Improving Math Performance

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Introduction

Throughout the United States, the Bill & Melinda Gates Foundation is supporting teachers and administrators engaged in large-scale high school reform. The ultimate goals of this reform are to increase the college preparedness, college enrollment rates and academic success of all students, especially those from poor and minority backgrounds. The reform effort includes commitments by individual schools to maintain high expectations of students; create personalized learning environments; facilitate collaboration among teachers, schools and the surrounding community; and encourage effective teaching by means of active inquiry and in-depth learning. These reform efforts often are summarized in terms of greater rigor, more relevance and stronger relationships.

Studies of student achievement data from foundation-supported schools show noteworthy improvements in English language arts. However, math performance has not shown a similar improvement. Additionally, site visits across a large sample of foundation-supported schools suggest that high schools face several tough obstacles to improving math performance as they undergo foundation-supported reform.

This article examines the challenges that foundation-supported schools face in math education during the early years of their reform efforts. Strategies that many of the schools use to address these challenges are presented, along with some promising practices from other sources. Last, this article points educators to additional resources, ideas, practices and sources of support that may assist them in enhancing their students' mathematical skills and sophistication.

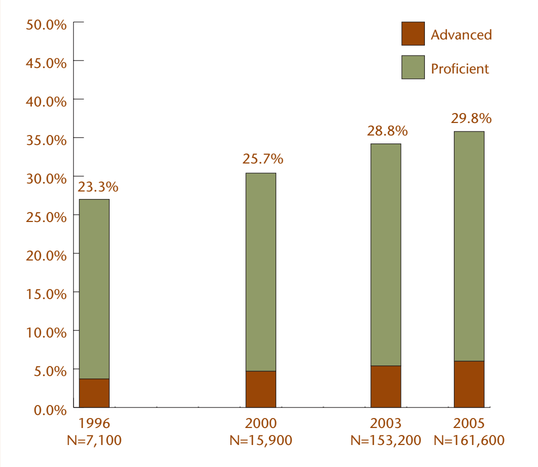
Challenges Faced by Foundation-Supported Schools

Over the past four years, the foundation's evaluation partners have conducted classroom observations and staff interviews at more than 100 high schools engaged in foundation-sponsored reform. The data collected show three major challenges to math education in the schools:

- Students entering high school with substantially deficient math skills;
- Teachers having difficulty using nontraditional pedagogies and curricula; and
- Schools struggling to provide adequate professional development and support for teachers of mathematics.

The weak math skills of students entering high school present a problem nationwide. In the past four cycles of the National Assessment of Educational Progress (NAEP), for example, the total percentage of eighth graders who achieved proficient or better status in mathematics did not reach 30 percent (see Figure 1).

Figure 1. Cumulative Percentages of Students Scoring Proficient or Advanced on the National Assessment of Educational Progress (NAEP) Mathematics Assessment[1]



While students' weak math skills are an obstacle for math teachers at most public schools, they are particularly problematic for schools that enroll high percentages of minority, low-income and English language learner students — groups for which the proficiency rates entering ninth grade are on average even lower.[2] Foundation-supported schools generally fit this latter profile.

This research brief is based on information from the American Institutes of Research database, 2006.

[1]National Center for Education Statistics, National Assessment of Educational Progress (2005). *NAEP Data Explorer.* Retrieved Feb. 7, 2006, from http://nces.ed.gov/nationsreportcard/nde/viewresults.asp?pid=4-2-8-MAT-National---10-TOTAL-20053,20033,20003,19963,19962,19922,19902--MC-BB,AB,AP,AD-5-0-0--1-0--2-3--0--1.

[2]National Center for Education Statistics, National Assessment of Educational Progress (2005). *The Nation's Report Card: Mathematics 2005* (NCES 2006-453). Washington, DC: U.S. Department of Education, Institute of Education Sciences.

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While there is a shortage of certified math teachers nationwide, that issue is compounded for low-income, high-minority schools, such as those the foundation supports.

The second challenge facing foundation-supported schools arises from the schools' commitment to implement nontraditional math instruction methods and curriculum. This commitment requires the use of more concept-oriented, project-based pedagogies that are relevant to students' lives and futures. Moving from a theoretical commitment to actual implementation, however, has proven to be difficult for many schools.

Research indicates that implementing effective problem-based instruction requires in-depth training for teachers and continued support, preferably from within the school.[3] While math teachers at foundation-supported schools expend great amounts of labor and time to improve their materials and instruction, they often operate without a great deal of knowledgeable support, quality curricula or professional experience in the methods they wish to use. Many teachers interviewed during site visits indicate, for instance, that they have had difficulty creating or finding interdisciplinary projects that use grade-level math. Also, many math teachers report difficulty in finding conceptual-based curricula or teaching methods that address the needs of students whose skills are below the levels tested in state-administered mathematics assessments.

The third challenge that foundation-supported schools face is setting up adequate support for their mathematics teachers. While data point to many successes resulting from foundation-supported reforms, one trade-off of the creation of smaller high schools is that the schools' faculties now are generally smaller. For a subject such as math that can be difficult to weave into interdisciplinary work, this decrease means that sources of support and networking within a school for math teachers may be diminished. Furthermore, smaller faculties at reformed schools often also mean that teachers face a narrowed circle of co-workers with whom to share curriculum ideas and a regular flow of information that is specific to math instruction. In fact, some foundation-supported schools have as few as one or two math teachers. Sometimes this shortfall means that a teacher is asked to teach beyond his or her experience or credential to cover all mathematics courses. While there is a shortage of certified math teachers nationwide, that issue is compounded for low-income, high-minority schools, such as those the foundation supports.[4]

The following section presents strategies for addressing these challenges. Many of the strategies are being used at foundation-supported schools, while others are examples of promising practices in use elsewhere.

Strategies for Addressing Challenges to Math Performance

Supporting Students

When a student arrives in high school substantially deficient in math skills, it can be quite difficult to bring that student up to grade level. Foundation-supported schools have relied on a variety of strategies to address this challenge, such as additional instructional time and courses, tutoring and other focused supplemental instruction, and curriculum restructuring and software.

Additional instructional time. To provide additional instructional time, one period in the student's schedule may be reserved for an extra class in the subject of need. According to teachers at some schools, these classes — called "shadow classes" or "challenge classes" — work best when aligned closely with the curriculum and methods of the core classes that they are supplementing; they should not be time to do homework or to learn unrelated concepts. After-school programs also provide students the benefit of extra instruction. Like shadow classes, after-school programs reportedly provide the greatest benefit when the instruction is coupled closely with the goals of the main class, either through the main teacher's direct involvement or through communication between that teacher and after-school program staff.

Tutoring and other focused supplemental instruction. Within the classroom, math teachers at foundation-supported high schools sometimes employ peer tutoring and differentiated instruction as supports to students' mathematical learning. Speaking of his instruction methods since teaching at a new school, one math teacher reported, "I have a lot more peer tutoring going on, and that's when [the students] really get it." Similarly, some teachers are attempting to use differentiated instruction techniques as they confront classrooms of students with wide ranges of mathematical skills. Speaking of his switch to forming student work groups based on ability and tailoring instruction for different groups in the classroom, one math teacher at a foundation-supported school reported that "that's when things got much better in terms of teaching the math, and the kids' scores improved a lot."

[3]Teacher Education Materials Project: A Database for K–12 Mathematics and Science Professional Development Providers (2005). *Building on Current Knowledge About Professional Development.* Retrieved Nov. 7, 2005, from www.te-mat.org/building.

[4]U.S. Department of Education, National Center for Education Statistics (2004). *The Condition of Education 2004* (NCES 2004–077). Washington, DC: U.S. Government Printing Office.

Curriculum restructuring. Facing high school students who need to review middle school math concepts, some foundation-supported schools have made Algebra I a two-year course instead of the traditional one-year sequence. The prolonged time frame is used to review older concepts and provide supplemental skill work, often through computer software or Web-based programs. Such additional work in basic math and algebra allows many students to successfully continue on through Geometry and, in their senior years, Algebra II. Some students are able to satisfy college entrance requirements by completing three yearlong units of college-preparatory math, though the courses comprising these units are taken over four years.

Increasing Teacher Access to Quality Nontraditional Curriculum

A high-quality curriculum can assist teachers in their efforts to help students advance their learning. For foundation-supported schools, which often enroll students with weak mathematics skills, the need for such a curriculum is even stronger. Steps taken by these schools to obtain such curricula include the introduction of mathematics curricular software, concept-oriented, packaged mathematics curricula and schoolwide project-based curricula.

Mathematics curricular software. Many schools are experimenting with computer-based or Web-based math programs. Math computer programs used at some foundation-supported schools include Riverdeep, BoxerMath and Accelerated Math.[5] These programs often are used to supplement project work with grade-level skill work. Teachers' reviews of the efficacy of software-based math remediation programs vary, but with proper training, there is some evidence that if a quality computer-based program is used as a course supplement, the software can aid students by increasing the amount of time students spend on level-appropriate tasks.[6]

Concept-oriented packaged mathematics curricula. Many schools have adopted concept-oriented, packaged math curricula as a means to raise student math achievement. These programs may include software aides, but they differ from the software programs discussed previously because they are comprehensive programs that include books, workbooks and full-scale curriculum for a year or more. Interactive Mathematics Program (IMP) and College Preparatory Mathematics (CPM) are two such examples.[7] These packages are mapped to standards set by states or by the National Council of Teachers of Mathematics (NCTM). According to one teacher, this kind of curriculum "brings it all around for you," integrating cooperative learning, student presentations, problem-solving strategies and multiple skill levels into the daily lessons. Some teachers find these packages helpful in developing the skill levels of low-achieving students because the materials balance basic skills with more advanced analysis and inquiry-based learning.

The materials are not without their detractors, however. Some teachers note that students with low literacy skills struggle with some of the math programs that are text heavy, further compounding the students' low achievement. Other teachers feel that these programs do not provide enough complex, interesting projects or concept learning. Indeed, some teachers find it necessary to supplement the curriculum because their students start the program so far behind in basic math skills.

At some schools, teachers use the prepackaged curriculum as a supplement to project work. These teachers often devote a great amount of time and energy to developing classroom projects. Such projects have included asking students to prove math theories, solve real-life scenarios or create objects using mathematical principles. Students in one project at a foundation-sponsored school used logarithms to determine a person's time of death. Another project required students to use linear algebra and graphing to make predictions and find the best trail in a cross-country trip. These projects ask students to apply their mathematical learning to real-life scenarios and complex projects.[8]

Introduction of schoolwide, entirely project-based curricula. Some foundation-supported schools have curricula that are entirely project based. In these instances, schools pick a theme or unit, and teachers work in an interdisciplinary manner to integrate skill development into a project designed around the theme. These projects often are based on real-life experiences, and their topics can be student

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[5]For additional information on Riverdeep, see www.riverdeep.com; for additional information on BoxerMath, see www.boxermath.com; and for additional information on Accelerated Math, see www.renlearn.com.

[6]Ysseldyke, J., Spicuzza, R., Kosciolek, S., Boys, C. (2003). "Effects of a Learning Information System on Mathematics Achievement and Classroom Structure," *Journal of Educational Research,* Jan./Feb. 2003, Vol. 96, No. 3, pp. 163–174.

[7]For additional information on IMP, see www.mathimp.org, and for additional information on CPM, see www.cpm.org.

[8]The issue of low student skills again presents a barrier for teachers, who find it hard to introduce classroom projects if their students lack a strong foundation in basic skills. Teachers have tried to address this obstacle by providing skill-based lessons that complement classroom projects so that students have support as they try to apply math to classroom projects.

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>
> **— A student**

generated. As one student says, "We're not going to be doing math worksheets on future jobs. Here, we create things; we use math." For example, one student at a project-based school was doing an internship in a cooking business. She used math to project future earnings for the business, based on current sales, so that they could plan for future work.

The mathematics focus in interdisciplinary, project-based curricula is on using numbers in a way that is meaningful to students and that allows students to see the real impact of numbers. In practice, however, several teachers have noted that math is the most difficult subject to integrate into interdisciplinary projects and that the discipline is not as fully integrated as it should be. Some projects lack mathematical rigor, according to interviewed teachers. Additionally, the recurrent problem of students with weak math skills is sometimes exacerbated with interdisciplinary projects because students do not receive direct instruction in fundamental mathematical principles. To address these issues, some schools that are almost entirely project based are now offering math seminars several times a week. These seminars focus on basic math skills as a supplement and support for project-based work.

In the search for projects that incorporate grade-level math, teachers both post to and pull from Internet Web sites. One example, produced by NCTM, is a Web site that seeks to engage students interactively while delivering content that conforms to NCTM standards (http://illuminations.nctm.org/swr/list.asp?Ref=0&Grd=9). The Center for Innovation in Engineering and Science Education also provides an online source of free interdisciplinary projects (http://k12science.org/currichome.html). The math skills required in these projects are linked to NCTM standards. Other sites of interest that provide high school-level math projects or project ideas are listed in the resources section at the end of this brief.

Providing Support and Professional Development for Teachers

One compendium of best practices strongly advocates providing a quality professional support mechanism as teachers transition from traditional methods of teaching math to problem-based learning and interdisciplinary projects.[9] Without appropriate teacher training, schools run the risk that only a veneer of problem-based learning will be practiced around the edges of a system that continues to emphasize lectures followed by individual practice. The professional training should be designed to improve teachers' understanding of and abilities in nontraditional teaching methods, particularly problem-based learning. The training also should take into account teachers' prior experience and knowledge, operate with a close connection to the teachers' school, and give teachers opportunities to practice in a supportive environment.[10] The consensus is that "teachers who have participated in professional development on the use of particular instructional materials and are using the materials as designed are much more effective than those who either had not received professional development or who attempt to modify the materials."[11]

On-site support. Several foundation-supported schools are providing on-site support for math teachers. The support varies depending upon the size and needs of the math departments, although the theme of collaboration is a constant. Some schools have designated lead math teachers who serve as mentors and supporters for other math teachers in the school. These lead teachers host meetings on instructional topics, observe teachers or conduct demonstration lessons in teachers' classrooms.

A few foundation-supported schools have hired outside consultants to provide on-site support using funds from grantees' professional development accounts and grant money from private sources. The consultants' routines vary, with some serving full time at a school for an entire year while others come to schools intermittently, holding workshops. Some schools have partnered with local universities to hire professors to work with their staff as a whole or one on one with math teachers. While the particular mechanism for providing on-site support varies from school to school, the shared goal across campuses is to provide teachers with on-site development that fits their particular needs.

Professional development and common planning time. Support for teachers is not limited to coaching on pedagogy. Some school leaders have engaged the entire school staff in math professional development workshops or curriculum training to encourage interdisciplinary collaboration and project design. Furthermore, conscious of the need to give teachers time to improve their curricula and lesson plans, some schools' math departments have instituted common

[9]Teacher Education Materials Project: A Database for K–12 Mathematics and Science Professional Development Providers (2005). *Building on Current Knowledge About Professional Development.* Retrieved Nov. 7, 2005, from www.te-mat.org/building.

[10]The Urban Institute (2005). *What Do We Know?* Retrieved Nov. 9, 2005, from www.urban.org/url.cfm?ID=311150.

[11]Weiss, I., Gellatly, G., Montgomery, D., Ridgway, C., Templeton, C., Whittington, D. (1999). *Local Systemic Change through Teacher Enhancement, Year Four Cross-Site Report.* Retrieved Nov. 11, 2005, from www.horizon-research.com/reports/1999/year4.php.

planning time for teachers. During this common planning time, math teachers come together to ensure that they are integrating concepts across instructional years or that they are interpreting the curriculum in similar ways. Interviewed teachers noted that common planning time was a key enabler to helping them teach effectively. Institutionalizing such interactions also fosters a culture of collaboration and experimentation for teachers on the campus.

Support from grantee organizations. In many cases, the grantee organizations that serve as intermediaries between the foundation and the foundation-supported schools have created support systems for math teachers. Some grantees, for example, host annual conferences to share best practices with teachers from their affiliated schools. These conferences often have sessions designed around mathematics content and various instructional supports for in-service teachers. Additionally, some grantees have hired math coaches for their affiliated schools. The coaches have several years of math teaching experience and provide direct professional development to teachers in the form of weekly or monthly workshops, curriculum support, observations, or departmental meetings. Other grantees provide opportunities for teachers from different schools to communicate through mini-conferences or workshops. Interviewed teachers often referred to such grantee support as helpful for their instruction, although the ultimate impact on student achievement has yet to be determined.

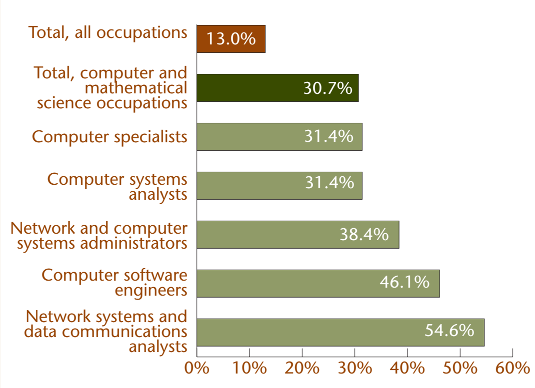
Example from overseas. Perhaps the most salient examples of a culture of support for math teachers come from overseas. The 2003 report of the Trends in International Mathematics and Science Study describes teaching supports that are built into day-to-day interactions of Japanese mathematics teachers. The report describes a teaching culture in which there are faculty meetings dedicated to math instruction, professional discussions on topics of learning and routine videotaping of classroom instruction.[12] Math teachers participate regularly in curriculum development meetings and are assigned action plans and individual research assignments and follow-up tasks. In the United States, such an intense and ongoing degree of collegial interaction is rare. Indeed, without the concerted support of a wider network, such collaboration would be nearly impossible for math teachers at smaller schools, where an entire department may consist of as few as one or two teachers.[13]

Conclusion

Creating a mathematically literate citizenry is as important today as it ever has been. Between 2004 and 2014, for example, employment growth in technology-related fields is projected to far outstrip the overall projected rate of job growth (see Figure 2).

Additionally, independent of any individual's occupation, the policy and financial decisions made by an educated populace require an ever greater understanding of fundamental mathematical concepts. And yet, large portions of the country's youth currently are passing into adulthood with minimal math sophistication.

Figure 2. Projected Percentage Increases in Employment for Select Occupations, 2004–2014[14]



Against this backdrop, educators at some foundation-supported schools are reforming math education. Specifically, they are shifting from traditional methods of presenting mathematics in class and instead are embedding math instruction in projects that are interdisciplinary, relevant and interesting to students. This emphasis on relevance simultaneously requires that students master the skills necessary for higher-level math and statewide assessments. The educators' ultimate goal is to educate imaginative learners who grasp concepts and have the ability and willingness to investigate ideas and solve real-life problems.

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[12]Stevenson, H.W. (1998). *A TIMSS Primer: Lessons and Implications for U.S. Education.* Retrieved from www.edexcellence.net/FOUNDATION/publication/publication.cfm?id=50&pubsubid=725.

[13]An example of a public high school in the United States that consistently exhibits high student outcomes in mathematics is Adlai E. Stevenson High School, a large comprehensive high school in the Chicago suburb of Lincolnshire. The school dedicates about 15 days each year when other educators are encouraged to visit. For more information, see the school Web site at www.district125.k12.il.us.

[14]U.S. Department of Labor, Bureau of Labor Statistics (2005). *Employment by Occupation, 2004 and Projected 2014.* Retrieved Feb. 7, 2006, from http://stats.bls.gov/emp/emptabapp.htm.

The educators' ultimate goal is to educate imaginative learners who grasp concepts and have the ability and willingness to investigate ideas and solve real-life problems.

While the experience, enthusiasm and intelligence of teachers and administrators at these schools go a long way toward accomplishing these goals, there is a wider circle of interested parties with resources and talents that can help with this endeavor. Districts, states, community organizations and higher education partners can fill critical training and systemic needs in the effort to improve the nation's level of mathematics skills. They can offer training in solid, innovative teaching practices; they can provide access to rich, concept-oriented curricula; and they can construct for teachers systems of continued feedback and support from a network of professional peers. With such support, teachers and administrators may find that even the achievement score numbers start adding up in their students' favor.

Resources

Materials for teachers to use in the classroom

Education Development Center (www2.edc.org/MathProblems). A searchable database of math word problems, many of which are based in practical scenarios.

The Illuminations Project (http://illuminations.nctm.org/swr/list.asp?Ref=0&Grd=9). Sponsored by NCTM, materials and lesson plans aligned with NCTM standards.

Math Forum @ Drexel (www.mathforum.org). Lesson plans and activities, including a problem of the week.

National Library of Virtual Manipulatives (http://nlvm.usu.edu/en/nav/index.html). An online library of interactive manipulatives and tutorials focused on mathematics.

Web sites to support teacher professional development

Annenberg Media Learner.org (www.learner.org). Fee-based courses and complimentary video libraries on teaching strategies for several different math concepts.

Lesson Lab (www.lessonlab.com). A resource geared toward administrators, offering several fee-based professional development courses based on using textbooks and research to shape practice.

National Council of Teachers of Mathematics (www.nctm.org). Online workshops, materials and resources.

Teacher Education Materials Project (www.te-mat.org/home). A searchable database that reviews math and science professional development materials and allows you to search by several different criteria.

Background information

Creating Mathematical Futures through an Equitable Mathematics Approach: The Case of Railside School, Jo Boaler and Megan Staples, 2005 (www.stanford.edu/~joboaler/equity.pdf). A case study that highlights one urban school that increased student math achievement and engagement through innovative teaching strategies.

National Center for Education Statistics Report, 1999 (http://nces.ed.gov/pubs99/timssvid). The official report on the TIMSS video study from the U.S. Department of Education.

Radical Equations, Bob Moses, 2001 (http://thealgebraproject.org). Description of Moses' work in founding and leading The Algebra Project, an innovative program that targets minority youth.

The Teaching Gap, Jim Stigler, 1999 (www.lessonlab.com/teaching-gap). Rooted in the TIMMS video study learnings, highlights the need for effective instructional methods to drive student achievement.

A TIMSS Primer: Lessons and Implications for U.S. Education, Harold W. Stevenson, 1998 (www.edexcellence.net/FOUNDATION/publication/publication.cfm?id=50&pubsubid=725). Lessons learned and "best practices" from the TIMSS study.

What Do We Know? The Urban Institute, 2005 (www.urban.org/url.cfm?ID=311150). Summary of the research that exists for dozens of popular math and science curriculum programs.

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