STEM Smart Brief
STEM Smart: Lessons Learned From Successful Schools

Raising the Bar: Increasing STEM Achievement for All Students

THE PROBLEM

The problems are well known, but the statistics still startle. Science and mathematics achievement gaps along racial, ethnic, linguistic, and socioeconomic lines have widened substantially over the past 20 years. Consider math, viewed as the "gatekeeper" to academic opportunity generally, and to science learning in particular. Scores on the National Assessment of Educational Progress (NAEP)—known as "the nation's report card"—reveal gulfs that start in grade 4 and just keep growing. The most recent math scores of high school seniors are just one example.

Striking Statistics: Growing Math Achievement Gaps

Recent grade-12 math scores on the NAEP illustrate the persistent achievement gaps between students of different racial, ethnic, income, and language backgrounds. In 2009, the following percentages of each group of high school seniors scored at the "Basic" level or better:[1]

Racial/Ethnic Background

* 75% of Whites
* 45% of Latinos (a 30% difference)
* 36% of Blacks (a 39% difference)

English Language Proficiency

* 66% of students who are proficient in English
* 20% of English language learners (a 46% difference)

Income Level

* 71% of average-income students
* 44% of low-income students (a 27% difference)

> *When students from non-mainstream backgrounds receive equitable learning opportunities, they are capable of attaining science outcomes comparable to their mainstream peers. The same is true for mathematics and, presumably, for other STEM subjects, as well.*

It is generally accepted that disparities in math and science performance are the result of vast disparities in educational quality in the United States. Research shows that schools with large numbers of racial and ethnic minorities, low-income students, and English language learners (ELL) are systematically under-resourced compared with schools serving middle and upper class and White students. They have fewer well-trained teachers, fewer advanced courses, and less access to academic basics—from pencils and paper to computers and calculators. It all adds up to students from historically marginalized groups having significantly fewer "opportunities to learn" than their more advantaged peers.[2]

However, when students from non-mainstream backgrounds receive equitable learning opportunities, they are capable of attaining science outcomes comparable to their mainstream peers.[3] The same is true for mathematics and, presumably, for other STEM subjects, as well.

THE RESEARCH & PROMISING PRACTICES

Despite reams of research describing the growing math and science achievement gaps between advantaged and disadvantaged student groups, there is less to suggest how to reverse these trends. Most studies focus on individual programs; they lack data to compare the pros and cons of various strategies. However, researchers have been able to identify characteristics of approaches to STEM education that have been shown to produce positive outcomes for a diverse range of students:[4]

- Providing high-quality curricula and instruction to all students
- Using classroom practices that support equity
- Connecting to students' cultural experiences and native languages
- Connecting to "real-world" problems
- Organizing schools to foster equity

Many schools have adopted—or tried to incorporate—one or more of these features into their daily practice. However, no single element is likely to improve performance; achievement increases when all of these factors are working together.

Providing High-Quality Curricula and Instruction to All Students

A large number of schools with diverse populations focus their curriculum and instruction primarily on basic skills in an attempt to "teach to the test" and boost scores on state exams. While mastering fundamentals is critical, a narrow emphasis on basics severely limits opportunities to learn higher-level concepts and strategies. It also can be boring, because it seems unimportant to students and disconnected from their daily lives—they tune out.

What makes a math or science program high-quality for diverse learners? The best combine rich content and challenging activities with instruction that is student-centered, conceptually oriented, and focused on problem solving. Questions are grounded in familiar contexts. Explicit connections are made between students' understanding of math and science in everyday situations and the formal language of math and science. Math students start to act like—and see themselves—as mathematicians. Science students start to act like—and see themselves—as scientists.

Example: QUASAR—Quantitative Understanding: Amplifying Student Achievement and Reasoning

The QUASAR project introduced advanced mathematics curricula to low-income, urban middle school students in six cities. About half of the lessons covered basic calculations in traditional topics, such as decimals, fractions, and percents, while the rest covered more challenging concepts from statistics and algebra. Teachers encouraged students to represent math problems in multiple ways and allowed multiple solution strategies, thereby emphasizing student understanding and reasoning as opposed to memorization. Over five years, this approach showed substantial learning gains—in open-ended problem solving and in NAEP scores—for Black, White, and ELL students compared with students using simpler tasks and single strategies.[5]

Using Classroom Practices to Support Equity

It is not only the curriculum but also the delivery that determines whether students engage with challenging material. Studies show that traditional teacher-led instruction—such as lectures or question-and-answer discussion—often fails. Student-centered approaches are more beneficial for all students. Rather than direct students, teachers set up and facilitate conversations and small-group activities, explicitly explaining how to talk with peers about math, science, or other subjects. They provide ongoing feedback, which is critical to learning success, and publicly recognize each student's contributions. These practices help foster student identities as competent members of a math or science community. Teachers make explicit "the rules of the game" of mathematical and scientific practice, such as inquiry, vocabulary, discussion, as well as classroom norms, that are not inherently obvious or may even be different in the home cultures of many students.

Example: The Rules of Science

Due to the fact that school in general, and science in particular, is taught from a western point of view, there may be unfamiliar and invisible cultural divides between a student's cultural framework and that of his or her school. Effective instruction should make these rules explicit for students to give them the opportunity to cross these cultural borders. This could include being explicit about classroom norms and academic content areas. For example, in one instructional intervention with elementary teachers serving a diverse community that served ELL students, they found that explicit instruction in a lot of areas of science normally taken for granted in a traditional approach to science instruction effectively leveled the playing field between ELL and non-ELL students in the classroom. Students improved in measures of science achievement, literacy achievement, and inquiry skills.[6]

Connections to Culture and Native Language

Few people may pause to ponder it, but learning is an inherently cultural endeavor. Students from racial and ethnic minority groups find themselves disadvantaged in a school culture that seems to overlook the linguistic and cultural resources that are valued in their homes and communities. In fact, some aspects of cultural traditions may be "inconsistent with a scientific orientation toward knowledge construction and problem solving."[7] In non-Western cultures, for example, learning is primarily observational, fostered by adults in formal or informal apprenticeships. Before ever stepping foot in a school, all children carry around knowledge grounded in their home and cultural values. Connecting new information to this prior knowledge is a fundamental part of learning, and is much easier for mainstream students, whose cultural backgrounds are far more likely to be in line with typical classroom practices.

Students from different cultures bring "funds of knowledge" from their homes and communities that can serve as intellectual resources in class. The challenge for teachers is to help students make the connections. This is clearly easier with groups of students from similar backgrounds, rather than students from across the world.

Students with limited English language skills face a double disadvantage in math and science. First, many are placed incorrectly in low-level classes because they can't demonstrate all they know on placement tests written in English. Second, students placed appropriately, based on their actual ability, often lack the English proficiency to participate in discussions necessary for grappling with the material. Some research suggests translated texts could help students access the content. But for complex topics, the ideal classroom approach may be conducting conversations in a student's native language. In fact, students often switch to their dominant language to engage with higher-level math and science concepts.

Example: Using Haitian Talking Traditions to Connect Students with Science

The Cheche Konnen Center in Cambridge, Mass., promotes scientific inquiry among language minority and low-income students who are struggling in school. Created in 1987, the center is now part of TERC, an independent, educational research organization. A key part of this work is documenting the sense-making resources—such as oral and literate traditions used in daily life outside of school—that children from ethnically and linguistically diverse backgrounds bring to the study of science and how these factors interact.

Haitian students are typically quiet and respectful in the classroom, but they become quite animated when in a culturally familiar environment. A researcher with the Cheche Konnen Center used her knowledge of the traditional Haitian form of talk called "bay odyans" (which means "to give talk," or "chatting," and may include storytelling or telling jokes or riddles in public settings) to foster arguments and promote discussion in science classrooms for Haitian students. She worked with members of the center to help other poor, bilingual students build on their interest in talking and in exploring phenomena in the world by using this indigenous practice (and their interests in African drums and other native customs) as a link to more conventional scientific investigations, such as the physics of sound and the causes of mold. As a result of this instructional shift by teachers, students were able to engage in scientific reasoning. [8]

Connecting to Real-World Experiences

In U.S. schools, connecting math and science instruction to the daily experiences that are familiar to students is vitally important. Research has shown greater achievement gains among students with this type of schooling. Teachers need to understand the disparities between traditional classroom strategies and what is most meaningful to students day to day—and find ways to bridge the divides.

Example: Investigating a Community's Water Quality

A study of U.S.-Mexican border schools that investigated water quality and had youths explore how it was relevant to their lives enhanced students' enthusiasm for science and their knowledge and understanding of the content. They tested water in their homes and investigated ways to improve water standards. They understood the precariousness of water availability in their desert region and tried to encourage families to conserve water. This helped them see science investigations as worthwhile.[9]

Organizing Schools to Foster Equity

Studies of schools and districts serving large numbers of racial, ethnic, socioeconomic, and language minorities consistently point to the importance of organizing for equity: a shared mission, a curriculum aligned to that mission, and developing supportive professional communities. Key is an explicit commitment to improving learning outcomes for all, limiting tracked courses, and making available ongoing training and collaboration on instructional improvement for diverse learners.

Example: Eliminate Tracking

Access to advanced and rigorous math courses—calculus, pre-calculus, and trigonometry—is perhaps the most important gateway to math and science learning. The widespread practice of "tracking" students into courses of different levels may be the biggest obstacle. Research repeatedly has found that tracking puts Black, Latino, poor, and ELL students at an unfair disadvantage. They are overrepresented in remedial classes and underrepresented in college preparatory classes, which is of particular concern since, more often than not, tracking is a dead end: with no access to advanced concepts, few low-level students can progress into college prep work.[10]. Even with similar achievement, Black and Latino students often are assigned to lower tracks than Whites and Asians.[11] Initial research indicates that schools with fewer tracks may produce higher—and more equitable—achievement.

RECOMMENDATIONS

With increasing cultural and linguistic diversity in classrooms across the country, and growing divides in student learning, schools and teachers must implement practices to reach all students in their classrooms to effectively level the playing field. The strategies outlined in this brief offer promise to support the learning needs of all students while bolstering the learning of diverse learners in particular. The following characteristics can be found in schools that support the learning needs of all students:

- Using classroom practices that support equity
- Connecting to students' cultural experiences and native languages
- Connecting to real-world problems
- Organizing schools to foster equity

A one-size-fits-all instructional approach will certainly fail to meet the learning needs of all—or even most—of the students in any classroom.

[1] National Center for Education Statistics. (2011). *NAEP data explorer*. Washington, DC: U.S. Department of Education, Institute of Education Sciences.

[2] Nasir, N. S. et al. (2011). *Mathematics learning and diverse students*. Paper presented at the National Research Council's Workshop on Successful STEM Education in K–12 Schools, Washington, DC, May 10–12, 2011.

[3] Lee, O. (2011). *Effective STEM strategies for diverse and underserved learners.* Paper presented at the National Research Council's Workshop on Successful STEM Education in K–12 Schools, Washington, DC, May 10–12, 2011.

[4] Nasir, 2011. Lee, 2011.

[5] Silver, E. A., & Stein, M. K. (1996). The Quasar Project: The 'revolution of the possible' in mathematics instructional reform in urban middle schools. *Urban Education, 30*(4), 476–521.

[6] Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*(4), 491–530

[7] Aikenhead & Jegede, 1999; Snively & Corsiglia, 2011 – in Lee, p. 3

[8] Forman, E., & Sink, W. (2006). *Sociocultural approaches to learning science in classrooms: Final draft of a report to the National Research Council Committee on Science Learning K–8*. Pittsburgh: Department of Instruction and Learning, University of Pittsburgh.

[9] Rodriguez, A. J., & Berryman, C. (2002). Using sociotransformative constructivism to teach for understanding in diverse classrooms: A beginning teacher's journey. *American Educational Research Journal, 39*(4), 1017–1045.

[10] Darling-Hammond, L. (2010). *The flat world and education: How America's commitment to equity will determine our future*. New York: Teachers College Press; Oakes, J. (1985). *Keeping track: How schools structure inequality*. New Haven: Yale University Press.

[11] Oakes, J. (2005). *Keeping track: How schools structure inequality,* 2nd edition. New Haven, CT: Yale University.

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