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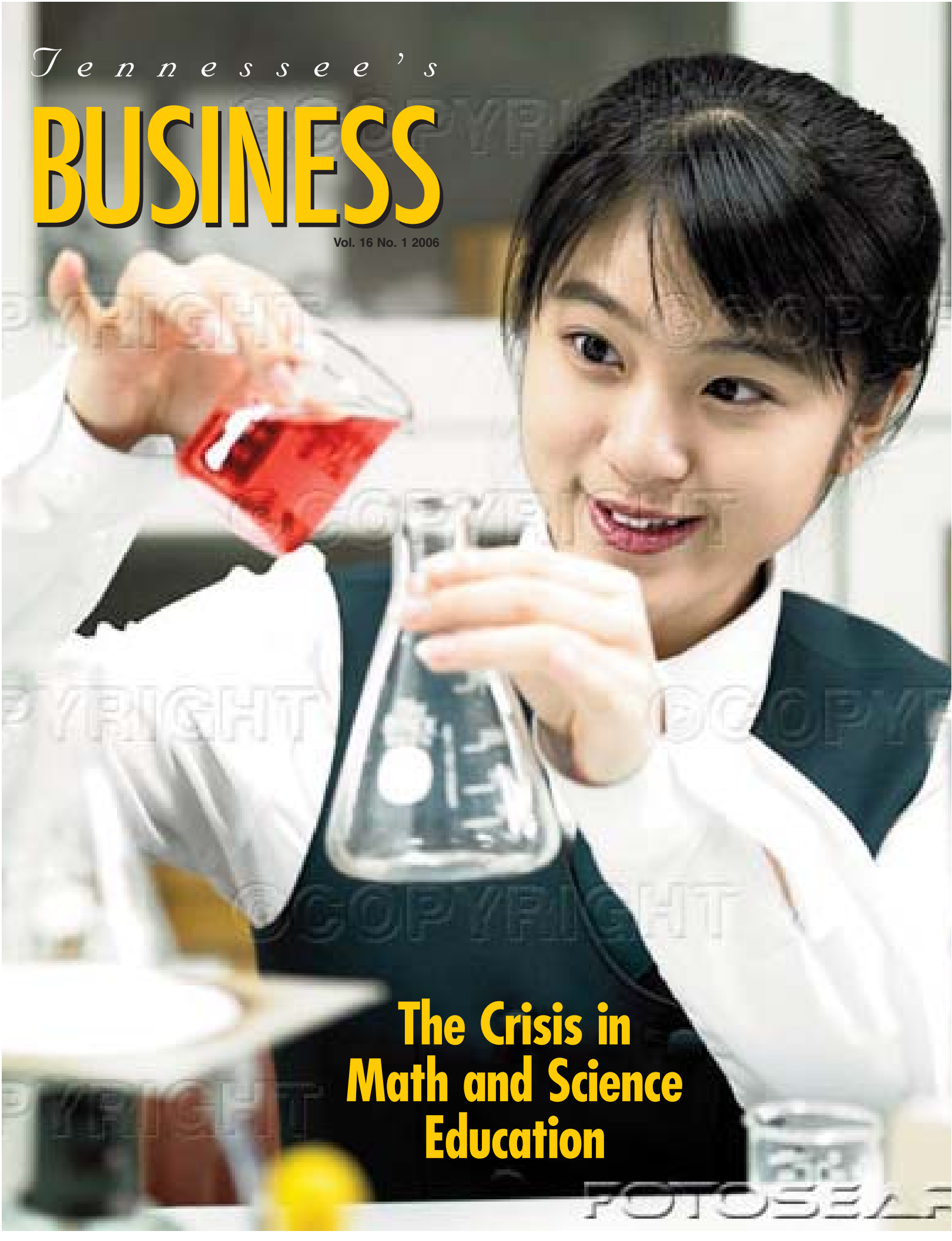

The Crisis in Math and Science Education

Tennessee's

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Recipient of the 1991, 1996, 2000, and 2004 AUBER Award of Excellence in Publications

MIDDLE TENNESSEE STATE UNIVERSITY

EDITOR'S NOTE

The National Academy of Sciences (NAS) recently assessed America's ability to compete and prosper in the 21st century. In its report, *Rising Above the Gathering Storm*, the NAS identified key actions needed to ensure that the U.S. "continues to enjoy the jobs, security, and high standard of living that this and previous generations worked so hard to create."

The NAS noted that although the U.S. faces a big disadvantage—the cost of labor—in being economically competitive, science and technology can overcome this. If we create scientists and engineers, they can in turn create entirely new industries. America is not as competitive and dominant in science and technology as it once was. Although still the leader, we cannot remain so without renewing our effort to boost the foundations of our competitiveness: science and technology, in which we must accelerate progress or risk poorer prospects for future generations to enjoy the same prosperity, security, and good health Americans now take so much for granted.

The NAS report listed a number of worrisome indicators:

- The U.S. has become a net importer of high-tech products (we import more high-tech manufactured goods than we export);
- U.S. 12th graders recently performed below the international average for 21 countries in math and science;
- Low-wage employers (e.g., Wal-Mart and McDonald's) are creating more new jobs than high-wage employers;
- Considerably more than half of undergraduates in China and Japan earn degrees in science and engineering compared to one-third in the U.S.;
- In 2004, China graduated 500,000 engineers, India 200,000, and America 70,000.

The NAS identified creating high-quality jobs and responding to the need for clean, affordable, reliable energy as challenges to improving our scientific and engineering education. Resulting NAS recommendations focus on (1) actions in K–12 education, (2) research, (3) higher education, and (4) economic policy, specifically:

- *Increase America's talent pool by vastly improving K–12 science and math education.* We should (a) annually recruit 10,000 science and math teachers by providing scholarships; (b) strengthen the skills of 250,000 existing teachers through training and education programs; (c) increase the number of students who take Advanced Placement and International Baccalaureate science and math courses.
- *Sustain and strengthen the nation's commitment to potentially transformational long-term basic research to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.* We should implement actions to increase federal investment in long-term basic research.
- *Make the U.S. the most attractive setting in which to study and perform research so we can develop, recruit, and retain the best and brightest students, scientists, and engineers in the world.* We should (a) promote ways to increase the number of undergraduate and graduate students in science and math, and (b) facilitate visa extensions for international science and math graduates to remain in the U.S. to seek employment.
- *Ensure the U.S. is the premier location for innovation and creating high-paying jobs by modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.* Stronger research and development tax credits will encourage private investment in innovation, and broadband Internet access for home, school, and business must be ensured.

—Horace Johns, editor

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At the Creative Discovery Center in Chattanooga, one exhibit includes a coil that allows visitors to make sparks (lightning!).

Creative DIscovery Museum

COMPETING FOR TOMORROW'S JOBS

As the recently named chair of the House Science Committee, I look forward to working with congressional leadership to improve math and science education and ensure the U.S. remains a leader in competitiveness and innovation.

by Bart Gordon

Unless the U.S. maintains its edge in innovation through a strong science and technology enterprise, the best jobs may soon be found overseas instead of in our communities. As the father of a five-year-old daughter, I worry that today's children could grow up to have a standard of living lower than that of their parents. Providing high-quality jobs for hardworking Americans must be our first priority. In order to accomplish that, we must be proactive.

I recently participated in the second education summit organized by the Tennessee Business Roundtable. In focusing on science education, the summit addressed exactly the right issue for ensuring that Tennessee and the nation remain leading players in today's global marketplace.

As the recently named chair of the House Science Committee, I look forward to working with congressional leadership to improve math and science education and ensure the U.S. remains a leader in competitiveness and innovation. This issue will be a top priority for the Science Committee in the coming Congress.

We must have an education system that succeeds in preparing students from all segments of society for a changing workforce: one that requires individuals to be grounded in math, science, and technology as well as one that attracts sufficient numbers of students to pursue the specialized knowledge required for careers in science and engineering.

But there is an equally important reason for effective science and math education. Technology now infuses more and more aspects of daily life. This means all citizens need a sufficient understanding of science, technology, and math to function in an increasingly technological world.

The necessary first step is to improve science and math education in the schools because an educated workforce is the foundation for economic strength. If we are going to have the jobs of the future, we need a more highly skilled workforce. Unfortunately, we have a long way to go in preparing students for success in science and technology courses in college.

Recently, the Program for International Student Assessment compared American students with their contemporaries in 49 industrial countries. The U.S. ranked 19th in science and 24th in math. A separate set of international comparisons, the Third International Mathematics and Science Study (TIMSS), tracked the performance of students in three age groups from 45 countries. The results showed that U.S. fourth-grade students performed above the international average in both math and science. But by eighth grade, U.S. students scored only slightly above the international average in science and below average in math. For 12th grade, U.S. students dropped to the bottom, outperforming only Cyprus and South Africa. The bottom line is that the TIMSS results found that U.S. students actually fare worse in science and math comparisons the longer they stay in school.

There are no simple answers for how to improve K–12 science and math education, but I believe the place to start is with reducing the number of out-of-field teachers, a problem that has been fueled by teacher shortages in our nation's schools. When the Science Committee held a hearing on the topic, every witness expressed the unlikelihood that students will be proficient in science and math if they are taught by teachers who are teaching content outside their areas of expertise.

The urgency of solving this problem is evident. For example, 69 percent of middle school students are taught by math teachers with nei-

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ther a college major in math nor a certificate to teach math, and 93 percent of those students are taught physical science by teachers with no major or certificate.

I am not alone in thinking that improving the skills of teachers is the first priority. In 2005, I joined Senators Lamar Alexander and Jeff Bingaman and then Science Committee Chairman Sherwood Boehlert in asking the National Academy of Sciences (NAS) to carry out an assessment of our ability to compete and prosper in the 21st century. Even more important, we asked the NAS to identify the key actions necessary for success.

The NAS formed a panel of business and academic leaders, ably chaired by Norm Augustine, the former Chairman of Lockheed Martin, which then conducted a study that was neither partisan nor narrow. The NAS panel subsequently released a report called *Rising Above the Gathering Storm*. The nation would be well served to follow its policy advice as closely as possible because it charts a course forward that will help create a vital, robust American economy with good-paying jobs for our citizens.

A serious problem with undergraduate science, technology, engineering, and math (STEM) education is the high attrition of students leaving the field, often not because of an inability to perform academically but due to loss of interest and enthusiasm.

The NAS report outlines a number of specific actions we can take to improve the innovation environment in the U.S., and its highest-priority recommendation involves teachers. In particular, the *Gathering Storm* report states that "laying the foundation for a scientifically literate workforce begins with developing outstanding K–12 teachers in science and mathematics." To implement this recommendation, the report calls for recruiting 10,000 of the best and brightest students into the teaching profession each year and supporting them with scholarships to obtain bachelor's degrees in science, engineering, or math with concurrent certification as K–12 science or math teachers.

I believe the *Gathering Storm* report got it exactly right in identifying teachers as the first priority. That is why I introduced legislation that takes the report's recommendations and creates programs to implement the highest-priority ones, particularly those focused on ensuring our science and math teachers are well grounded in their subjects and equipped to teach using the best educational practices. H.R. 5358, a bill that embraced the key features of my legislation, was approved by the House Science Committee last June. Another bill, S. 3936, was introduced in the Senate last September and includes similar provisions.

The key to the approach taken in the legislation is to provide incentives for universities to change the way they educate teachers. For this to work, it is important for universities to foster collaboration between science faculty and education faculty to design teacher education courses specifically designed to educate teacher trainees on how to teach science and math effectively. It is not sufficient just to encourage science and math majors to take enough off-the-shelf education courses to get a teaching certificate.

In addition, the teacher education program should provide early classroom teaching experiences for student teachers as well as mentoring by master teachers before and after graduation. Teachers who emerge from the program would combine deep knowledge of their subject with expertise in the most effective practices for teaching science or math.

This approach is modeled on the successful UTEACH program pioneered by the University of Texas. UTEACH has a record of success in not only attracting top-performing science and math majors to teaching careers but also keeping them in the classroom. In fact, three-quarters of their graduates are still teaching five years past graduation—a rate well above the national average of 50 percent.

In addition to improving the education of new science and math teachers, the legislation provides professional development opportunities for current teachers to improve their content knowledge and teaching skills. The activities authorized include part-time master's degree programs tailored for in-service teachers, summer teacher institutes, and training programs for preparing teachers to teach Advanced Placement and International Baccalaureate courses in science and math.

Without a sufficient number of high-quality K–12 science and math teachers, there is no realistic chance colleges and universities will be able to produce the number of scientists and engineers with the skills required to lead the world in technology development and deployment.

The legislation the House approved would place most of these education programs at the National Science Foundation. NSF's role is a key to success because of the agency's long history of accomplishment in this area, its close relationship with the best scientists and engineers in the nation, and its prestige, which cannot be duplicated by any other federal agency.

The programs I have described address the long-term problem of ensuring the nation produces future generations of scientists, engineers, and technicians as well as a citizenry equipped to function in a technologically advanced society. But there is also the problem of ensuring adequate numbers of graduates in science and technology fields in the near term.

The legislation at hand also includes provisions aimed at improving undergraduate science, technology, engineering, and math

Creative Discovery Museum

Visitors to Chattanooga's Creative Discovery Museum can observe the effects of static electricity created by a Van de Graaff generator.

(STEM) education with the goals of attracting students to these fields and keeping them engaged. A serious problem with undergraduate STEM education is the high attrition of students leaving the field, often not because of an inability to perform academically but due to loss of interest and enthusiasm.

This exodus in the STEM education pipeline can be addressed in many ways. Certainly, increased attention by faculty to undergraduate teaching and the development of more effective teaching methods will help. In addition, there is a role for industry and federal labs to partner with universities for such activities as providing undergraduate research experiences, student mentoring, and summer internships. The Tennessee Valley Corridor is rich with world-class labs and research centers and knowledge-intensive businesses, which could play an important role in helping to make science and technology careers attractive to students.

There is much that the federal government, states, and the private sector can do in partnership to bring about the result we all seek. The *Gathering Storm* report provides an excellent blueprint for action. The question is simply this: are we willing to invest in our children's future? I know I am not alone in answering "yes" to that question. We know what the problem is, and we have solutions. What we need now is the will to stop talking and start taking substantive action. ■

Bart Gordon, U.S. Representative from Tennessee's Sixth District, was recently named chair of the House Science Committee.

BREDESEN ADDRESS

EDUCATION SUMMIT

I'd like to bring you up to date on our plans for a residential math and science high school for Tennessee's best and brightest, discuss the steps I've proposed to help increase our high school graduation rate, and propose a plan for moving forward with a specific plan for partnership between business and education.

by Phil Bredesen

Tennessee Governor Phil Bredesen delivered the following remarks October 10 at the Tennessee Business Roundtable second annual CEO Summit on Math and Science Education on the campus of Vanderbilt University in Nashville.

It's a pleasure to be with you today. I want to commend you and the members of the Tennessee Business Roundtable for your leadership in creating this event and for your focus on the importance of improving the math and science skills of Tennessee graduates and increasing high school graduation rates to prepare our state's workforce of the future.

As I look around this room, I'm gratified to see leaders in business, education, and government. You are demonstrating that you understand the importance of working together to achieve these goals that are so critical to the future of our state. I want to recognize Commissioner of Education Lana Seivers for the outstanding leadership she and the members of her staff provide every day and to thank Chancellor Gee and Vanderbilt for hosting us.

When I joined you in Oak Ridge a little more than a year ago for the first Summit on Math and Science Education, we discussed the importance of attracting and retaining the best teachers and a new program called Teach Tennessee to enhance our dedicated teaching corps by bringing qualified mid-career professionals to our teaching ranks.

I'm pleased to report that 89 fellows have completed the Teach Tennessee Institute and the Department of Education is reviewing applications for our fourth Teach Tennessee class; 84 of those fellows who have completed the training are qualified in math or science, and five are already filling the need for more Advanced Placement teachers in our schools.

One of these new classroom teachers is a research scientist with a doctorate degree in engineering who's teaching AP and honors calculus in the Memphis City School System. Another holds a doctorate in biochemistry, has conducted breast cancer research for Vanderbilt University, and is teaching honors and AP biology in the Rutherford County School System.

The real-world experience and expertise these men and women bring to our public school classrooms will help students understand where the facts and figures and formulas they're learning could take them some day. And there have been other exciting achievements over the past year. We've

- increased to 527 the number of new pre-K classrooms through our voluntary "Pre-K for All" program,
- extended the Imagination Library to all 95 counties to make sure all children have the opportunity to develop a love of reading right from the start and show up on the first day of school ready to learn,
- continued full funding of the Basic Education Program (BEP) with improvements that include additional money to help

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Students perform experiments as part of Demomania, presented annually by the MTSU Chemistry Club in the Keathley University Center Theater for local high school students.

MTSU Photographic Services

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school districts with large numbers of at-risk or English Language Learner students meet their unique needs,

- committed $1 million to take the first steps toward the creation of a residential math and science high school,
- raised teacher pay above the Southeastern average so we can continue to attract and retain the best teachers,
- invested more than $600 million in new money for important maintenance and capital construction projects on college and university campuses across the state, and
- made improvements in higher education funding that have helped our state's public institutions keep tuition costs affordable.

None of these achievements would have been possible without the commitment of the members of the Tennessee General Assembly, both for their participation in this event and for their continued commitment to bettering Tennessee, especially in the area of education.

Today I'd like to do three things. I'd like to bring you up to date on our plans for a residential math and science high school for Tennessee's best and brightest, discuss the steps I've proposed to help increase our high school graduation rate, and propose a plan for moving forward with a specific plan for partnership between business and education.

I want to offer a new incentive: eliminating tuition at Tennessee's community colleges for every high school graduate who can demonstrate a reasonable level of college readiness.

Math and Science Residential High School

Earlier this year, I presented plans to the General Assembly to establish a highly competitive residential math and science high school.

Between my junior and senior years of high school, I had the opportunity to go to Cornell on a National Science Foundation scholarship to take a physics course. It was a life-changing experience for me. Coming from a small community, going off to a major university, and having the opportunity to be immersed in such a different set of experiences and people influenced my life in ways that are still very much a part of me. I want to offer a similar experience to as many children as I can. For Tennessee's most promising and motivated students, this will give them the knowledge and tools they need down the line to engage in world-class research, inventions, and advances.

We talked initially about locating the school at the UT Space Institute in Tullahoma, but—at least at the outset—we have decided to start in Knoxville, utilizing space immediately available at the Tennessee School for the Deaf.

I would be remiss if I did not publicly thank Tennessee School for the Deaf for inviting these students to share their campus, giving us the temporary location that will allow us to launch our efforts as quickly as possible. This is a beautiful campus, designed with small group cottages to create a home-like atmosphere where students can live and learn together.

Located just a few miles from the University of Tennessee's Knoxville campus and with close proximity to Oak Ridge National Laboratory, we will be able to take advantage of those resources and get the school up and running faster.

We expect to begin with approximately 25 high school juniors and seniors who will have the opportunity to take college-level courses, learn from world-renowned researchers and educators, and participate in apprenticeships and hands-on learning experiences that will bring their learning to life.

I expect the school to begin with its first class of students in the fall of 2007.

Improving Graduation Rates

When we were together last year, we also discussed that we have too many kids falling through the cracks, particularly at the high school level.

While there's no silver bullet for improving our high school graduation rate, which currently stands at 78 percent, a combination of efforts will push that rate higher over time.

I've set what I believe is an aggressive but reasonable goal to raise Tennessee's high school graduation rate to 90 percent by 2012—with the mission of ultimately hitting 100 percent. Our plan includes the following.

- **Attacking chronic absenteeism.** A recent study by the Bill and Melinda Gates Foundation found that roughly 43 percent of American students who dropped out said it was because they missed too many days of school to catch up.

  To address the problem, I want to add dedicated staff positions in each of our 400 high schools to attack absenteeism. And by this I mean professional educators who wake up every day thinking about how to engage these kids and keep them in school.
- **Focusing on individual schools and learning.** The same Gates Foundation study found more than one-third of students drop out because they're failing and can't handle the coursework. Educators agree identifying knowledge gaps early and working aggressively to give these kids the tools they need to catch up is key to helping them overcome their academic problems. To address this issue, I want to use benchmark testing for every eighth grader in Tennessee to design individual learning plans that will bring students up to speed before the 10th grade—before it's too late.

- **Changing students' motivations and expectations.** One of the toughest challenges to keeping some students in school is helping them better understand the potential rewards of finishing. That's why I want to offer a new incentive: eliminating tuition at Tennessee's community colleges for every high school graduate who can demonstrate a reasonable level of college readiness.

We have successful models already. In Kingsport and Sullivan County, local governments are paying graduates' tuition at Northeast State Community College. Unicoi County is doing something similar using private funds.

As I look at the potential for replicating this program, I'd like to see us approach it in much the way we did the Imagination Library. What Dolly Parton began as a program for children in Sevier County is now in every county in Tennessee and growing across the nation.

The funding approach may be different for different communities, as it is in Sullivan and Unicoi Counties. Like the Imagination Library, this is an area where public/private partnerships can come to bear and make a real difference for those students who are not interested in or ready for a four-year college or university. Better leveraging our community colleges is one of the best things we can do to improve the quality of our state's workforce and the quality of life for our young adults.

We are also looking at the possibility of launching a five-year high school program that lets graduates leave with an associate's degree.

The training and development of our workforce at all levels is key to supporting the burgeoning biotech sector in Tennessee. An article in *Memphis Daily News* recently highlighted a program that illustrates what I'm talking about.

Southwest Tennessee Community College has developed a program approved by the Tennessee Board of Regents that gives high school students the opportunity to graduate with a diploma and a technical certificate. The advisory board of Southwest's Engineering Technologies department, which includes representatives from the local bioscience industry, helped develop the curriculum. While most colleges don't accept certificates as credit toward a degree, this program is different because it has obtained national accreditation so the classes are college level and transferable.

From a residential high school for our most promising math and science students to programs that open doors to better paying jobs for students at all levels, these are concrete steps toward the goals of bringing greater relevance to the high school diploma and creating a more skilled workforce.

After high school, the next important signpost in preparing our state's workforce for the knowledge-based jobs of tomorrow is increasing the number of Tennesseans graduating from our colleges and universities.

The UT System and Board of Regents have plans to increase the number of Tennessee college graduates. I am extremely pleased with their focus, and I want to challenge them to move quickly to meet this important goal.

A Specific Plan for Partnership

The last thing I want to discuss is the need for a Tennessee Jobs and Education Workgroup that will elevate partnerships between business and education to an entirely new level. I'm talking about a consortium that will bring a constant business-driven and education-focused third-party view to our state's most important obligation—the education of its children. Unfailingly, we have a business community in Tennessee that responds when its input and assistance is sought on educational initiatives. I've experienced it, and I know my predecessors did as well.

I want to establish a model for more consistent involvement on the part of the business community. Yours is one of our most important voices, and I want it to be a part of the constant and ongoing dialogue pertaining to education in Tennessee. What I envision is something that will outlast any single governor or administration, a nonpartisan entity outside of state government to ensure our state is making—and keeping—education as Tennessee's top priority.

Several southeastern states have organizations in the Columbia Group, a network of business-supported policy centers focused on education. Kentucky's participant in this consortium is the Prichard Committee for Academic Excellence, an independent, nonpartisan group funded by foundations, corporations, and individuals that speak out for progress in education. There are similar organizations in Mississippi, Georgia, Louisiana, and North and South Carolina. I am asking you to work with me over the next year to begin developing such an organization in Tennessee to formalize the role of the business community as advocates for education.

I look forward to working with you in the months and years ahead to continue to move education forward in Tennessee. ■

We are also looking at the possibility of launching a five-year high school program that lets graduates leave with an associate's degree.

GRITS: GIRLS RAISED IN

Zachary Sensabaugh

Expanding Your Horizons workshops include the leader's introduction, a hands-on activity, and a question-and-answer period.

TENNESSEE SCIENCE

EXPANDING YOUR HORIZONS

Without a strong math and science background, our students, particularly women, will not receive the education needed to obtain jobs and be financially independent.

by Judith Iriarte-Gross

No one disputes that there is a "crisis" in science and math education in our country and in Tennessee. Our high-school students enter college without the skills needed to major in those subjects and compete for the higher paying, technology-based jobs in today's workforce. Even low-paying jobs require a fundamental knowledge of science and math. Without a strong math and science background, our students, particularly women, will not receive the education needed to obtain these jobs and be financially independent.

Recruitment, retention, and graduation of women with science, technology, engineering, and mathematics (STEM) training are critical needs. A report from the National Science Board, *Science and Engineering Indicators: 2006*,[1] states that between 2002 and 2012 employment in STEM occupations is predicted to grow by 26 percent while overall employment is predicted to grow only 15 percent. Approximately 78 percent of the increase in STEM jobs will occur in computer-related and technology-based occupations.[2] It is also important to note that 46 percent of the workforce is female, yet only 26 percent of STEM jobs are held by women.[3] A 2004 National Science Foundation (NSF) report indicates that in engineering, only 21 percent of bachelor's degrees were granted to women.[4] In the physical sciences, women attained 43 percent of the degrees.[5] In computer science, 27 percent (and this number is decreasing each year) of the undergraduate degrees were awarded to women.[6] To meet the demand for STEM jobs, women must be educated in the STEM disciplines today.

The challenges of educating and training women in STEM are compounded by attitudes and perspectives found in STEM education and everyday life. In early 2005, Dr. Larry Summers, economist and then president of Harvard, suggested that since fewer girls than boys attain the top scores on math and science high school exams, it must be genetic rather than social differences that explain why few women are successful in STEM fields. Obviously Summers was not aware of the Glenn Report, *Before It's Too Late*, which states that the preparation our students receive in science and math in grades K–12 is unacceptable.[7] Many reports and research studies also propose that women choose non-STEM careers for a variety of reasons that have little to do with their capacity to learn science and math and work in those fields. There are so many commonly held misconceptions, perceptions, and issues regarding women and STEM that science and math are stereotyped as male career categories.[8] Girls often fail at tasks they believe require higher intellectual abilities.[9] Girls frequently lose confidence in their abilities in science and math and thus lower their career goals as they grow up. This leads young women to take fewer science and math courses as they advance into high school and college.[10]

Are we addressing these concerns about women in STEM in Tennessee? Yes! MTSU is "serious about women in science," according to aa NSF reviewer. As the largest undergraduate and fastest growing university in the state, MTSU provides a large, untapped source of potential STEM majors, especially women. If MTSU does not encourage women to major in STEM, then these students will be lost to STEM disciplines. Consider also that MTSU trains approximately 25 percent of the teachers in Tennessee. Think of the potential impact that recruiting, educating, and graduating more STEM teachers would have on Tennessee. We can successfully and quickly influence STEM training across the state through our new teachers. In spite of this, the percentage of MTSU women students in STEM disciplines is below the national average in most areas, especially physics and astronomy, engineering technology, and computer science.

The STEM pipeline for women begins in middle school. In 1974, the Math/Science Network (now Expanding Your Horizons Network, www.expandingyourhorizons.org), realized that girls were dropping out of middle school and

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Zachary Sensabaugh

In the popular "Glitter Girls" workshop, attendees discover that chemistry is behind the lip gloss, body lotion, and hair products they yearn to use and learn to make bath fizzies using corn starch, baking soda, and raspberries.

The MTSU EYH is the only such conference in Tennessee and one of three in the southeastern United States.

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developed strategies to address this growing problem. The strongest and most successful strategy was a hands-on conference for girls only called *Expanding Your Horizons in Science and Mathematics* (EYH). MTSU's EYH just celebrated its 10th anniversary.

The MTSU EYH is the only such conference in Tennessee and one of three in the southeastern United States. It was first held in October 1997, after a year of planning by a committee of MTSU faculty and administrators along with community partners, the Girl Scout Council of Cumberland Valley and the Murfreesboro branch of the American Association of University Women (AAUW). The first MTSU EYH served more than 300 middle school girls from 38 counties in middle Tennessee as well as girls from southern Kentucky. For the past eight years, Buddy Sullivan, algebra teacher and graduate of the MTSU Department of Mathematical Sciences, has brought a busload of eighth-grade girls, potential first-generation college students, from Dalewood Middle School in Chattanooga. During the past 10 years, more than 3,000 middle school girls have attended the MTSU EYH along with 200 parents, teachers, and Girl Scout troop leaders.

Each EYH conference is designed specifically to meet the needs of the girls it serves, and thus the MTSU EYH is specifically designed for Tennessee girls. It is planned and executed with volunteers from the campus and community partners, the Girl Scout Council of Cumberland Valley and the Murfreesboro branch of the AAUW. Everyone's specific role makes the one-day MTSU EYH a well-executed and successful conference every year. Let me now describe a typical MTSU EYH conference.

The day begins with the MTSU EYH committee setting up the registration area and unloading boxes of goody bags stuffed with information about STEM careers along with pens, pencils, notepads, posters, and the EYH student packet. This year, we received a book, *So You Want To Be A Chemist*, from the Education Division of the American Chemical Society and pink pens from the MTSU Office of the Executive Vice President and Provost. The committee begins its work at 7 a.m. in anticipation of the opening of the conference an hour later, when the girls are assigned to groups and pick up their name badges, an EYH T-shirt, and a goody bag. The girls cannot wait, however, and often arrive around 7:30 a.m, eager to begin learning about STEM careers.

The MTSU EYH begins its formal program with welcomes from MTSU, the Girl Scouts, the AAUW, and the MTSU Women in Science and Engineering (WISE) student organization. The welcome is followed by a keynote address. MTSU EYH keynote speakers have included Rhea Seddon, Murfreesboro native and astronaut; Nancy Van Camp, WSMV-TV Channel 4 Pinpoint Weather meteorologist from Nashville; and Stacey Roberts-Ohr, national EYH director. After the keynote speech, EYH GROUP leaders and MTSU student volunteers direct the girls to their morning workshops.

MTSU EYH workshops are unique and designed to include an introduction by the workshop leader, a hands-on activity, and a question-and-answer period. I became involved in EYH by volunteering to present a workshop at the University of Texas–Arlington EYH conference. I still call my workshop, "Ooze, Goo, and Slime: An Introduction to Polymer Chemistry." I begin my workshop by introducing myself as Dr. Judith Iriarte-Gross. Immediately, a hand will rise with a question such as "What kind of doctor are you?" or "Are you a children's doctor?" This gives me an opening to explain what a Ph.D. degree is and the opportunity to explain what is required to earn one. More questions are asked such as "How much math did you take in high school?" and "Why did you study chemistry?" It is reassuring to see the girls asking questions without hesitation. As you can imagine, the hands-on activity for my workshop is to make slime. One question I always get is "Is your name really Dr. Gross?" after we make the gooey and gross slime.

Other MTSU EYH workshops have included "Open Up and Say Woof" on veterinary medicine, "Rocking Raider Robots" on

robotics, "How to Make a Million" on finance careers, and "High Flying Women" on careers in aerospace. WISE members have offered a popular workshop called "Glitter Girls" on cosmetics chemistry. In this popular workshop, the girls discover that chemistry is behind the lip gloss, body lotion, and hair products they yearn to use and learn how to make bath fizzies using corn starch, baking soda, and raspberries. Each MTSU EYH conference offers more than 40 hands-on workshops, and we add new workshops each year. In 2006, the new favorite was "Taking a Bite Out of Jaws" on marine biology.

After the two morning workshops, the girls, still in their assigned groups, go to lunch, relax, and chat with old and new friends about their morning adventures. Lunch is quick because the girls can't wait to attend the two afternoon workshops. Throughout the day, each girl attends four workshops, each in a different STEM discipline: physical science, biological or health science, math or engineering, and technology and computer science.

The MTSU EYH day ends with each girl completing an evaluation about her EYH experiences, required in order to win a door prize. The prizes are related to science and math or higher education. We have given away books such as *Women in Chemistry* and *Nobel Prize Women in Science,* calculators, math and science software, MTSU T-shirts, and passes to the Tennessee Aquarium in Chattanooga.

For more than 30 years across our nation and for 10 years at MTSU, EYH has been showing middle school girls they can succeed in science and mathematics. How do we know we are making an impact with these girls? We hear about STEM achievements from the girls themselves. In 1997 as we were planning the first MTSU EYH, I received a call from an engineering student at Vanderbilt. She volunteered to help, saying, "I am a mechanical engineer now because EYH showed me that I could BE an engineer." An early graduate of the MTSU EYH is now studying astronomy at the University of Chicago. A high school senior is entering the chemical engineering program at UT–Knoxville because of the MTSU EYH. And women students from Blackman High School presented a workshop, "Colorific Chemistry," because of the joy they discovered in chemistry as middle school girls attending the MTSU EYH.

What does the future hold for women in science at MTSU? We are supporting women in STEM majors through the Women In Science and Engineering student organization. WISE provides a supportive network of women who can talk to each other about calculus and organic chemistry, invites professional women from the community to network with the students over dinner in the residence hall, hosts the annual Women in Science invited lecture sponsored by the MTSU National Women's History Month Committee each spring, and gives back to the community by volunteering at EYH and other science-related events for children.

A new program beginning at MTSU in January 2007 is GRITS: Girls Raised In Tennessee Science. This program, funded by the NSF, is a program that will explore creative paths to disseminate information about STEM careers to girls in Tennessee, where many girls do not attend college or even graduate from high school. GRITS will provide parents, teachers, and guidance counselors with new insights on how to encourage their daughters in STEM classes and careers. A major goal is to positively affect STEM education, training, and workforce development as well as improve economic conditions for a significant number of women and their families in Tennessee. You can see that MTSU is serious about women in science! ■

Judith Iriarte-Gross is an associate professor of chemistry at MTSU.

A new program beginning at MTSU in January 2007 is GRITS: Girls Raised in Tennessee Science.

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MATH IS THE BACKBONE

I would like to share a little bit of what I have been seeing at the national policy level regarding math and science, drawing on my work with the National Math Panel and National Science Board. I also want to offer a few insights from my own experience over the course of several decades studying children with a high level of math talent. And finally, I want to suggest a few implications of all this for Tennessee and some ways I believe business can be helpful.

Foremost, math and science education is receiving a great deal of emphasis at the federal level—not only in the Department of Education but also in the Department of Defense and at agencies like the National Science Foundation (NSF), which funds not only basic scientific research but also research into better ways to teach math and science.

The attention these agencies are giving to math and science is driven by public discussions among intellectuals, the business press, policy experts, and politicians who believe that the U.S. is at risk of losing its competitive edge in the global economy. There is evidence to support their concern:

- Based on its rapid economic growth, many economists now project that China will surpass the U.S. within several decades to become the leading economy of the world.
- The Trends in International Mathematics and Science Study (TIMSS) shows eighth-grade students in 15th place internationally in mathematics and in 9th place in science.[1]
- In 2002, the U.S. produced only 15 percent of the world's doctorates in engineering, well behind both the European Union and the Asian/Pacific countries.[2]

Why should business people worry about the production of Ph.D.s? In the STEM professions (science, technology, engineering and math), the number of Ph.D.s we graduate indicates our national capacity for innovation and by implication our future economic well-being. Even those doctoral graduates who are working in educational settings make important contributions to the economy. The NSF recently released data showing that research and development funding—from all sources, including business—contributed 6.5 percent to economic growth in the U.S. between 1995 and 2002.[3] For economic growth to continue and to increase, we need highly educated people.

The fact is we live in an ideas-based economy. It is no longer about who has the most coal or oil. The economic winners of the future, including states, will be those who can generate ideas and rapidly turn them into products.

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The number of Ph.D.s we graduate in science, technology, engineering, and math indicates our national cpacity for innovation and by implication our future economic well-being.

by Camilla P. Benbow

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The president of MIT testified that only 6 percent of U.S. undergrads are likely to pursue careers in engineering, compared to more than 40 percent in China.

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The resource most needed in this new economy is talent. In fact, *talent* is the word of the moment. In devoting its October 7 issue to the topic, *The Economist* magazine proclaimed talent "the world's most sought after commodity."[4] The authors cited recent studies, including one from the Corporate Executive Board, of human resource managers. The vast majority of these respondents indicated that "'attracting and retaining' talent was their number one priority."[5]

Corporations are not the only ones responding to the perceived threats to competitiveness. In January 2006, President Bush launched his American Competitiveness Initiative. Education is a critical component of the initiative, especially in the areas of math and science. The U.S. Department of Education's National Mathematics Advisory Panel, on which I serve, is also part of this initiative.

The Math Panel, following the model of its successful predecessor the National Reading Panel, is charged with receiving public testimony, studying scientific evidence, and making recommendations on how to teach math from kindergarten through eighth grade. Our ultimate goal is to prepare children better for algebra and the higher maths that are so important to economic growth.

It is too early in the process to report any specific findings. We are holding public meetings in various locations and gathering public testimony. Some of the testimony we have heard reflects themes voiced in the media and other public forums.

For example, we have heard testimony that the K–12 pipeline is simply not preparing sufficient numbers of future engineers. The president of MIT testified that only 6 percent of U.S undergrads are likely to pursue careers in engineering, compared to more than 40 percent in China. People have told us that curriculum in math is too broad and lacks depth—that educators are trying to cover too much and that the resulting learning is only superficial. The number-one nation in math in the TIMSS study is Singapore, and our curriculum is often compared with theirs. Singapore's is very lean, focusing on key concepts and their mastery.

Textbook publishers have testified that the reason math texts are so thick (sometimes 700-plus pages) is because they are trying to respond to conflicting mandates across 50 states. Publishers lament the lack of nationally agreed-upon guidelines.

Teachers, meanwhile, are struggling to cover it all, and the result is that students do not get to do any work in depth. Moreover, at each successive grade, teachers review repeatedly. When introducing new concepts, they do not worry about achieving mastery because they know the concepts will be taught again.

We have also heard testimony from the National Council of Teachers of Mathematics, which released a new report in September offering a set of "curriculum focal points." Through a consensus of math educators and mathematicians, the council outlined key math concepts students should understand at each grade level. The new focal points attempt to resolve conflicts between state curricula and provide clarity. The testimony we are gathering will assist us in formulating recommendations to encourage more effective teaching.

On the funding side of the federal equation, I have observed increasing attention to developing programs for future STEM leaders.

- The Department of Defense is putting millions into increasing the STEM pipeline to ensure it can meet its own workforce needs. It is eager to partner with programs across the country and willing to provide funding.
- The NSF is also funding more projects we hope will help answer the question: How do innovations happen?
- The National Institute of Child Health and Human Development is decreasing funding for reading research and increasing funding for research in math and science education.
- The Department of Education is planning to launch Math Now grants to states to help implement the final recommendations from the National Math Panel.

Despite all the interest in math and science, I would argue that what is not generally clear is that there there are two separate issues at play. Each requires different educational answers. Issue #1 is how to create a prepared workforce literate in these subjects. Issue #2 is how to ensure a sufficient supply of STEM leaders.

STEM leaders will be the future innovators—those who create ideas and register patents. Designers of school curricula need to remember that, in terms of achievement, one person's ceiling is another's floor. At the same time, we need people who can take a new idea and run with it, putting ideas into production. We need a math/science literate workforce, so we must also raise the mean level of achievement for all children. The challenge is great. We have to raise the mean *and* lift the ceiling.

Two of Vanderbilt's professors, Rich Lehrer and Leona Schauble, have been working with middle school teachers and students in one of Nashville's tougher schools—for all practical purposes an inner city school. These are kids whose teachers had mostly given up on them before Lehrer and Schauble arrived on the scene. Though well along in their schooling,

these students still did not have basic numeracy skills. Our professors did something counter-intuitive: they went in through geometry, using modeling concepts like drawing, diagramming, and mapping to develop basic arithmetic skills. Remarkably, they succeeded.

At the other end of the continuum, my own research focuses on mathematically talented youth. I began at Johns Hopkins working with Julian Stanley and the Study of Mathematically Precocious Youth, a 50-year longitudinal study that I continue today at Vanderbilt. It is an amazing study that demonstrates, among many other things, the success that is possible when gifted children get the advice, educational enrichment, acceleration, and challenge they need. At Iowa State later and at Vanderbilt I also helped develop summer programs for the gifted and talented as well as academic-year programs.

One of our participants at Johns Hopkins was Terrance Tao. This fall, Tao won the Fields Medal, generally considered the math equivalent of the Nobel Prize. He also received a MacArthur genius grant. Tao started learning high school–level calculus when he was seven. By nine, he had progressed to university-level calculus. He earned his Ph.D. from Princeton at 20 and became a full professor at UCLA by 24.

Talent like Tao's is important to society. Through our study, we have found that 20 years after going through the special math/science programs for talented youth, participants are twice as likely to be in high-level STEM careers as equally able nonparticipants.

How can we increase the supply of such people here in Tennessee? At Iowa State we learned that talented students who attended our formal program of enrichment and acceleration in middle school were twice as likely to come to college at Iowa State and thus also more likely to stay in the state after college. We learned these programs can be especially helpful in keeping talented women on track in STEM fields.

By providing more special programming for math and spatially talented youth, we can produce more STEM leaders for Tennessee. We have to do a better job of offering the intellectual enrichment and acceleration that go beyond the coursework of a typical school if we want Tennessee to keep its most gifted young people, the innovators of the future. Although our state has a few such programs, we do not have enough.

Business leaders also have roles to play. Educators can improve the curriculum. We can improve teacher training and professional development. We can do some things to raise the mean and raise the ceiling, but we need partners. Here are a few suggestions:

- Too many students do not understand why math and science are relevant. Business can show them why. Open your companies to students and teachers. Kids need to see how what they are learning can be applied. Offer internships; help spark their passion.
- Partner with schools to strengthen math and science education. There are people in your companies working in the STEM areas who genuinely love what they do. Get them out in the schools from time to time to talk about what they do and share their knowledge.
- Collaborate with your local university. For example, Dell partners with the Vanderbilt Virtual School in a competition between local schools, "Dell Student Technology Leadership Competition and Showcase." The program stimulates interest in science and technology and rewards creativity.
- Help provide enrichment and acceleration to talented youth—to stimulate and keep the best and brightest here in Tennessee. Too many kids lack the means to participate in summer academies. Offer scholarships.
- Developing products and sponsor your own experiences emphasizing math and science. The NSF is putting more funding into informal education—what kids do with the 40 percent of time they're not in school, sleeping, or eating. There are opportunities here.
- Finally, work together to create communities that attract talent. Talented people cluster together. Make Tennessee such a Mecca.

I am enthusiastic about the opportunities before us. People are making the connection between competitiveness, education, prosperity, and quality of life. Government and schools are on board. With business as a partner, together we can preserve and even create opportunities for the success of all Tennessee children. ■

Camilla P. Benbow is the Patricia and Rodes Hart Dean of Education and Human Development at Vanderbilt University, Peabody College, and vice chair of the U.S. Department of Education's National Mathematics Advisory Panel. President Bush appointed her to the National Science Board. She is a codirector of the Study of Mathematically Precocious Youth.

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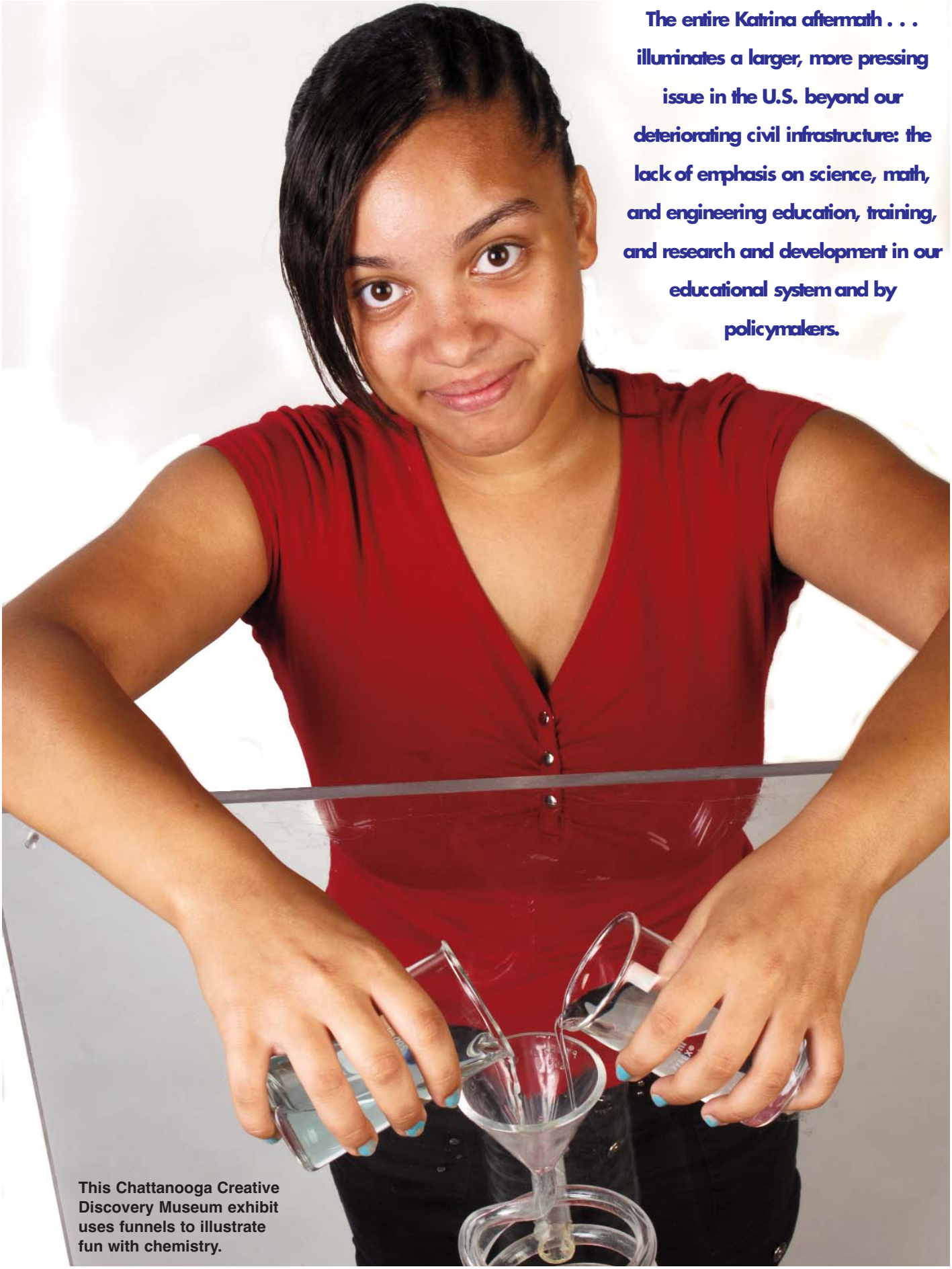
We learned that talented students who attended our formal program of enrichment and acceleration in middle school were twice as likely to come to college at Iowa State and thus also more likely to stay in the state after college.

The entire Katrina aftermath . . . illuminates a larger, more pressing issue in the U.S. beyond our deteriorating civil infrastructure: the lack of emphasis on science, math, and engineering education, training, and research and development in our educational system and by policymakers.



This Chattanooga Creative Discovery Museum exhibit uses funnels to illustrate fun with chemistry.

Creative Discovery Museum

HURRICANE KATRINA & GLOBAL COMPETITIVENESS

by Calvin Mackie

On August 29, 2005, Hurricane Katrina, the sixth storm of the hurricane season, rolled into the U.S. Gulf coast, causing unprecedented damage and loss of life. More than 93,000 square miles were affected and 275,000 homes severely damaged or destroyed. The storm surge from Katrina caused severe and catastrophic damage along the coast, devastating the cities of Waveland, Biloxi, and Gulfport in Mississippi and New Orleans and surrounding towns in Louisiana. The levees separating Lake Pontchartrain from New Orleans were breached by the surge, ultimately flooding 80 percent of the city or 140 square miles, an area equivalent to 7.5 times the size of Manhattan, for weeks. More than 58 billion gallons of water poured into New Orleans, enough to fill the Superdome 62 times over. In Louisiana alone, more than 200,000 houses were destroyed and 81,000 businesses affected or closed. In comparison, Hurricane Andrew in 1992 destroyed 28,000 homes in South Florida, and the four hurricanes that ravaged Florida in 2004 destroyed only 27,000 homes. Severe wind damage was reported well over 100 miles inland. At least 1,836 people perished in Katrina and the subsequent flooding, making it the deadliest U.S. hurricane since the 1928 Okeechobee Hurricane. The storm is estimated to have been responsible for $82 billion in damage, making it the costliest natural disaster in U.S. history.

On June 1, 2006, the U.S. Army Corp of Engineers presented their findings on the Levee failures in New Orleans, concluding what all of us in the New Orleans area already knew: that the levees, which are totally the responsibility of the U.S. Army Corps of Engineers, failed due to design flaws. Today more than 200,000 people remain displaced from their homes and city because scientists, engineers, and their government failed to properly protect them. In its defense, the Corps can build only what Congress authorizes. Over the years, the Corps, FEMA (Federal Emergency Management Agency), and local activists and political officials have feared the impact of such a storm on the most vulnerable place for flooding in the U.S.; everyone knew the system was inadequate. That the entire Katrina aftermath, viewed around the world, could have been avoided illuminates a larger, more pressing issue in the U.S. beyond our deteriorating civil infrastructure: the lack of emphasis on science, math, and engineering education, training, and research and development in our educational system and by policymakers. As the knowledge economy grows, it is important that we produce more scientists and engineers, invest in research and development infrastructure, and increase all American students' understanding of science, technology, engineering, and mathematics (STEM). Otherwise we threaten our economic welfare as well as the security of the country.

The Army Corps of Engineers had to build levees made out of bubblegum and matchsticks because Congress did not and still does not grasp the situation. Very few members of Congress have scientific backgrounds, so most arguments are not settled based on facts, figures, and scientific data but on what is politically expedient. In *The World Is Flat*, Thomas Friedman recalls a conversation in which Bill Gates says he loves talking to politicians in China because many are scientists and engineers who "get it," unlike those in the United States. Building levees, protecting New Orleans, and shoring up our failing infrastructure are not "sexy" and have not received appropriate funding from Congress regardless of the majority party.

For more than half a century, the U.S. has led the world in scientific discovery and innovation, and now that leadership is being challenged by factors at home and abroad. Foreign advances are challenging U.S. leadership in innovation and education. The U.S. has been a beacon, drawing the best scientists to its educational institutions, industries, and laboratories from around the globe. American educational institutions have always had the advantage of skimming the cream of the crop from nations like China, India, and Japan, bringing the best minds in the world to study and eventually work

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in the U.S. However, in today's rapidly evolving, competitive world, the U.S. can no longer take its supremacy for granted. Nations from Europe to Eastern Asia are on a fast track to pass the U.S. in scientific excellence and technological innovation (The Task Force on The Future of American Innovation: *Innovation is America's Heartbeat*).

Many of these intellectual first-round draft choices are deciding to return to their home country because of improved economic opportunities or not to attend school in the U.S. because of continuously increasing academic capabilities and advances. With the tragic terrorist events of 9/11 and the creation of the Department of Homeland Security, many foreigners have found it more difficult to obtain work and school visas in the U.S., and corporations have been feeling the pinch of a tight technologically trained work pool filled with mostly foreign workers. The aftermath of 9/11 demonstrates that we have to educate, develop, and train more U.S.-born scientists and engineers. Thus, many politicians, educators, and business leaders are truly concerned about the country's ability to compete in the future. President Bush in his 2005 State of the Union address called for a $136 billion boost in science and education research over the next 10 years. President Bush stated, "We cannot afford to be complacent. In a dynamic world economy, we are seeing new competitors, like China and India."

The aftermath of 9/11 demonstrates that we have to educate, develop, andt rain more U.S.-born scientists and engineers.

Why are President Bush and other leaders concerned? Consider the following:

- In 2005, China graduated 500,000 engineers, India 200,000, and North America 70,000 (National Academy of Science Report: *Rising Above the Gathering Storm*).
- According to the National Science Foundation (NSF), more than half of U.S. Ph.D. degrees awarded in physics, engineering, mathematics, and computer science are awarded to non-U.S. citizens. In 2004 alone, 46 percent of master's degrees and 57 percent of doctoral degrees were awarded to foreign nationals.
- In the U.S. in 2005, less than 5 percent of all undergraduate degrees were awarded to engineers, compared to 8 percent in 1985. The production of engineering degrees by women, African Americans, and Hispanics is declining or flat at best (American Society of Engineering Education, *PRISM*, October 2006, pp. 27–31).
- According to the National Science Board, the U.S. has fallen to 17th in the world in the number of 18–24 year olds who receive science degrees, whereas it ranked third three decades ago.
- According to the NSF, the percentage of scientific papers written by Americans has fallen 10 percent since 1992.
- The percentage of American papers published in the top physics journal *Physical Review* has fallen from 61 percent to 29 percent since 1983 (*New York Times,* May 3, 2004, William Broad, "U.S. Is Losing Its Dominance in the Sciences").
- Asian students are less likely to study in the U.S. From 1994 to 1998, the number of Chinese, South Korean, and Taiwanese students who chose to pursue their Ph.D. at U.S. universities dropped 19 percent (from 4,982 to 4,029). At the same time, the number who chose to pursue their Ph.D. at universities in their own countries nearly doubled (from 4,983 to 9,942). This indicates these countries are quickly developing their own higher educational capabilities (NSF, *Science and Engineering Indicators 2002*, Appendix, Table 2-41; adapted from Diana Hicks, "Asian Countries Strengthen Their Research," *Issues in Science and Technology*, Summer 2004; compiled by the American Physics Society Office of Public Affairs).

To remain competitive, there are great challenges to overcome, including but not limited to a shortage of scientific mentors, parental pressure on kids to seek more lucrative careers, discrimination against science-bound women and minorities, the prevailing nerdy image of scientists and engineers, the lack of science and math preparation for K–12 teachers, and the country's unhealthy, overzealous focus on celebrity and fame. As Thomas L. Friedman noted in his bestseller *The World is Flat*, "In China, Bill Gates is a star, a celebrity; students would hang from rafters to get a glimpse of or hear a speech from Bill Gates. In China, Bill Gates is Britney Spears, and in America, Britney Spears, well, is Britney Spears."

We have to do a better job of preparing our children for the future and informing them of what will be needed to succeed and thrive in a global community. For example, in 2005, the Raytheon Corporation surveyed 1,000 11-to-13-year-olds and discovered that 84 percent would rather "clean their room, eat vegetables, go to the dentist, or take out the garbage than learn math or science." In essence, 84 percent of the kids have no interest in preparing themselves to participate in the global knowledge economy. Recently Craig Barrett, the former CEO of Intel, noted that Intel's annual international science competition in 2004 attracted about 50,000 American high school kids. "I was

in China 10 days ago," Mr. Barrett said, "and I asked them how many kids in China participated in the local science fairs that feed into the national fair [and ultimately the Intel finals]. They told me six million kids" (*The World is Flat*, Thomas L Friedman). Our students and their parents must realize that they are now competing against the world and that other nations are doing a better job of preparing their children for a stable future based on a technological economy.

To remain competitive, the U.S. must train and develop an emerging talent pool that looks very different from that of years and decades past. Women and minorities are the fasted growing populations in the U.S., and efforts must be made to include them. Therefore, we need professors and teachers who can serve as role models and mentors for women and minority students in the STEM pipeline. While the percentage of tenured women faculty at the university level in STEM areas is edging up, the percentages of Hispanics (2.3 percent) and African Americans (2.4 percent) among tenured or tenure-track faculty were essentially unchanged from 2004 to 2005 (American Society for Engineering Education, *PRISM*, October 2006, p. 31). While our competitive future is in question, many are still debating and questioning the need for and benefits of racial and ethnic diversity in the workforce and especially on our college campuses. Without a comprehensible plan of inclusion to make sure all segments of society have access to opportunity via the educational system, America will move closer and closer to losing its technological- innovation leadership in the world. The country cannot move forward leaving most of its people behind. If the country and its leaders fail to prepare and equip citizens from all population groups to participate and succeed in the present and future knowledge and technology driven economy, we risk undermining our own demise on the world stage, economically and intellectually.

Research, education, the technical workforce, scientific discovery, innovation, and economic growth are intertwined. To remain competitive globally, the U.S. must ensure that each of the stated factors remains vigorous and healthy, which will require sustained investment and informed policies. Based on the aftermath of Katrina, we have a long way to go since Congress still does not understand that failed and uninformed policies caused the levee failures in New Orleans. As of July 1, 2006, 55 percent of the Senate and 75 percent of the House of Representatives had not visited the worst natural/manmade disaster in the country's history. Therefore, it only makes sense that Congress has authorized and allocated funding for the U.S. Army Corp of Engineers to restore and repair the flawed levees in New Orleans only to pre-Katrina levels. Congress does not understand that we need a comprehensive protection system that includes levees as well as coastal restorations. Louisiana officials estimate $14 billion is needed to regain the 2,000 square miles of wetlands lost since the 1930s, putting the Gulf of Mexico in New Orleans's backyard. However, the Bush Administration and Congress have committed only $6.7 billion for rebuilding and strengthening the levees and $115 million for coastal wetland repairs: a spending ratio of 60 to 1. Congress also does not seem to comprehend the "gathering storm" off our coast as it relates to STEM and global competitiveness. The solution, just like the necessary solution in New Orleans, is not a cheap, short-term, "stay the course," "do as we have always done" solution. To remain competitive, we must reinvest in our scientific and engineering workforce and training as we did in 1957 when the Soviet Union challenged our science competitiveness with the launch of a basketball-sized satellite called Sputnik. Today's Sputnik is China and India. The growth in their high-technology capabilities is the "gathering storm," and we must respond. While the solutions are complex and intertwined, one solution we cannot deny is cultural, requiring all of us to make science, technology, engineering, and math attractive to and necessary for all students today. In the future, we will need scientists, technologists, and engineers not only in laboratories, corporations, and universities but also in policymaking positions—even in Congress and the White House. If we do not do the necessary things now, once again the country will be blindsided by the gathering category-5 storm off her coast, and we will look to India and China to do for us what we otherwise could have done for ourselves. ■

Speaker, author, and inventor Dr. Calvin Mackie is an associate professor of mechanical engineering at Tulane University in New Orleans, specializing in heat transfer and fluid dynamics. President Bush honored him with the 2003 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring. Louisiana Governor Kathleen Blanco appointed Mackie to the 33-member Louisiana Recovery Authority, leading the state's rebuilding efforts following hurricanes Katrina and Rita. He is the author of A View from the Roof: Lessons for Life and Business. *He was featured in Spike Lee's HBO documentary* When The Levees Broke: A Requiem in Four Parts *and on the* News Hour with Jim Lehrer *as a panelist discussing the one-year anniversary of Katrina.*

To remain competitive, we must reinvest in our scientific and engineering workforce and training as we did in 1957 when the Soviet Union challenged our science competitiveness with the launch of a basketball-sized satellite called Sputnik.

IMPROVING STATE MATH

CENTER (TMSTEC) TO FOCUS ON

by E. Ray Phillips and Dovie Kimmins

No one would argue the point that the American educational system has had serious problems for some time. A series of national reports, from *A Nation at Risk* in 1983 to *Rising Above the Storm* in 2005, indicate these problems have reached a crisis level in math and science education. The Glenn Commission (2000) stated:

> *We as a nation must take immediate action to improve the quality of math and science teaching in every classroom in the country. If we delay, we put at risk our continued economic growth and future scientific discovery.*

National Assessment of Education Progress data show that reading, math, and science scores of high school seniors have changed little over several years. On the latest Trends in International Achievement in Mathematics and Science Study (TIMSS, 2003), U.S. students were outperformed in math by their counterparts in 13 other countries. This year President Bush announced the American Competitiveness Initiative, which focuses on strengthening schools' capacity to improve instruction in math and science.

Tennessee Mathematics, Science, and Technology Education Center (TMSTEC)

Only about a third of Tennessee's high school graduates are prepared for college or the workplace due largely to a weak foundation in math and science. A skilled workforce with a strong preparation in math and science is critical to maintaining our nation's economy, security, scientific and technological edge, and quality of life. To encourage, motivate, and facilitate collaborative efforts among leaders from education, government, and industry to improve math and science education in the state, TMSTEC was established in 2002 with initial funding from NASA. Housed in the College of Basic and Applied Sciences at MTSU, TMSTEC serves the state and is Tennessee's member of the National Alliance of State Science and Mathematics Coalitions. NASSMC is a national group that focuses on helping states initiate systemic change in math and science education through appropriate partnerships.

TMSTEC's vision is that Tennessee will develop programs of distinction in math, science, and technology for all K–16 students to encourage participation and success at students' full potential. TMSTEC's mission is to enhance the quality of math, science, and technology education in Tennessee through collaborative partnerships among business, industry, education, and policymakers. To pursue its vision and achieve its mission, TMSTEC will focus on six major goals:

- develop and provide quality professional development for math and science teachers;
- inspire and motivate students to study and learn more math and science;
- influence state policies related to math, science, and technology education;
- encourage and promote the development of undergraduate and graduate programs of excellence in math and science education;
- promote and facilitate scholarly research on the teaching and learning of math and science; and
- encourage and facilitate collaboration among business, industry, education, and state policymakers to ensure a skilled, capable future workforce.

Since its inception, TMSTEC has focused its efforts on the overall enhancement of K–16 math and science education in the state. Through collaboration among business/industry, education, and government leaders and policymakers, TMSTEC has engaged in professional development for teachers, innovative curricula, research and evaluation, state math and science education policy, and motivation of students.

Partnership Building

NASSMC, with strong support from NASA and the U.S. Department of Education, is a national organization that supports the development of state science and math coalitions. NASSMC's goal is for all states to develop a coalition. At present, coalitions have been organized in 40 states. TMSTEC was selected as Tennessee's NASSMC member, a significant recognition of TMSTEC's achievements in a short period of time.

Since its inception, TMSTEC has participated in NASA's Linking Leaders program,

TH AND SCIENCE EDUCATION

aimed at bringing together stakeholders from education and business/industry as well as government/policymakers to work together to improve math and science education in Tennessee. In 2006 TMSTEC organized the *Tennessee Summit on Math and Science Education: Educating Tomorrow's Workforce Today*. The summit was funded by NASA, the U.S. Department of Education, and NASSMC with additional support from State Farm, Nissan, and TVA. More than 70 invited key stakeholders from across the state (15 representing business/industry) engaged in general and working sessions aimed at identifying specific problems to be addressed and developing a plan for action. The Linking Leaders group is continuing to develop recommendations for en-hancing the state's math and science education programs. With the help of influential legislative members of the Linking Leaders team, the appropriate state-level

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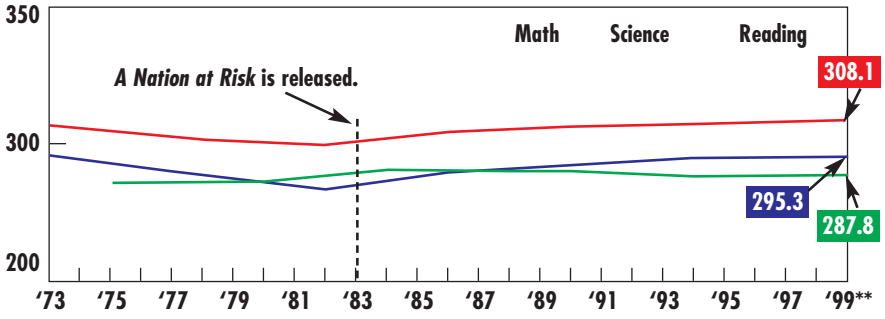
The Tennessee Mathematics, Science, and Technology Education Center focuses on enhancing the quality of math, science, and technology in education in the state through collaborative partnerships among business, industry, education, and policymakers.

This display about light and optical illusions is one of many science exhibits at Creative Discovery Museum in Chattanooga.

Creative Discovery Museum

Three Decades of NAEP Scores

Long-term trends reflect little change in reading, math, and science scores among high school seniors.*



* According to National Assessment of Educational Progress standards
** Most recent data available
Source: National Center for Education Statistics

Tennessee ranked 41st in the nation on the 2005 National Assessment of Education Progress math scores.

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policymakers will be made aware of these recommendations.

Professional Development

Teacher quality is a critical determinant of how much students, regardless of background, will learn. Students of good teachers can learn the equivalent of a full year more of content than students of weaker teachers (Hanushek, 1992; Goldhaber and Brewer, 2000; Newborn, 2003). There is evidence that teachers who know more about their subject matter are generally more effective, especially in math and science (Goldhaber and Brewer, 1996; Rowan et al., 1997). However, the math and science that teachers need and how they need to know it may be different from needs in other arenas (Lewis, 2006; Ball et al., 2005; National Research Council, 2001). In addition, effective math and science teachers must be able to use alternative strategies that motivate learners of diverse backgrounds and abilities. Instructional strategies that focus on the meaningful development of important mathematical and scientific ideas, incorporate students' intuitive solution methods, and promote problem-solving and critical thinking are essential tools for helping students learn (National Research Council, 2005, 2001; Grouws and Cebulla, 2000). Enhancing teachers' mathematical and scientific knowledge and instructional skills will boost their confidence as teachers (Greabell and Phillips, 1990). Teachers who are confident in their ability to teach math and science are in a better position to help all students to learn more math through student-centered activities and technology and to take control of their own learning (National Research Council, 2005).

Through collaboration with the Tennessee Department of Education, the Tennessee Higher Education Commission, school districts across the state, university educators, mathematicians and scientists, and master classroom teachers, TMSTEC is developing and delivering quality research-based professional development for math and science teachers. The TMSTEC professional development model focuses on (1) giving teachers a much broader and deeper understanding of math and science content related to the K–12 math and science curriculum and (2) providing teachers with alternative teaching strategies focusing upon inquiry and problem-solving; effective use of technology and models; integration of math and science; and emphasis on connections, applications, and the language of science and mathematics. While further studies are needed, there is evidence that this type of professional development enhances teachers' confidence and effectiveness and their ability to motivate students, which results in better performance of all students in math and science. Additionally, these results could have implications for the revision of undergraduate teacher education programs for math and science teachers in the middle grades.

Innovative Curriculum

Data show that teachers who have participated in TMSTEC professional development have enhanced their content knowledge and instructional strategies and are more confident in their ability to help all students reach their full potential in math and science (Martin et al., 2006; Phillips et al., 2006; Kimmins and Chappell, 2004; Phillips and Kimmins, 2002; Kimmins and Phillips, 2002). These teachers are motivated and enthusiastic about changing their instructional practices to include more inquiry and problem-solving approaches; effective use of technology, models, laboratory activities, and student projects; and emphasis on connections, applications, and the language of science and math. Research on how students learn math and science indicates that the aforementioned approaches are essential for elementary and middle school students to develop the meaningful understanding necessary to successfully study high school math and science. In collaboration with the Tennessee Department of Education, TMSTEC is making a strong effort to raise the awareness of districts regarding innovative math and science curricula based on the principles of how students learn math and science. In collaboration with the Tennessee Department of Education, TMSTEC has organized two statewide seminars showcasing standards-based National Science Foundation

developed curricular materials in math and science. In addition, TMSTEC houses Tennessee's NASA Educator Resource Center, where these materials and NASA-developed materials are available for teacher use.

High School Success or Dropout

Far too few teenagers are graduating from Tennessee high schools. More than 31,000 students failed to graduate from Tennessee's high schools in 2004–2005, costing the state more than $8 billion in lost wages, taxes, and productivity over their lifetimes (Alliance for Excellent Education). Further, the state's low graduation rate has a negative impact on the economic development and industrial recruitment efforts of communities (Johnson City Press, 2006). This is a high cost for the state to pay but not nearly as high as the personal cost to students of dropping out. *High school dropout* is a label that prevents an individual from obtaining a job that pays reasonably to support a quality lifestyle. Even when a high school dropout finds a job, there are very limited benefits and almost always no chance for advancement. A high school graduate makes $9,200 more per year on average than a high school dropout. The bottom line is that achieving the American dream for a high school dropout is a nightmare.

Dropping out of school and ways to prevent it are complicated issues that cannot be fully addressed here. However, data show that only 57 percent of Tennessee's ninth graders will graduate with a diploma in four years, compared to 71 percent nationally. Nationally this number has stayed constant over the past 10 years while decreasing in Tennessee (Center for Civic Innovation, 2005). While many factors contribute to this situation, the main academic problem is low performance in reading and math. More effective teaching and student support, particularly for at-risk students, are essential in preparing elementary school students for middle school as well as middle school students for transition to high school. Much of TMSTEC's professional development is aimed at providing middle and elementary school teachers with these tools.

Beginning in 2007, TMSTEC will lead a three-year statewide initiative to prepare more teachers to effectively teach upper-level and Advanced Placement math and science. This project is a collaborative effort among TMSTEC, MTSU, the University of Tennessee–Knoxville, the University of Memphis, Oak Ridge Associated Universities, the College Board, and the Tennessee Department of Education. As a result, these courses will be more accessible to academically talented students. More students completing these advanced courses in math and science will obviously result in more high school graduates being college-ready.

While these courses will enhance the education of some students, many students struggle to complete the present requirements, particularly in math. Data suggest that many of these students learn math and science better when the content is embedded in context (situations and applications related to the learner's interest) (Education Development Center and National Sciences Resource Center). This seems to support the assumption that many students would be more motivated to study math and science required for graduation within a quality career/technical path. A career/technical path option for students interested in specific areas has the potential of retaining students who might otherwise drop out and graduating them ready for many jobs in Tennessee. The majority of business and industry leaders participating in the *Tennessee Summit: Educating Tomorrow's Workforce Today* supported this concept. Many such students could enter postsecondary education at the state technology centers or community colleges. Other states have successful working models for career/technical paths (i.e., South Carolina).

Research

Research is the key to improving all aspects of math and science education—best practices in teaching college-level science and math for majors and nonmajors; what science and math prospective elementary, middle, and secondary teachers need to know to be effective teachers; how to encourage more students to study math, science, and related fields; how to enhance student achievement at all levels; how to help students overcome math phobia; effective methods of making the public more aware of the seriousness of the issues related to math/science/technology education in the state and the consequences of not dealing with them now; and many other important issues. A major goal of TMSTEC is to encourage, facilitate, and conduct math and science education research.

TMSTEC uses research to guide its actions and is actively engaged in conducting research in math and science education. Professional development provided by TMSTEC is based on research identifying best practices in professional development. Further, the center is conducting research to validate its model for professional development and to determine what effect the professional development has on participating teachers' students' achievement.

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TMSTEC has three major math/science partnership grants funded by the Tennessee Department of Education to support professional development.

Creative Discovery Museum

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With funding from the Tennessee Space Grant Consortium, TMSTEC is organizing a math/science education research seminar for math and science educators from colleges and universities across the state. Through this research seminar and the Linking Leaders program, TMSTEC is striving to achieve more collaboration across the state in conducting research that can lead to the improvement of science and math education for all K–16 students.

Summary

TMSTEC is a state center funded by MTSU and external grants. The center is engaged in numerous activities and programs aimed at improving the overall quality of math and science education for all students. TMSTEC has developed meaningful working partnerships with school systems across the state, higher education institutions, policymakers, and business/industry leaders. TMSTEC has the respect, credibility, and clout to make a positive contribution to math and science education in the state.

This article provides only a brief overview of the crisis in math and science education in American and in Tennessee. Our intent here is to make more people aware of the status of math and science education in the state and how TMSTEC is working collaboratively to facilitate improvement. We need change and improvement in math and science education, but we want to encourage state policymakers to give careful consideration to the needs of all students whether they are college bound or not. We must have programs that motivate more students to stay in school and graduate. ■

E. Ray Phillips is the director and Dovie Kimmins is the associate director of TMSTEC.

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Increasing the state's graduation rate by 1 percent adds approximately $2.6 million to the economy yearly.

—Alliance for Excellent Education 2005

This visitor to the Creative Discovery Museum in Chattanooga is learning about the phases of matter and what causes things to change from one state to another.

THE 21ST CENTURY

ANSWERING THE CHALLENGE

From *Answering the Challenge of a Changing World: Strengthening Education for the 21st Century*, U.S. Department of Education, Washington, D.C., 2006

To Americans, innovation means not just the latest gadget but creating a more productive, prosperous, mobile, and healthy society. Innovation fuels and improves our quality of life, and its wellspring is education.

President Bush has made innovation and education top priorities. He worked with Congress to pass the most far-reaching education reform in decades, the *No Child Left Behind Act (NCLB)*, which has brought high standards and accountability to public schools and sparked a mathematics revival in the early grades.

Countries such as China, India, and South Korea have invested heavily in education, technology, and research and development. Billions of new competitors are challenging America's economic and educational leadership, with students from many developed nations outperforming ours in math and science tests. The impact may be felt well into the future: America's share of the world's science and engineering doctorates is predicted to fall to 15 percent by 2010.[1]

This global challenge calls for bold action. America has done it before. Following the Soviet Union's 1957 launch of Sputnik, the world's first satellite, Congress passed and President Eisenhower signed the National Defense Education Act of 1958, which brought together the public and private sectors to accelerate the study of math and science teaching. Within a decade, the number of science and engineering doctorates awarded in the U.S. annually had tripled to more than half the world's total by 1970.

America faces a rapidly changing global workforce. The spread of freedom is spurring technological innovation and global competition at a record pace. A high school diploma is now essential—and, increasingly, insufficient. About 90 percent of the fastest-growing jobs of the future will require postsecondary education.[2] It is unacceptable that about three in 10 ninth-graders do not graduate on time (for black and Hispanic students, five in 10).[3]

For both blue- and white-collar positions, employers seek workers who are practical problem-solvers fluent in today's technology. If trends continue, by 2012 over 40 percent of factory jobs will require postsecondary education, according to the National Association of Manufacturers. Yet almost half of our 17-year-olds do not have the basic math understanding to qualify for a production associate's job at an auto plant.

Improving education is critical to America's financial and national security. Today, 3,000 satellites circle the earth. U.S. soldiers use the latest technology and communications to fight terrorism. Advanced math skills are used to identify and undermine terrorist networks. Government and the private sector look to engineer new ways to protect lives and infrastructure.

Rigorous instruction, high standards, and accountability for results are helping to raise achievement in the early grades. With our students working to achieve grade-level proficiency in math by 2014 as called for by NCLB, innovative education reform is needed.

In this changing world, knowledge of math and science is paramount. "It's a magnificent time to know math," writes *Businessweek*, in an article titled "Math Will Rock Your World." "Math entrepreneurs" are translating the world into numbers—which translates into big salaries. According to the Bureau of Labor Statistics, job openings requiring science, engineering, or technical training will increase by more than 24 percent to 6.3 million by 2014.

Of all the recommendations in the National Academies' report *Rising Above the Gathering Storm*, the highest priority is to vastly improve K–12 math and science education. Schools must help students develop the skills they need to compete and succeed in higher education and the workforce. They must develop a pool of technically adept and numerically literate Americans to ensure a continual supply of highly trained mathematicians, scientists, and engineers.

High school test scores in math have barely budged since the early 1970s. The percentage of seniors scoring below "basic" level on the National Assessment of Educational Progress assessments rose between 1996 and 2000. Less than half of high school graduates in 2005 were

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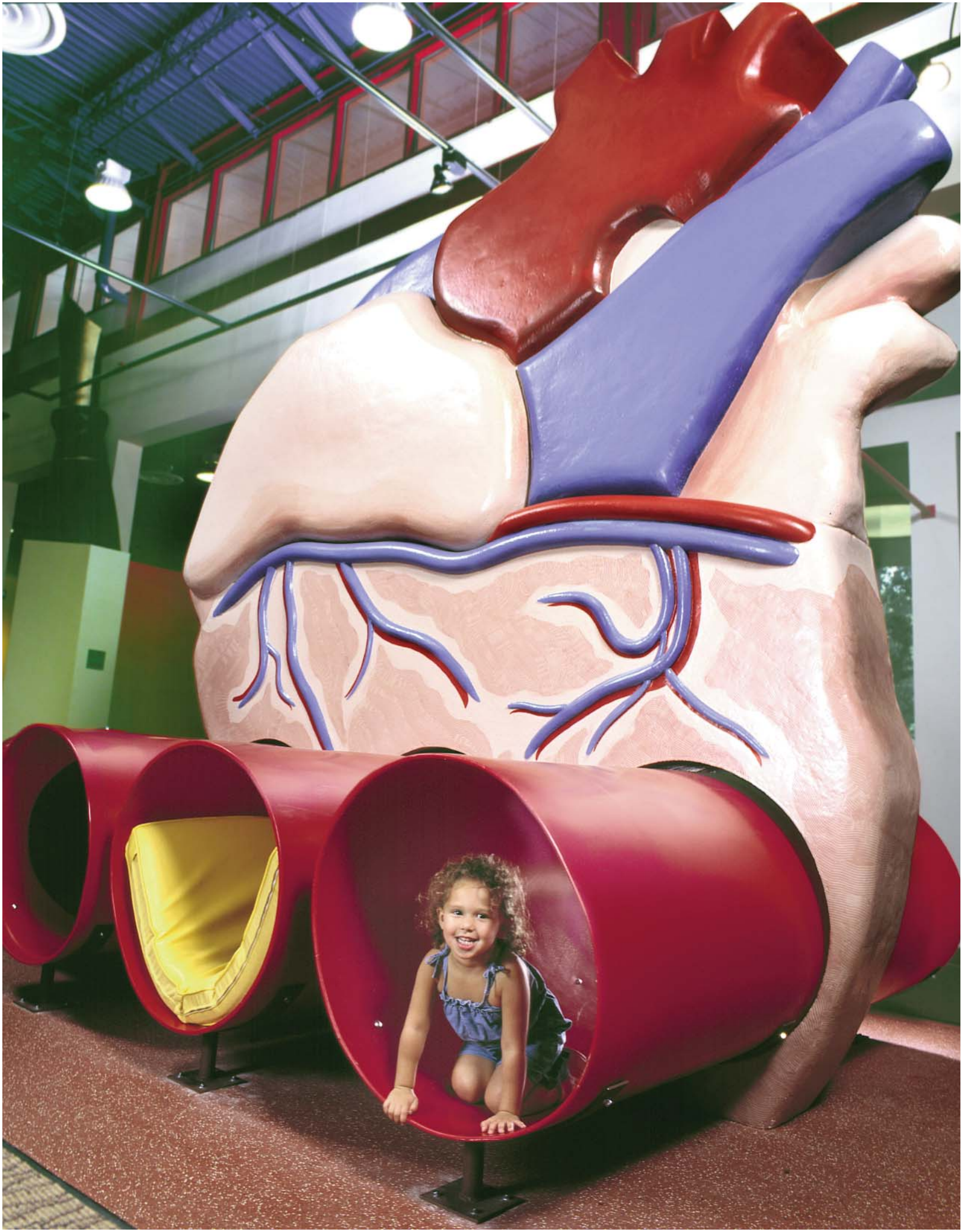
Children's Museum of Memphis



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ready for college-level math and science course work, according to ACT.

In 1983, the landmark *A Nation at Risk* report recommended that high school students be required to take at least three years each of math and science, yet only 22 states and the District of Columbia require this. Even fewer require high school exit exams (often given in 10th or 11th grade, leading many employers and universities to discount results). Only Alabama requires students to take four years of both science and math.

As America's students grow older, the rest of the world catches up. Our 15-year-olds ranked 24th out of 29 developed nations in math literacy and problem-solving, according to the 2003 Programme for International Student Assessment test. The U.S. had a smaller percentage of top performers and a larger percentage of low performers than the average of all developed countries.

A major part of the answer is teacher training. Three out of four fourth-grade math and science teachers in the U.S. do not have a specialization in those subjects. Students from low-income communities are far less likely to have teachers certified in the subject they teach. Two-thirds of our math and science teachers are expected to retire by 2010, according to the National Commission on Mathematics and Science Teaching for the 21st Century.

Providing greater access to AP courses is a must. Students who take advanced math courses such as trigonometry, precalculus, and calculus in high school are far more likely to earn a bachelor's degree in college. AP calculus students ranked first in the world on the Trends in International Mathematics and Science Study test; U.S. students overall ranked second to last.

Since 2000, the percentage of students who have taken and passed AP courses has risen in all 50 states and the District of Columbia, according to the College Board. Still more than one-third of high schools—many serving predominantly low-income and minority students—do not offer any AP courses. Based on PSAT scores, nearly half a million students in America ready for AP calculus last year did not take it or have access to it.

While many students eagerly await this opportunity, others harbor negative views toward math and science. A recent survey commissioned by the Raytheon Company found that 84 percent of middle school students would rather clean their rooms, take out the garbage, or go to the dentist than do math homework.[4] According to the Business Roundtable, just 5 percent of parents say they would "try to persuade their child toward careers in science, technology, mathematics, or engineering."[5] Many people view math and science as "nerdy" subjects with little relevance to the "real world."

Initiatives include the following.

- **The American Competitiveness Initiative** ($380 Million in FY 2007):
  - **The National Mathematics Panel** ($10 million) would convene experts to evaluate effectiveness of various approaches to teaching math, creating a research base to improve instructional methods.
  - **Math Now for Elementary School Students** ($125 million) would promote research-based math instruction practices and prepare students for more rigorous middle and high school math.
  - **Math Now for Middle School Students** ($125 million) would diagnose students' deficiencies in math proficiency and provide intensive and systematic instruction.
  - **AP-International Baccalaureate Incentive Program** ($122 million) would train 70,000 more teachers to lead AP-IB math and science courses over five years and increase the number of students taking AP-IB tests to 1.5 million by 2012, tripling the number who pass and giving them the chance to earn college credit.
  - **Adjunct Teacher Corps** ($25 million) would encourage 30,000 math and science professionals to serve as adjunct high school teachers by 2015.
  - **Evaluating Effectiveness of Federal Science, Technology, Engineering and Math programs** ($5 million) would determine the most effective programs to fund and consolidate with NCLB's goals and aims. Thirteen agencies reported spending $2.8 billion on 207 education programs in FY 2004; about half of the math and science programs received less than $1 million in funding, with most targeted to postsecondary education.
  - **Including Science Assessments in NCLB** (in each of three grade spans by 2007–2008) will ensure students learn necessary content and skills.
- **Academic Competitiveness grants** and **SMART Grants** ($850 million in FY 2007), approved by Congress, will benefit over 500,000 needy students. Academic Competitiveness grants will provide funds for low-income students who take a rigorous academic curriculum in high school: $750 to qualified first-year college students who complete a rigorous high school program, $1,300 to second-year students who complete a rigorous program and maintain a 3.0

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U.S. manufacturing will no longer employ millions in low-skilled jobs. Tomorrow's jobs will go to those with education in science, engineering, and mathematics and to high-skill technical workers.

—National Association of Manufacturers, *The Looming Workforce Crisis*, 2005

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Children's Museum of Memphis


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average in college. SMART grants of $4,000 will go to college juniors and seniors studying math or science with a 3.0 GPA.

- **Mathematics and Science Partnerships** ($182 million in FY 2007) provide state formula grants to improve students' academic achievement in rigorous math and science courses and assist teachers by integrating proven teaching methods into the curricula.
- **Expanded Teacher Loan Forgiveness** offers up to $17,500 in loan forgiveness for highly qualified math, science, and special education teachers serving challenging, low-income students and communities.

It took time for eight other developed nations to surpass America's high school graduation rate among adults aged 25 to 34, and it will take time for the U.S. to regain leadership.

NCLB set a course for all students to attain grade-level proficiency in math by 2014. Students in grades three through eight are learning under high standards. Teachers are using proven instructional methods, schools are being held accountable for results, parents have more information and choices, and states have more flexibility to spend federal K–12 education funds, which have increased 40 percent since 2001.

Across the country, academic achievement has risen significantly in the earliest grades, with math scores at all-time highs. In the past two years, the number of fourth-graders who learned fundamental math skills increased by 235,000. According to the Nation's Report Card, achievement gaps in math between white and African-American nine-year-olds and between white and Hispanic nine-year-olds are at all-time lows.

For the first time, all 50 states have unique accountability plans in place, with real consequences attached. The results can be seen in schools like Maryland's North Glen Elementary, where 84 percent of students are proficient in math compared to 46 percent in 2003. At Charles L. Gideons Elementary School in Atlanta, the number of students meeting state standards in math increased by 34 percentage points since 2003. In Garden Grove, California, where three-fourths of the Unified School District's students did not speak English and nearly 60 percent were from low-income families, all but two of the district's 67 schools met or exceeded Adequate Yearly Progress goals under NCLB.

It's time to apply NCLB's successful principles to high schools. Every year about a million high school students drop out, costing the nation over $260 billion dollars in lost wages, taxes, and productivity over their lifetimes. A high school graduate can earn about $275,000 more over the course of a lifetime than a student who doesn't finish high school; someone with a bachelor's degree can expect to earn about $1 million more. Dropouts are 3.5 times more likely to be arrested. Encouraging at-risk students to stay in school will improve their quality of life and that of their fellow Americans.

The president's High School Reform Initiative ($1.475 billion in FY 2007) would give states formula grants to support:

- development, implementation, and evaluation of targeted interventions to improve the academic performance of students most at risk of failing to meet state academic standards, and
- expanded high school assessments to assist educators in increasing accountability and meeting the needs of at-risk students.

Interventions would be designed to increase high school students' achievement; eliminate achievement gaps between students from different ethnic, racial, and income groups; and help ensure that students graduate with the skills and knowledge necessary to succeed in postsecondary education and the technology-based global economy.

A key strategy would be the development of individual performance plans for students entering high school, using eighth-grade assessment data in consultation with parents, teachers, and counselors. Interventions may combine rigorous academic course work with vocational and technical training, research-based dropout prevention activities, and the use of technology-based assessment systems to closely monitor student progress. Programs that identify at-risk middle school students would help prepare them for high school and postsecondary education.

America's schools have made great progress in improving academic achievement in the early grades. But like athletes or musicians, children of all ages must work hard every day if they wish to compete, perform, and succeed. The president's 2006 education agenda will help prepare the students of today to become the successful leaders—pioneers, discoverers, and Nobel Prize winners—of the 21st century. ■

We must improve the way we teach math in our elementary schools. It's not just about helping younger students develop strong arithmetic skills; it's about planting the seeds of higher-order thinking for later in life.

—U.S. Secretary of Education Margaret Spellings

Notes

1. Richard B. Freeman, "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" Working Paper Series, National Bureau of Economic Research: Working Paper 11457, June 2005, p. 5.
2. U.S. Secretary of Labor Elaine L. Chao, February 22, 2006, WIRED Initiative Town Hall Event, Washington, D.C.
3. Jay P. Greene and Marcus A. Winters, "Public High School Graduation and College-Readiness Rates: 1991–2002," Manhattan Institute for Policy Research, New York: Education Working Paper No. 8, February 2005.
4. www.raytheon.com/about/contributions/mathmovesu (accessed April 4, 2006).
5. www.businessroundtable.org/pdf/20060112Two-pager.pdf (accessed April 4, 2006).

COLLEGE OF BUSINESS

FACULTY CANDIDATE SHORTAGE

by E. James Burton, Dean, Jones College of Business, MTSU

The shortage of high quality math and science teachers has reached a critical level, but at least it has captured the attention of policymakers. Another problem that has received less media coverage is the shortage of new faculty candidates for colleges of business.

In fall 2002, AACSB International (the best-known accrediting body for U.S. business colleges) released a management education task force report expressing concern about the coming global shortage of doctoral faculty in business. The AACSB International Board of Directors appointed a doctoral faculty commission, which in 2003 released "Sustaining Scholarship in Business Schools," the data source for this article. (Both publications are available at www.aacsb.edu/publications/.)

The production of business doctorates declined 19 percent from academic 1994–1995 to academic 1999–2000. The shortage is expected to be about 1,150 by 2008 and about 2,420 by 2013. This shortage is created by numerous factors, especially reduced numbers of students entering Ph.D. programs (partially because of the schools' cutback on admission slots) and increased numbers of retiring faculty.

Four of the five largest producers of business doctorates are public institutions that have faced significant budget constrictions. (Ph.D. programs are cost centers, not profit centers as M.B.A. programs can be.) Many enrolled in U.S. doctoral programs are foreign nationals whose limited visas do not permit them to accept U.S. jobs immediately upon graduation.

New Ph.D.s are produced by research-oriented institutions, whose prestige is highly dependent on the research their faculty produces and placement of their doctoral graduates in other research institutions. Faculty committees and mentors often strongly encourage new doctorates to accept jobs only at other research institutions, sometimes suggesting the students may not graduate if they accept a position at a "lower-level" school. Such pressure may put teaching institutions at a disadvantage in the recruitment process. Also, state "flagship" schools and private research institutions can offer salary and other incentives that teaching institutions have no hope of matching, including fewer classes and more research resources.

In the short term, some faculty members, nervous about the stock market's performance, are delaying retirement until they have more confidence in their portfolio. The problem may become more acute if a marketplace event causes many to retire suddenly.

Possibile solutions include allowing people to receive retirement as well as additional compensation for continued teaching or reducing expectations of faculty at the end of their careers for ongoing research productivity, focusing on teaching expectations only.

There are several hindrances to entering and completing doctoral programs. The time necessary to complete doctoral programs seems to have lengthened; it is not unusual for such a program to take five years beyond a master's degree. The opportunity cost may be an important consideration. Even when doctoral candidates receive significant financial support (tuition and assistantships), the difference between that and a salary in a full-time job is substantial. The number of slots available in doctoral programs has been declining even for those willing to sacrifice.

The commission has estimated that $55 million dollars infused in doctoral research programs in the U.S. (from state and federal government, foundations, corporations, or private sources) could help produce 950 additional doctoral graduates in 10 years.

The process of getting the degree could be made faster and more convenient, requiring some change in standard doctoral education delivery methods. Faculty members with doctorates in lower-paying disciplines could be encouraged to receive discipline-based education and teach in business colleges. Accrediting standards could be changed to accept as "professionally qualified" faculty those with master's degrees and significant business experience who would like to teach after retiring from or making enough money in another job.

MTSU's Jones College, with 129 full-time faculty members and adjunct professors equaling seven full-time faculty members, has a comparatively large faculty. We typically recruit six to 12 new faculty members per year, while many other colleges recruit one or two if any.

Research institutions are considering hiring graduates from more schools than in the past. The competition and related costs continue to escalate. The Jones College has an excellent faculty, but maintaining that standard of excellence will continue to be a struggle. ■