with the larger goals—**While "every child a reader" is a clear goal statement, the literacy movement has had an academic agenda far larger than reading alone, including writing, oral communication, comprehension, vocabulary, and knowledge acquisition. Likewise, the high school reform movement has a set of goals around "rigor, relevance, and relationships" that far transcend the stated mantra of "every student college ready."

  For middle school mathematics and science, our goals are obviously far beyond Algebra proficiency, including critical thinking, numeracy, sequencing, problem solving, and analytic thinking. So, while it will be important to have a simple and compelling mantra to animate our efforts, it will be important that the middle school mathematics and science movement establish an agenda that captures the breadth of all these goals to ensure we accomplish the desired outcomes in student performance.

- **Realize that change needs to be broad and long term—**It is critical to maintain a long-term commitment to successfully mobilize the breadth of change of the magnitude envisioned by these movements. By 2006, the literacy movement now has had a life span of 10–15 years, while the high school reform movement is only 5–7 years old. Each of these movements has mobilized far-reaching changes that take years to effect and replicate.

  For middle school mathematics and science, we will need to identify a clear set of broad-based, systemic changes to be undertaken over the next 5–7 years that will ultimately create improvements in student performance. There is no single "silver bullet;" the change agenda must envision a broad set of key players involved in systemic changes that will collectively combine to yield the desired outcomes in student performance over the long term. This change needs to occur within the larger as well as local policy arena. The effort will only be successful if all key players—businesses, families, elected officials, and school districts—are involved and working toward the same goal.

- **Maintain a central focus on instructional improvement—**Ultimately, the success or failure of any educational movements will be predicated on its ability to improve (or not) the quality of the instructional relationship between a teacher and his/her students. It can easily be argued that the success of the literacy movement in increasing student performance has been primarily driven by its deep commitment (in terms of professional development, curriculum, intervention, etc.) to improving reading and writing instruction at the elementary level. The high school reform movement's initial focus on structural, as opposed to instructional, change raises some serious questions about its ability to raise student outcomes over the long term.

To generate success in middle school mathematics and science, we will need to make improvements in the quality of mathematics and science instruction as the central element of our agenda. This will be a difficult challenge, since many middle school teachers (even those teaching mathematics and science) have little or no background in mathematics and science. As a result, deep commitments to teacher professional development at both the pre-career and in-service phases must be a central component of any districtwide effort at middle school mathematics and science reform.

- **Acknowledge that more resources will be needed—**Systemic change of this magnitude cannot successfully occur within the confines of school districts' existing resources. Even with the aggressive redeployment of existing resources, there are simply not enough dollars in the K–12 system to accomplish the goals of these movements. For the elementary literacy movement, the federal government and many states increased their funding for early literacy initiatives; for the high school reform movement, the Gates Foundation and other foundations provided substantial funding to the reform effort.

  We should expect that a similar increase in resources will be required to launch a movement around middle school mathematics and science. There is already some additional money coming from philanthropic and governmental sources, but more will be needed to fuel the breadth of this change agenda.

## Conclusion

To be fully participating citizens of the 21st century, today's young people will need significantly higher levels of academic skills than the generations that preceded them. The Information Age workplace assigns a high premium to the analytic competencies of mathematics and science that are so central to our global digital economy.

Unfortunately, today's K–12 education systems in Washington State and across the country are proving to be inadequate in producing high levels of student achievement in mathematics and science. Even America's highest performing students are coming up short compared to their international counterparts. This weakness in the skill sets and academic abilities of our students is quickly emerging as a serious threat to America's long-term economic vitality and the overall strength of our democracy.

A review of the educational research from the last several decades clearly highlights the need to dramatically increase the rigor of the academic experience for all students, especially in the areas of mathematics and science. In particular, creating proficiency in Algebra by 9th grade is the key gatekeeper for student access to advanced-level high school courses, high school graduation, and college attendance and completion.

Preparing students for this important gatekeeper early in high school necessitates reform at the middle school level. However, the work does not stop there. Taking an Algebra course is not an end in and of itself; Algebra merely signifies the beginning of the process to get students ready to be successful during and after high school. Simply taking and passing an Algebra class is not sufficient to ensure long-term student success; steadily progressing through the academic pipeline of upper-level, highly rigorous coursework is what unlocks long-term academic benefits for students.

In light of this research, educators in Washington State and across the country need to develop a reform agenda that will significantly increase the rigor of the middle school experience for all students. A policy framework for this reform agenda should be based on the following key elements:

- Establish a fundamental goal that all students pass Algebra 1 by 9th grade.
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The success over the last decade of the elementary literacy movement and the high school reform movement provides us with some direction on how best to organize a middle school reform agenda focused on mathematics and science. There are challenges and opportunities in middle schools that are specific to this arena, but the energy and the traction these other two movements have generated provides us with a roadmap for crafting a new movement for middle school mathematics and science reform.

## Endnotes

[1] National Center for Education Statistics.

[2] In 1983, an 18-person commission formed by the Reagan administration, called the National Commission on Excellence in Education, came out with an open letter to the American people regarding findings on the state of the American public education, calling it "eroded by a rising tide of mediocrity." The commission proposed, among other things, increased credit requirements in high school.

[3] National Commission on Mathematics and Science (2000).

[4] National Commission on Mathematics and Science (2000), p. 4.

[5] ACT, Inc. (2006).

[6] Please note that additional resources mirror the ideas presented, but the goal of this document was to summarize and provide a list of refined articles rather than an exhaustive record.

[7] Council on Competitiveness (2001).

[8] Business-Higher Education Forum (2005).

[9] U.S. Department of Education (1999), pp. 2,4,7,9.

[10] Business-Higher Education Forum (2002), p. 13.

[11] National Center for Educational Statistics, *Remedial Education at Degree-Granting Postsecondary Institutions in Fall* (2000, 2004), pp. iii, 17.

[12] National Center for Education Statistics, *The Condition of Education* (2004).

[13] National Science Foundation, *Science and Engineering Indicators* (2002), Table 2–18, p. A2–25.

[14] Committee for Economic Development (2003), p. 25. Data quoted from National Science Board, *Science and Engineering Indicators: 2002*, Figure 2–9.

[15] National Science Foundation (2002), Section B, Table 4.

[16] National Science Foundation (2002), Section B, Tables 4 and 6.

[17] Pelavin & Kane (1990); Rodriguez (2002); Adelman (2006).

[18] Department of Education (1997).

[19] RAND Mathematics Study Panel (2003).

[20] National Center for Education Statistics (1998).

[21] Pelavin and Kane (1990).

[22] Adelman (2006).

[23] The Education Trust (2003), pp. 17–18.

[24] The Education Trust (2005).

[25] Rodriguez et al. (2002).

[26] Klein, D., Parker, T., Quirk, W., Schmid W., & Wilson, W. S. (2005).

[27] Achieve, Inc. (2005).

[28] Greene and Forster (2003).

[29] Quality Counts: Washington (2006).

[30] National Science Foundation (2004).

[31] Ingersoll (2004).

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November 1, 2006

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