

# Never Too Late to Learn: Lessons from the Teachers Academy for Math and Science

## Foreword

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Last April, in a speech to the National Academy of Sciences,<sup>1</sup> President Barack Obama announced his renewed commitment to improving the quality of math and science education across the United States. He noted the stunning lack of qualified math and science teachers currently in schools and challenged states to enhance teachers' preparation and training to meet 21<sup>st</sup>-century demands for a scientifically sophisticated workforce. The U.S. Department of Education will provide competitive grants for such efforts through its \$5 billion Race to the Top initiative.

President Obama's stress on the great need for improvements of U.S. math and science instruction and the positive force of his national commitment create an ideal atmosphere for a new effort modeled on the success of the Teachers Academy for Math and Science (TAMS) in Chicago. TAMS addressed the problem of teaching mathematics and science to children, especially in grades below six. Positive experiences with mathematics and science from children's earliest schooling increase both their knowledge base and the likelihood they will choose career paths related to those fields.

Our specific experience points to the positive outcomes of a rigorous program of classroom-based teacher training. President Obama and others have focused their reform ideas on attracting new blood to the teaching profession; TAMS showed that working teachers, including the most senior veterans, are eager to learn new strategies to help their students learn the math and science they will need to succeed in further education and in life. With the modeling and in-class support provided by TAMS trainers, working teachers successfully changed their instructional practices. Their

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<sup>1</sup> President Obama spoke on April 27, 2009.

classrooms became more open to the inquiry and hands-on experimentation that breed true scientific thought and understanding.

The TAMS model is in line with the best thinking about teacher professional development. Experts agree that the best teacher training focuses on content, provides concrete strategies, and puts trainers directly into classrooms working side-by-side with teachers; however, such training is hard to find in U.S. schools. TAMS offered exactly that kind of training to some of Illinois' neediest schools for over a decade.

We offer this document as a template, in the sense the word is used among computer scientists: a starting point from which to create a new application. How such a new venture might look will vary by context. As with many educational reforms, a TAMS-like program needs the enthusiasm and support of principals and parents, as well as the collaboration of local universities. Here we stress the need for strong business community support and university-based leadership. Given the widespread dissatisfaction with American K-12 students' performance in math and science, funding could be found for new TAMS-like efforts in the states or even nationally.

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## **Introduction: How TAMS-style Teacher Training Can Rebuild U.S.**

### **Leadership in Math and Science**

The United States currently faces a crisis of competitiveness. Long the world's leader in technological innovation, the nation now must import scientists and engineers from India, China and elsewhere. The lack of home-grown interest in math and science has its roots in the poor quality of elementary-level math and science teaching. Until teachers colleges revamp their methods of training elementary teachers, schools and districts will inevitably struggle to build a high-quality teacher force. Developing cadres of elementary-level teachers with the knowledge and passion to teach math and science well has proved a particularly difficult task.

Many recent efforts to improve education—No Child Left Behind, charter schools, and alternative routes to enter the teaching profession—overlook the importance of continuing training for veteran teachers. No Child Left Behind's school restructuring options include replacing staff but say nothing about retraining teachers. Many charter schools rely on an ever-changing cadre of young teachers to survive economically. Programs like Teach for America, the New Teacher Project, and urban teacher residency programs in Boston, Chicago, and Denver concentrate their efforts on recruiting and training a new breed of teachers largely separate from the traditional pipeline. All of these measures fail to address the training needs of more senior teachers, who comprise the majority of the continuous K-12 education workforce, even in high-turnover urban schools. As Barnett Berry (2009) observes, "From a viewpoint of developing a stronger teaching profession, however, most of the innovation still seems to be on the margins, with little attention being paid to developing teacher leaders who can promote student learning that will meet the demands of our 21<sup>st</sup>-century society and economy." States and districts must develop and support training programs that help on-the-job teachers understand math and science well enough to teach confidently, and train teachers in the inquiry-based methods that help students think mathematically and scientifically.

Training programs for working teachers are notoriously inadequate. A recent report from the National Council of Staff Development and Stanford University's School Redesign

Network (Darling-Hammond et al. 2009) found that U.S. teachers have much less opportunity than their international peers to participate in extended learning opportunities that can significantly improve their knowledge and practices. Research shows that it takes at least 50 hours of intensive teacher professional development to raise student test scores, but more than half of U.S. teachers receive no more than 16 hours of training in their subject areas each year. Though we know better, teachers are still subjected to “one-shot” workshops, often because districts lack the time, money, and knowledge base to provide better alternatives. A better method is “job-embedded” professional development, through which schools build time into the day for teachers to observe best practices and try them in their own classrooms with support from a trainer and/or peers. But time and funding constraints often prevent U.S. districts and schools from implementing job-embedded training.

In the face of these challenges, a model program in math and science teacher training provides a solid example of how to offer sustained professional development at scale and over the long haul. The Teachers Academy for Math and Science (TAMS), a Chicago-based teacher-training program, lasted 13 years and served eight Illinois districts, including Chicago. With a strong, business-based board, TAMS was able to sustain itself long-term by obtaining funds from a variety of sources, including the National Science Foundation, the U.S. Department of Education, the State of Illinois and regional philanthropy. Although TAMS ceased operations in 2004, the training it provided has had a lasting impact on teachers and students, particularly in the Chicago Public Schools. Its track record of results demonstrates that TAMS-style teacher training increases teachers’ content knowledge, sustains their use of quality instructional practices and ultimately has positive effects on student achievement.

The history of TAMS and its results offers useful lessons for school leaders and policymakers at the state and national levels. This document traces the history of the origins of TAMS, describes the TAMS model of teacher training, and explores its impact over time. The final section distills this information into a set of “lessons learned” that policymakers, district and school leaders, universities and other training providers and local communities can use to improve the quality of math and science teaching in their schools.

Given the Obama administration's unprecedented commitment to improving the nation's public schools, now is the time to tackle the challenge of improving teacher training in math and science. The lessons of TAMS can help guide the way.

### **TAMS: Rooted in Chicago School Reform and the Mathematics Revolution**

The Teachers Academy for Mathematics and Science (TAMS) was created in 1991 to address elementary school teachers' lack of preparation in math and science. Teacher colleges are regularly criticized for failing to connect coursework to the real work teachers do in the classroom. This disconnect is nowhere more apparent than in the teaching of math and science in elementary school. "The problem we have in this country still is [that] a teacher is marching out of college about as ignorant of math and science as you can measure. The kids catch their insecurities, and it sows a dislike of math and science in an early age. This works most viciously in the poorest and most needy schools," said Leon Lederman, Nobel physicist and the force behind TAMS' creation.

Though TAMS was created to solve a perennial problem in teacher education, it was forged during efforts to reform Chicago's public schools in the late 1980s and 1990s. TAMS' strategy and approach was shaped, in part, by the Chicago school reform movement.

In the late 1980s, the Chicago Public Schools were referred to by the U.S. Secretary of Education as the worst in the country. The fall of 1987 marked the ninth teachers' strike in less than 20 years. On the heels of this strike, Mayor Harold Washington convened an Education Summit that brought together an unlikely coalition of grassroots groups, education reformers and Chicago business leaders, who agreed that taking power out of the central bureaucracy and placing it in the hands of parents and local community leaders was the way forward. In 1988, this coalition won passage of the School Reform Act, which created Local School Councils (LSCs), parent-led school site-management organizations with power to set budgets and hire and fire the principal.

Researchers have observed that LSCs have had a positive effect on both schools and local communities. In a 10-year retrospective on the results of Chicago school reform, a group of senior scholars from the Consortium on Chicago Research wrote, “the vast majority of LSCs are viable governance organizations that responsibly carry out their mandated duties...largely validating the wisdom of the 1988 Reform Act” (Bryk et al. 1998). According to their research, for about one-third of Chicago’s schools, expanded local democracy served as a lever for systemic change focused on instructional improvement. The research found only 10 to 15 percent of LSCs were inactive, enmeshed in sustained conflict, or had engaged in unethical behavior. Harvard professor Archon Fung (2004) found LSCs were models of participatory government, especially in poorer neighborhoods; he uses them as a model in his work on urban participation. Fung also found support from community groups was vital to LSC success.

Though LSCs had beneficial effects on overall school climate and participatory democracy in local communities, their effects on student achievement as measured by standardized test scores have been less clear. Between 1990 and 1995, elementary student achievement as measured by standardized test scores in math and reading remained basically flat, with no more than 30 percent of students at or above the national average on the Iowa Test of Basic Skills in either subject (*Catalyst Chicago* 2000.)

LSCs may not have had direct impact on student achievement in part because they have had no direct role in improving instruction. Significantly, LSCs had no effect on unsatisfactory teacher recruitment and training that kept students trapped in classrooms with low-quality instruction. Urban systems across the nation have struggled for decades with a predominantly young, poorly-equipped teaching force that turns over rapidly. The founders of TAMS reached out to LSCs and school principals to enlist their support for increased attention to the quality of math and science instruction.

Meanwhile, on the national scene, a revolution was taking place in the teaching of math and science. In 1989, the National Council of Teachers of Mathematics released curriculum and evaluation standards that emphasized developing students’ skills in problem solving and mathematical reasoning as well as computational fluency. The new

standards sent shock waves through classrooms nationally as teachers began to shift away from lectures, drills, and worksheets toward posing real-world problems for students to solve, allowing them to work in small groups and providing tools to assist the process, from rulers and simple manipulatives in elementary classrooms to graphic calculators in high schools. As a state, Illinois showed strong evidence that reform based on the new standards worked. Data from 1992 to 1995 showed that students in schools with the strongest implementation of such reforms showed increases in mathematics achievement nearly one standard deviation above the state mean. (National Council of Teachers of Mathematics). However, in Chicago, the new standards initially had little impact on teaching and learning. The founders of TAMS explicitly sought to bring the best of the new standards and methodologies to Chicago's neediest schools and support teachers in their use.

Shortly after the citywide coalition succeeded in gaining local control of Chicago's schools, a group of experts in mathematics and science education met with political and community leaders to develop a conceptual framework for helping elementary school teachers teach mathematics and science. Leon Lederman spearheaded the work. Early board members came from the scientific community, such as University of Chicago physicist Henry Frisch, and the business sector, notably Richard Morrow of Amoco and Bruce Rauner of the private equity firm GTCR. With the help of a five-year grant from the U.S. Department of Energy, TAMS opened its doors in 1991. It capitalized on the new freedoms won by LSCs and principals by recruiting individual schools to participate in its training programs. Over time, TAMS programs evolved to meet the needs of partner schools, which were embedded in the larger context of school reform. Eventually, TAMS programs incorporated work to address other school needs identified through research, reflection, and data analysis.

### **How TAMS Did It**

Although TAMS' primary focus was on professional development for elementary school teachers to help them enhance their math and science instruction, TAMS' founders recognized that teachers do not work in isolation from their school communities. Thus, TAMS adopted holistic school improvement and whole-school reform strategies.

TAMS worked toward three broad goals:

- 1) Equip teachers with the knowledge and tools needed to change their pedagogy;
- 2) Work with parents, school leaders and administrators to create a supportive environment for the study of mathematics and science;
- 3) Support this environment with technical assistance in improvement planning, building administrator, teacher and parent teams, and understanding the use of data and technology in school improvement.

The core of TAMS' work was a two-year, comprehensive, standards-based professional development program in mathematics and science for elementary teachers. Participating teachers completed a 60-hour workshop sequence targeted at improving elementary math and science instruction, including model lessons. National and state standards in mathematics and science provided the foundation for content learning. Math topics included number and operations, geometry, measurement, data analysis, probability, and algebra. Physical science topics included properties of and changes in matter, position, forces and motion, transfer of energy, and electricity and magnetism. Pedagogy emphasized constructivist, inquiry-based instruction. Curricula developed by the Lawrence Hall of Science in Berkeley, California proved to be helpful. Teachers in the program also received manipulatives and technology for classroom use. By conducting hands-on inquiry and experiments during the workshops, teachers in the program both increased their content knowledge in math and science and learned to apply the concepts and pedagogy in their classrooms with their students.

Participating teachers also worked directly with TAMS staff in their own classrooms: each teacher received 15 classroom visits from TAMS staff over the two years of professional development. During these visits, TAMS staff observed how the teacher incorporated TAMS training into their daily lessons. This job-embedded element of the professional development program was crucial for helping teachers transfer and refine their new knowledge about math and science content and pedagogy into their own classrooms.



As TAMS' experience with professional development grew, its core program adapted to meet the challenges of working with teachers in high-poverty, high-minority elementary schools where working conditions often do not support an intense teacher training effort. The students served by participating schools were predominantly minority, low-income and initially low-achieving on standardized tests. Between 1993 and 2003, an average of 89 percent of students in TAMS schools were eligible for free or reduced-price lunch (one measure of poverty) and an average of 94 percent were students of color. Of these, 68 percent were African American and 23 percent were Hispanic (Ciotola et al. 2004).

Few teachers in TAMS' partner schools had had prior experience with inquiry-based instruction; most taught mathematics and science via textbook and worksheets. Many feared inquiry-based lessons would disrupt their fragile hold on classroom management. Another common fear was that inquiry-based lessons would be too difficult for their students.

To begin reducing these fears, initial teacher workshops focused on data analysis and measurement. Teachers sorted and classified objects, collected data, and created simple bar and picture graphs to display their findings. Early grade teachers also studied length, area, and volume. Teachers in the upper grades studied mass and density and conducted more advanced data collection activities, including experiences with sampling. A key early science workshop focused on observation and making inferences. Later in the workshop sequence, teachers learned to use inquiry when studying the properties of matter, magnetism, force and energy, and position and motion.

As teachers progressed through the workshops, they were introduced to materials that could easily integrate into any school math/science curriculum while fostering inquiry-based learning: the University of Chicago's Math Tools, materials used with its Everyday Math series, and the University of Illinois-Chicago's Teaching Integrated Math and Science (TIMS) laboratory investigations. The TIMS investigations allow students to practice their data collection and measurement skills in hands-on activities. Teachers learned to apply TIMS principles to a variety of topics beyond those modeled in the workshops.

The key element in helping teachers overcome their fears of inquiry-based instruction was the classroom visits by TAMS staff. “When teachers are allowed to try some new activity with a professional developer present to help them if things get out of control, the teachers grow quickly and become more willing to try other new things,” said researchers Nicholas Ciotola, Anthony Ragona and Darlene Ulrich. “When teachers see children doing experiments and hear them coming up with their own questions, they begin to see how beneficial [inquiry] is” (Ciotola et al. 2004).

### **TAMS Supports to Schools for Continued Teacher Growth**

Over the two years of professional development each school received, TAMS helped develop a set of school and community supports to foster teachers’ continued growth as math and science instructors. In 1993, TAMS had sufficient funding to establish a School Improvement Unit, through which specialist staff worked with administrators, teachers, parents and community members to support school improvement planning and raise awareness about quality math and science learning. The School Improvement Unit conducted a two-phase, thirteen-day workshop series devoted to understanding the process of changing a school. While the first phase concentrated on introducing school stakeholders to change theory, team building, and conflict resolution, the second phase zeroed in on using assessment data to inform planning, concrete strategies for school improvement, and action planning.

The School Improvement Unit also developed a principal-support strategy. Many principals in TAMS schools valued control, discipline and order in their classrooms, which they envisioned as students listening quietly to a teacher. Inquiry-based learning requires small work groups, experiments and discussion. Some administrators saw student discussion and movement, which are integral to inquiry-based learning, as a threat to classroom order. To address this concern and expand principals’ understanding of good math and science instruction, the School Improvement Unit held four principal workshops annually, including a two-day retreat. These workshops offered an opportunity for principals to learn more about national and state standards in mathematics and science, deepen their understanding of TAMS’ work and sharpen their team-building and organizational management skills.

TAMS helped parents actively participate in their children's education through its School Community Partnership Development Group (SCPD). SCPD conducted a three-year parent program centered on Family Math and Family Science, widely recognized instructional materials developed at the University of California, Berkeley and Portland State University. In the first year, interested parents participated in 72 hours of training in Family Math and Family Science, formed a core team and began strategizing how to engage more parents and how to build partnerships with teachers and administrators. In the second year, the core team facilitated the 72-hour sequence in Family Math and Family science for a new group of parents and met monthly to learn more about school improvement. By the third year, the SCPD prepared parent core teams to continue their work without TAMS support.

### **TAMS' Positive Impact on Students and Teachers: Significant, Measurable, Scalable**

Over its 13-year lifespan, TAMS had a measurable positive impact on both student achievement and classroom instructional practices, most notably in grades one through three. Researchers examined student data in a variety of ways, all of which showed statistically significant positive impacts for students whose teachers had received TAMS training. These effects were observed across a number of studies using different methodologies and conducted at different levels of analysis.

TAMS served more than 5,000 teachers in 200 schools across six Illinois school districts. The four major districts TAMS served systematically were Chicago, Aurora, East St. Louis, and Joliet. (Ciotola, et al. 2004) TAMS took evaluation seriously and pioneered efforts to construct a system to measure the value-added impact on standardized test scores for students whose teachers had received TAMS training.

Ciotola et al. (2004) summarized multiple research studies on TAMS and its effects over the period from 1993-2004 and found students taught by TAMS-trained elementary teachers consistently showed higher performance on state tests in math and science than their peers in similar classrooms where teachers lacked TAMS training, even within the same school (2004). As shown below, in the 1999-2000 school year, primary-grade students in TAMS classrooms performed better on state math test questions than their

same-school peers whose teachers had not received TAMS training.

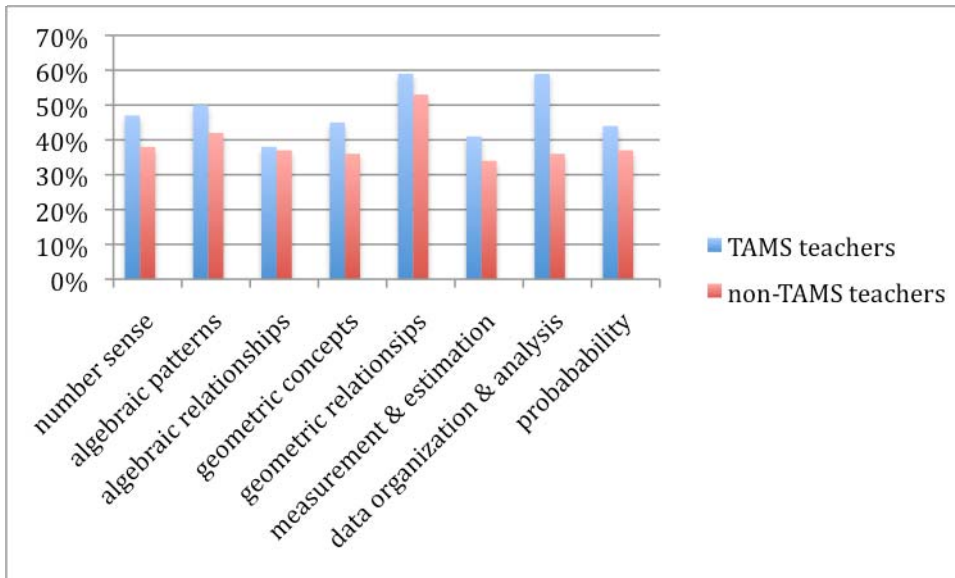


Fig. 1: *Same School Performance of Primary Students in the 1999-2000 Chicago Cohort of Academy Schools by Math Subsets in 1999-2000* (Ciotola, et al. 2004).

This higher performance appeared to hold true and increase as time went on. Over time, students in schools with TAMS-trained teachers showed greater gains on state math and science tests than their peers in schools that did not participate in TAMS. This effect was observed in both Chicago and districts elsewhere in Illinois, though the impact was greater in districts outside Chicago. Most importantly, regression analyses showed that TAMS teacher training had medium to large effects on student performance in math and science across elementary grade levels.

TAMS also used data to track changes in teachers' content knowledge and their attitudes toward teaching math and science. Participating teachers took content skills tests in mathematics and science and completed attitude surveys three times during their TAMS training—at the beginning, after completing the first year, and again after completing the second year. After undergoing TAMS training, teachers showed stronger content knowledge of math and science. Most of the gain occurred after the first year of TAMS training, and results were consistent across the state.

Although evidence that teacher instructional practice changed as a result of TAMS is not easily quantifiable, observational records kept by TAMS staff developers offer strong qualitative evidence for changing practices (Ciotola et al, 2004). Common observations recorded by TAMS staff included such comments as:

- Teachers attempt lessons they would not have tried before.
- Teachers give students more time to explore when using manipulatives and understand the importance of hands-on activities.
- Teachers learn to take time to think, let the students think, slow down, let the students inquire without too much interference, and take lots of time for reflection.
- Cooperative group skills used in mathematics and science activities are used in other subject areas.
- Some teachers choose to continue on and take courses so they are able to obtain endorsement in mathematics or science.

Perhaps the strongest qualitative evidence that teacher instructional practices changed as a result of TAMS comes from the teachers themselves. For example, first-grade teacher Lisa Smith, quoted by CIRCE (Center for Instructional Research and Curriculum Evaluation) researchers in a 1995 report, commented on the value of co-teaching with a TAMS staff developer. Smith and TAMS developer Jeannie Hall led an activity in which students practiced measuring an irregular area by drawing dinosaurs outside and measuring them with meter sticks. “If Jeannie hadn’t come, maybe the kids wouldn’t have gotten the full idea of my knowledge. She asked the kids questions I wouldn’t have thought of. She was more scientific. Now I can do more of what she did. I had the chance to observe her and learn from her successes and her failures” (Stake and Migotsky 1995).

The impact of TAMS has also been felt across Chicago, the state’s largest school district. “They created a good cadre of math and science leaders,” said former Chicago Public Schools district director of math and science Martin Gartzman. “I hired at least a half dozen of their professional developers to work on our [math and science] outreach team. Others were hired in schools as coaches and lead teachers. A lot of the people they trained in schools got hired in leadership roles in math and science. There’s a kind

of human resource capacity building they did that is still having an impact on the district” (August, 2009).

During his tenure as director of math and science for the Chicago Public School district, Gartzman noted that schools with TAMS experience were much more ready to take on new district initiatives in math and science than their peers without that background. “People who went through [TAMS] got a lot of support and a lot of learning. We saw they were far more ready to take the leap into sophisticated curriculum. They had much stronger math and science leadership in the school. The work at TAMS primed the pump. They were ready to do it.”

### **Lessons Learned**

The United States continues to face a crisis in competitiveness due to a lack of native-born scientists and mathematicians. The roots of this problem lie in the weakness of U.S. math and science education starting in the earliest grades. The TAMS experience illustrates key lessons for policymakers, district administrators, universities, school staff, and local communities interested in ramping up the quality of math and science education.

- Policymakers can support job-embedded professional development targeted to improving the math and science content and pedagogical knowledge of elementary teachers. An appropriation written into the state budget, which TAMS enjoyed for nearly a decade, is likely the most effective way to secure this support over time. In 2003, the state withdrew its funding, which caused the program to cease operations.
- District superintendents looking to boost student performance in math and science with their existing teacher force could be well served by a TAMS-like model for professional development. Contrary to much current thinking, it is not too late to retrain teachers already in the field, including veteran teachers. TAMS’ results show that working teachers hunger to improve their practice and will do so when offered job-embedded training and committed support within their own

classrooms and from their principals as they implement new instructional practices.

- Universities, curriculum developers, and training providers can build public/private partnerships with districts to create TAMS-like training and teacher support programs. Although the state and national climate may be more conducive to district/private partnerships now than it was when TAMS ended, district administrators interested in building stronger professional development for teachers and willing to seek outside partners to help build strong teacher training programs can still be hard to find. Universities, consultants and other curriculum/professional development providers can offer districts strong math and science curricula to support quality teacher training. It would be worthwhile for many universities to develop TAMS-like programs supporting working teachers to improve their methods for teaching pedagogy to prospective teachers.
- School staff wishing to improve their students' performance in math and science should be prepared to invest a substantial amount of time and energy into sustained job-embedded training. Teachers cannot undertake such an endeavor alone; it takes the support of their principals and local community to create the whole-school climate required for intensive TAMS-style training to take root and produce results. Principals can lend support by arranging for the time needed for training, including provision of substitutes as required to release teachers. They can also use their leadership to encourage faculty to invest in training and create a professional climate where teachers feel safe exposing their classrooms to trainers and possibly to one another.
- In Chicago, local communities looking to enhance their children's knowledge of math and science can use Local School Councils as a forum to encourage school staff to take on a TAMS-like training program, and can support principals in budgeting accordingly. Elsewhere, communities will need to use appropriate local avenues to lobby principals and district leaders to take on the work. Local communities can also partner with universities and other providers to take

advantage of family math and science programming built into a TAMS-like format. Community leaders might be well served to search for like-minded scientists in their local universities to partner in the work.

Given the current national interest in improving the quality of teaching and increasing the competitiveness of U.S. students in math and science, now is an excellent time to look to the lessons of TAMS and find way to replicate them at scale across the country.



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