STEM Smart Brief

STEM Smart: Lessons Learned From Successful Schools






Preparing and Supporting STEM Educators

THE PROBLEM

Teachers do make a difference in student outcomes—and it can be a big one. Research has shown this to be especially true in mathematics, which forms the foundation for all future STEM learning. But most U.S. students do not get a series of good teachers—and highly skilled math and science teachers are not the norm. Excellent instruction requires both deep content knowledge and expertise in teaching that content to all kinds of learners. Developing inspiring STEM instruction is particularly demanding, while STEM teachers are particularly poorly prepared.

Striking Statistics: Uneven STEM Teacher Preparation[1]

Certification & College Majors

* An estimated 10–20% of science and math teachers in U.S. middle and high schools are not certified in their subjects—nor did they major in a related field in college.

Math Study

* Future elementary school teachers take, on average, only two college math courses.

Studies of the teacher-training pipeline from initial preparation through on-the-job professional development identify challenges at each stage. The U.S. offers more than 1,200 teacher education programs at universities and another 130 alternative routes to licensure, but no central oversight or curriculum standards.[2] This has resulted in a teacher preparation system that researchers have described as chaotic, incoherent, and uncoordinated, filled with "excellent programs, terrible programs, and many in between."[3]

The need to overhaul the nation's teacher training programs is now the consensus of practitioners, politicians, and policymakers alike. A top priority is improving the practices of STEM teachers—and their job-based supports. Recent research emphasizes that teacher quality alone cannot improve student achievement at scale. School leadership, staff collaboration, and a positive climate are among essential organizational elements that contribute to meaningful change.

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Key Conditions: Five Organizational Supports Crucial for School Improvement[4]

A 20-year study of Chicago Public School reform efforts concluded that what matters most for high learning gains is whether a school is organized to support students as learners. While teacher quality is important, it actually makes no difference in an unsafe environment. A disorganized school can't take advantage of a high-quality curriculum.

The district's student population is 85% minority and 85% from low-income families, according to the Consortium on Chicago School Research at the University of Chicago, which conducted the landmark study. Students aspire to college and STEM careers, but very few succeed.

To improve, the study found, schools must build organizational capacity in five essential areas:

* *School leadership*—Principals must be strategic, focused on improving the four other organizational supports, and include staff and parents in decision-making.
* *Strong professional capacity*—Individual teaching staff must be skilled instructors. But even more important is the degree to which teachers work together to improve the learning climate and instruction in the school.
* *Parent-community ties*—Schools must actively involve parents and local organizations as partners to support instruction in a coordinated way.
* *Student-centered learning climate*—The school environment must be safe, stimulating, and supportive for all students.
* *Instructional guidance*—The focus of instruction must be engaging all learners; the curriculum must be aligned across grade levels and subjects so that students continuously develop their skills through increasingly challenging tasks.

One of the key studies examining these organizational supports compared mathematics and reading improvement in 400 low-performing Chicago elementary schools. The schools with strong organizational supports—in at least three of the five essential areas—were 10 times more likely to improve learning gains over time than those with any weakness. No schools with poor learning climate and weak professional capacity improved in six years. Schools in the most disadvantaged neighborhoods were most in need of strong organizational supports.

THE RESEARCH & PROMISING PRACTICES

Despite 20 years of guidance from professionals about what teachers need to know and be able to do, there is little empirical research to support what makes particular teacher preparation, professional development, or school leadership strategies effective in improving teacher quality or student outcomes. There is even less known about solid STEM instruction because math and science teachers are rarely separated out for studies of their own. Still, individual programs show promise.

Teacher Preparation

A growing number of states are redesigning teacher preparation programs to require more science and mathematics instruction, particularly to build content knowledge and inquiry skills. Some are offering incentives for talented science majors and mid-career science professionals to pursue science teaching. They also are providing earlier practical experience in public schools to show prospective teachers the realities of running a classroom of diverse learners.

Simply, the amount of time future teachers spend studying science and math in college may be critical. Many states have identified low course-taking in science and math by elementary and middle school teaching students as a major factor in poor teacher quality and poor student outcomes. There is modest evidence that more time spent on in-depth study of science and mathematics may contribute to improved teacher quality. In fact, the authors of a major international study found a strong correlation between elementary teachers with a stronger background in math and student achievement. Future elementary and secondary school teachers in high-achieving countries had more opportunities to learn tertiary level mathematics (geometry, continuity, functions) and school-level mathematics (functions, calculus, probability, statistics, structure) than elementary teachers in other countries.[5] Older studies following secondary student achievement and teacher preparation in math and science in the United States also found a correlation between the number of math and science courses a teacher took in her teacher preparation program and student learning gains.[6]

Example: UTeach

One promising STEM teacher preparation program appears to be UTeach, which was created to attract bright college students majoring in science, mathematics, and computer science into secondary teaching. The incentive is that training—including certification and an undergraduate science major—can be completed in four years instead of five by combining individualized coaching, intensive teaching experiences in K–12 classrooms, and relevant STEM content integrated with pedagogy.

UTeach began in 1997 at the University of Texas at Austin and, since, has been replicated in 14 states around the country. The program has been recognized as a model for science, mathematics, and computer science teacher preparation by a number of prominent organizations, including the National Research Council and the U.S. Department of Education. In fact, the University of Texas at Austin has developed an institute to partner with other universities across the country to replicate the model. Since most began in 2008, and data on the graduating cohorts will not be available until the spring of 2012, the success of this initiative has yet to be seen. However, early efforts are promising, and the UTeach program has found a high degree of fidelity of implementation across the new sites.[7]

The original Texas program, which recruits freshmen in the College of Natural Sciences, enrolls about 600 students. Supervised by master teachers with exemplary secondary teaching experience, UTeach students start field experiences in public school classrooms early—in their freshmen year. In a final apprenticeship senior year, students assume full teaching responsibilities in a secondary classroom approximately four hours per day for 12 weeks. Master teachers or other trained observers visit at least 10 times and give intensive feedback.

About 27% of UTeach students represent two minority populations—Hispanic and African American—that traditionally have been underrepresented in STEM courses and careers. About 88% of graduates become teachers, and about half teach in low-income schools. More than five years following graduation, about 80% are still teaching.

Professional Development

The weaknesses of teacher preparation programs heighten the need for high-quality continuing training. Unfortunately, STEM professional development is "often short, fragmented, ineffective, and not designed to address the specific need of individual teachers."[8] The overall record is mixed: Some studies of particular programs have shown positive effects on achievement; others have shown no effect or negative effects.

Some professional development is mandatory, but much is voluntary; many teachers wander from one workshop to another, rarely building on anything from session to session, or year to year. Perhaps the most fundamental problem is that "there is no way for a teacher to develop her knowledge of the content and content-based teaching practice over time in increasingly sophisticated ways."[9]

A study of 25 professional development programs for math and science teachers in 14 states showed positive student outcomes if three conditions were met: (1) the programs focused on content in mathematics and science, (2) the programs included on-site follow up in classrooms, and (3) the teacher-contact time reached at least 50 hours.[10]

Example: Michigan Teacher Excellence Program

The Michigan Institute for Teacher Excellence Program—which aims to elevate the content knowledge and pedagogy of middle school Earth science teachers with limited training—is considered a model for improving Earth science education nationwide. Groups of 12–24 teachers from the cities of Grand Rapids, Kalamazoo, and Jackson commit to three years of summer field work, professional development days, online courses, culminating experiences at national parks, and district leadership opportunities. Michigan Technological University faculty contributes its expertise.

For two summers, teachers spend a week in the Upper Peninsula, exploring Keweenawan volcanics, rifting, and copper mineralization; water supply and quality; glacial deposits and climate change; wind energy; and the geologic history of the state. They also take a week each summer near their home districts to explore the city water supply and flood history, shallow and deep aquifers, local glacial geology, late Paleozoic bedrock exposures, surface water quality, and coastal geology. Field days are correlated with Earth Science Literacy Principles, state standards, misconceptions, and district curriculum.

During the school year teachers attend professional development days on topics they identified as areas of greatest need and participate in online Earth science and education courses. Teachers can apply course work towards a master's degree in Earth science education. In their third year, teachers do internships at Midwest national parks such as Isle Royale, Sleeping Bear Dunes, or Pictured Rocks National Lakeshore.

A program evaluation is due in 2014. Meanwhile, participants have emerged as teacher-leaders, providing professional development for peers in their district or presenting their work at state science teacher meetings.

Instructional Leadership

School leaders are more important than many people may realize in improving specific areas of instruction, including STEM subjects. But schools increasingly are recognizing that teachers cannot improve student math and science achievement without principals focused on the same goal. Just as teachers need ongoing professional development, so do instructional leaders—especially if they have gaps in their subject-specific knowledge.

Principals play a critical role in strengthening mathematics programs by fostering a shared commitment to improving math learning outcomes, engaging with teachers, supporting strong math professional development, and setting expectations that teachers will integrate professional development lessons into their classroom practices. Also extremely important is their own content knowledge—their ideas about the nature of mathematics and mathematics learning and teaching—which affects the ways they enact their roles.[11]

Example: MIST Middle-School Mathematics and the Institutional Setting of Teaching

The MIST project is designed to address the limited understanding that principals typically have of high-quality mathematics instruction. In collaboration with University of Pittsburgh's Institute for Learning, MIST developed three half-day workshops for 80 school leaders and math coaches from several large, urban districts in 2009. The main goal was to help principals distinguish between cognitively low- and high-demand math tasks and recognize the value of key aspects of ambitious instruction, such as whole-class discussions that support the development of conceptual understanding.

The results from the pilot have been encouraging. School leaders' ability to distinguish between high- and low-level mathematics tasks increased significantly.[12] Their ability to recognize key aspects of ambitious mathematics instruction also moderately increased.

The second phase of the project, which began in the 2011–12 school year, is helping to test and refine theories developed out of the first phase. The two key leadership practices identified so far are (1) observing math instruction and providing feedback, and (2) participating in mathematics professional learning communities, where groups of teachers discuss general strategies, specific lessons, and individual student challenges.

RECOMMENDATIONS

Improving STEM teacher preparation and ongoing supports has become a major national priority. Practitioners and policymakers are finding a balance between "What do teachers need to know?" and "What do they need to do?"

These supports emerge as common factors that can yield improvement:

- Teachers need sustained science-specific training, including content, current research on how children learn science, and strategies for teaching science.
- Initial training should be aligned with district-specific curricula so that teacher candidates are learning what they actually will be teaching.

- Ongoing professional development must address teachers' classroom work and the problems they encounter in school settings, and then teachers need to try out new strategies in their classrooms, report back on their experiences back to the training program, discuss, reflect, and learn from them.
- On-site professional support should allow for regular interaction and collaboration with colleagues and school leaders, such as professional learning communities.
- Teachers need multiple and sustained opportunities for continued learning over a substantial time interval.

It is crucial to focus improvement efforts on the full continuum of teacher training from initial preparation through induction and ongoing professional development. This is true not only because STEM understanding is constantly changing, but also because there is not just one chance to ensure that teachers have the skills they need. Moreover, it is important to remember that the investment in training and recruiting high-quality teachers is unlikely to have a positive effect on chronically low-achieving schools without a corresponding push to improve the organizational health of schools.

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Community for Advancing Discovery Research in Education

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