NORTHEAST OHIO

STEMM / 21ST CENTURY SKILLS REGIONAL SUMMIT

(SCIENCE, TECHNOLOGY, ENGINEERING, MATHEMATICS, MEDICAL)

FINAL REPORT

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Executive Summary

Although Ohio's schools acknowledge a need to prepare young people for twenty-first–century careers, many must implement changes in both curriculum and classroom practice to equip students for success. Such changes must include igniting students' curiosity about science and mathematics, offering teachers authentic science-research professional development, introducing interdisciplinary and "soft" people skills into the curriculum, and partnering with colleges and businesses.

Those were among the key conclusions of the Northeast Ohio Regional Summit on "Learning 21st Century Learning Skills in Science, Technology, Engineering, Mathematics and Medical (STEMM) Education," held February 27–28, 2008 in the WVIZ/PBS and 90.3 WCPN ideastream® Idea Center™ at Playhouse Square in Cleveland, Ohio. The Northeast Ohio Regional Summit gathered together regional leaders from Northeast Ohio educational organizations, medical centers, NASA Glenn Research Center, teacher and labor unions, philanthropic groups, community mayors, and other groups to discuss the need to formulate a plan to carry Northeast Ohio's educational system forward into the 21st century.

The Summit's primary recommendations and supporting action steps included the following:

Recommendation #1: Ignite students' curiosity from the earliest grades.

Refocus K-12 science and mathematics instruction to *ignite the fires of curiosity*, so that students experience the excitement of discovery, observation, inquiry and investigation.

Refocus K-12 science and mathematics instruction on investigation, experimentation, design, tinkering with physical objects and logical problem-solving.

Emphasize how all the sciences and technology are fundamental to assessing and addressing some of the greatest challenges now facing humanity

Recommendation #2: Create a "line of sight" from school to careers.

Invite individuals from hospitals, research laboratories, engineering companies, manufacturers, scientific publishers, and other technology-rich workplaces into the classroom.

Create a workshop on STEMM careers targeted to school counselors.

Offer more shadowing and visitation opportunities, in which not only students but also teachers and counselors are invited to workplaces to experience a day in the life of various STEMM professions and trades.

Partner with local businesses, laboratories, hospitals, and industries to offer students more internships, mentorships, apprenticeships, and workplace interviews.

Produce and broadcast children's programming that is focused on the many science, technology, engineering, mathematics, and medical career paths that are available today.

Encourage more collaboration of K-12 faculty with STEMM faculty at institutions of higher education.

Engage and work more closely with professional societies of scientists and engineers, many of which already have substantial pre-college programs.

Recommendation #3: Give teachers authentic research experiences.

Develop a pool of STEMM teaching talent by creating new college scholarships for undergraduates and graduate students who pledge to teach grades K-12 in Ohio.

Encourage close collaboration between every Ohio teacher's college or college or university department of education with the departments of business administration, sciences, engineering, and pre-med.

Provide practical learning experiences for practicing teachers in scientific research laboratories, manufacturing plants, and businesses as part of their regular professional development.

Involve regional research scientists, engineers, and medical professionals in professional development for K-12 teachers.

Recommendation #4: Offer students interdisciplinary and "soft" skills.

Integrate "21st Century Skills" (including teamwork, innovation, creativity) into the curriculum.

Integrate science and mathematics with the arts, literature, history, and other subjects to make a more effective impact across the curriculum.

Teach basic business etiquette skills and practices in school from kindergarten through high school graduation.

Recommendation #5: Encourage learning opportunities outside the classroom.

Raise the awareness of students' wider family structures—parents, aunts, uncles, grandparents, and other guardians—so that the family structure encourages and supports students' full participation in science and mathematics opportunities in school.

Partner with Northeast Ohio's many informal science education establishments, and encourage students and their families to take advantage of science-related learning opportunities outside of school.

Encourage increased student participation in hands-on science and engineering, and promote local science fairs, robotics contests, and similar events for all students.

Encourage kids to tinker with hands-on hobbies.

Connect with the media, and through them, the larger community.

Recommendation #6: Think globally, act locally.

Develop a strategic plan to effectively prepare more students for the global economy and encourage students and in particular the best and the brightest to stay in Northeast Ohio after graduation.

"Stop talking and start acting."

Introduction:
Twenty-first century Northeast Ohio

Northeast Ohio suffers from a reputation for being a depressed region—a "rust belt" of closed steel factories and automotive plants and high unemployment.

Facts and numbers, however, belie that tired stereotype. In addition to an internationally acclaimed orchestra and art museum, Cleveland boasts NASA Glenn Research Center, a university renowned for its first-ranked engineering and science programs (Case Western Reserve), and one of the nation's top systems of research and teaching hospitals (including the Cleveland Clinic, Rainbow Babies' and Children's, and the University Hospitals). Neighboring Akron has its own fast-growing university (University of Akron) positioning itself to be a leader in polymers, nanotechnology, and technology transfer.

Gone are the days when 18-year-olds could realistically expect that a high-school diploma could put food on the table until retirement

In healthcare, one of Ohio's premier high-tech industries, there is an acute labor shortage. In northeast Ohio alone, nearly 4,000 vacancies are at any given time in need of skilled medical professionals ranging from entry level technicians to Ph.D. researchers. In science and engineering, manufacturing facilities just in this one region perennially have approximately 6,000 openings for technical professionals ranging from entry-level maintenance technicians and skilled welders to materials scientists and design engineers. Indeed, some high-tech companies are concerned that they may have to leave the state because of a *lack* of a qualified workforce, despite the fact that some entry-level technical positions requiring only a B.A. or even an A.A. degree offer as much as $60,000 to start.

Gone are the days—not just in Ohio, but also anywhere in the U.S.—when most 18-year-olds could realistically expect that a high-school diploma plus some skill in metal-working or auto mechanics would be enough to secure a job that would put food on the table until retirement. Ohio, like the rest of the nation, must tool up for the 21st century. Ohio's future, as the nation's, lies in nanotechnology, polymers, robotically-assisted medicine, space technologies, sustainable energy, and other pioneering opportunities.[1] For well-prepared young college graduates, career opportunities in Ohio are limitless.

Preparation for such 21st-century opportunities, however, must start with the education of Ohio's children.

Educational Reform is Needed

Participants in the Northeast Ohio Regional Summit pointed to abundant signs that reform is needed throughout Northeast Ohio's educational system—not just from kindergarten through high school (K-12), but all the way from preschool through college (P-16), a view also expressed by the Ohio Mathematics and Science Coalition and the Ohio Grantmakers Forum.[2]

For example, a large and rising enrollment in remedial mathematics courses in community colleges clearly indicates that high school graduates are inadequately prepared in workforce math skills. As one recruiter at the Summit observed, "Thirty years ago, employers took just about anyone and made them employable through a 90-day training period as an apprentice. In today's high-tech knowledge economy, that's not an

option. Employers, although willing to invest in higher-level training, are not able to do remedial work to provide students with basic skills they should have learned in school. They need recent graduates to walk in the door with a working knowledge of the fundamentals and algebra."

Moreover, some employers are demanding job-ready graduates trained in skills specific to the employers' needs, such as familiarity with certain software or computer-aided design (CAD) techniques. In Northeast Ohio, Cuyahoga and Lorain community colleges have expanded beyond their traditional role of preparing students to transfer to universities for four-year degrees, to offer courses that impart knowledge that has traditionally been part of on-the-job training.

In addition, employers are now seeking skills that go beyond technical knowledge taught in most schools. Such "21st Century Skills," as they have been called, include creative critical thinking across disciplines, ability to communicate effectively, experience in working in teams, and a host of other "soft" people skills [see sidebar "21st Century Skills" on page 22].

Yet, at this time of greater demand for effective mathematics and science teachers, many mathematics and science majors in Ohio's colleges and universities are entering fields other than education. Noted one Summit participant, "education is perceived to be unattractive in terms of pay, status, and working conditions," such as students' lack of interest or respect. This migration of mathematics and science majors away from K-12 teaching has led to a shortage of qualified and confident pre-college mathematics and science instructors. Mathematics and science are all-too-often taught by teachers who feel ill-prepared. In the frank admission of one teacher at the Summit, "it's scary to teach science to fifth graders when you are not really sure about the science yourself." According to another participant, even in Ohio's two- and four-year colleges, there is a critical shortage of qualified instructors, increasing the difficulty of preparing high-school graduates to fill Ohio's medical vacancies.

Employers are now seeking "soft" people skills that go beyond "hard" technical knowledge

Most importantly, scientific understanding and critical thinking are no longer only for those interested in scientific, engineering, or medical careers. They are crucial literacies for participation in twenty-first century citizenship. Regardless of profession or trade, every U.S. citizen now lives in a high-tech information society. Many public policy issues—including medical ethics, pollution control, climate change, school education about evolution—require voters to comprehend technical material and understand the principles of scientific uncertainty and debate. In the words of the Board of Science Education of the National Academies, "With scientific knowledge, we are empowered to become participants rather than merely observers. Science, in this sense, is more than a means for getting ahead in the world of work. It is a resource for becoming a critical and engaged citizen in a democracy." [3]

Becoming the Change We Want to See

To attain technical literacy for all Ohio students, the Summit concluded that nothing less than wholesale change of Ohio's culture is needed. Change that will extend beyond just the educational culture in Ohio's schools, but also reaches into Ohio's businesses, communities, and the dinner tables of individual homes.

This report is organized around the six principal recommendations from the Northeast Ohio Regional Summit. Each section groups together several supporting sub-recommendations, supplemented by observations from participants' experience. Where relevant, points are amplified by citations of national research.

As a whole, the Summit's recommendations call for significant long-term change in the culture of Northeast Ohio's schools, school districts, communities, and even individual homes. Such comprehensive school improvement must be strategic; it must also address a wide range of social and cultural issues, recognizing that not all solutions are academic—observations that support recent conclusions by the Ohio Grantmakers Forum.[4]

Beginning such a change at first may seem daunting. Thus, a blue sidebar accompanying each recommendation features a group of bullets headed "Suggested Steps for the Immediate Future." The bullets collate suggestions for *practical, short-term, low-cost, high-payoff, quick-win first steps* that Northeast Ohio consortia, school districts, schools, and even individual teachers can take quickly—some even within the 2008-2009 academic year—all aimed at jump-starting the

process of offering the children of Northeast Ohio the best education for the twenty-first century.

[1] See The Ohio Board of Regents, *Report on the Condition of Higher Education in Ohio: Meeting the State's Future Needs*, March 31, 2008, available at http://universitysystem.ohio.gov/pdfs/strategicPlan/ConditionReport_final.pdf . See also The Ohio Board of Regents, *Strategic Plan for Higher Education 2008–2017*, available at http://universitysystem.ohio.gov/pdfs/strategicPlan/USOStrategicPlan.pdf .

[2] *The Future of Mathematics and Science Education in the Public Schools of Ohio: Scenarios and Strategies,* A Leadership Paper from the Ohio Mathematics and Science Coalition, February 2008, at http://www.ohiomsc.org/omsc/PDF/Ohio2025.pdf . See Priority 9 in the briefing paper "Priorities, Partnerships and Philanthropy: Improving Public Education for Ohio's Future," April 2008, pp. 7, 11; available from http://www.ohiograntmakers.org/newsarticle.cfm?articleid=10005017&ptsidebaroptid=0&returnto=index.cfm&returntoname=Home&siteid=194&pageid=5410&sidepageid=5329 .

[3] The necessity of technical literacy for all citizens is eloquently discussed in Board of Science Education (BOSE), National Academies, *Ready, Set, Science: Putting Research to Work in K–8 Science Classrooms*, National Academies Press, 2008, p. 2; . See also BOSE, *Taking Science to School: Learning and Teaching Science in Grades K-8*, National Academies Press, 2007. More information about both reports is available from http://www7.nationalacademies.org/bose/TSS_RSS_FAQ.html .

[4] See Priorities 4 and 5 in the briefing paper "Priorities, Partnerships and Philanthropy: Improving Public Education for Ohio's Future," April 2008, p. 5; available from http://www.ohiograntmakers.org/newsarticle.cfm?articleid=10005017&ptsidebaroptid=0&returnto=index.cfm&returntoname=Home&siteid=194&pageid=5410&sidepageid=5329 .

Recommendation 1:
Ignite students' curiosity from the earliest grades

"Students' lack of interest—and sometimes outright fear—of STEMM [science, technology, engineering, mathematics, and medicine] courses and careers is disturbing," observed one Northeast Ohio Regional Summit participant. Another participant pointed out that "employers want passion."

The Summit identified a trend in Northeast Ohio troubling thousands of teachers and parents across the nation for decades. Although many children are eager to enter school in kindergarten, midway through the elementary grades a significant number of them have become unmotivated reluctant learners, no longer curious about their environment. By middle school, many students suffer from what the March 2008 issue of *Educational Leadership*, in a special issue devoted to reaching the reluctant learner, calls "the boredom crisis."[1] A National Academies study *Engaging Schools* states: "We can require adolescents to attend school, but learning requires conscious and purposeful effort, which cannot be legislated."[2]

We can require adolescents to attend school, but learning requires conscious and purposeful effort, which cannot be legislated

Worse, by middle school—an age when students are beginning to think seriously about careers—many children *lose interest* specifically in science and math.[3] Anecdotal observations are also supported by studies. A white paper of the U.S. Secretary of Energy Advisory Board's Science and Mathematics Education Task Force reports: "Students come to perceive science to be dull, full of bewildering technical terms and abstract equations for which they think they will have no earthly use—because science is all-too-often presented as pedestrian memorization, devoid of excitement and real-life examples."[4] More sobering, a 2006 Public Agenda survey found that "nearly four in 10 students say they would be quite *unhappy* if they ended up in a career with a math or science focus."[5]

Many Summit participants related experiences that amplify the conclusions of the national studies. "Many students think the bar has been set so high for career paths that require math and science, that it is not attainable for them. So they don't even *try* to achieve them," observed one Summit participant. Others noted that too many Northeast Ohio students come to experience math anxiety, which may be heightened by our continual emphasis on standardized tests. Added another: "Students' general attitude is negative: 'It's too hard. I can't do it because I'm not good at it'. We need to change that perception so they realize that with appropriate instruction, *everyone* can learn science and math."

Instead of regarding the all-too-common transformation from positive interest to negative attitude toward science and math as normal or inevitable, it should be recognized as the long-term danger sign to Ohio and the United States that it is. Why? *Students don't enter fields they perceive to be boring, irrelevant, or intimidating.* On the contrary, it is basic human nature for people of any age to be attracted to fields they find both internally gratifying and relevant to their life and world.

What is needed, the National Academies study asserts, is "motivating adolescents to be engaged—cognitively, behaviorally, and emotionally—in their coursework… Motivation is essential to learning at all ages."[6] As the

Department of Energy task force concluded, "fascination, excitement, and relevance to real-world problems are central to achieving educational goals." [7]

In short, for knowledge to be not only taught by a teacher but also absorbed by students, every individual student must *want* to learn.

What can be done?

First, refocus K-12 science and mathematics instruction to *ignite the fires of curiosity*, so that students experience the excitement of discovery, observation, inquiry, and investigation. "Students are not vessels to be filled, but fires to be lit," declared one Summit participant. [8] Another participant pointed to the work of the Ohio Academy of Sciences, which dedicates itself "to foster *curiosity, discovery,* and *innovation* and to unite all who value education, science, engineering, technology, or their applications for the benefit of society." [9]

From toddlerhood, a child's world is full of stimulation that spurs them to ask questions and to experiment rather than simply accept verbal cautions or instructions. [10] From their observations, children ask countless questions, some of them profound scientific questions: "Why is there wind?" "Why is the sky blue?" "What are the stars?" "How do birds fly?" If encouraged from the earliest grades, a young child's *natural curiosity can be a powerful engine for learning*. Satisfaction of personal curiosity becomes learning's reward, *making learning personally relevant and gratifying*. [11]

Historically, curiosity has often spurred fundamental scientific discovery—and continues to motivate the many professional scientists, surgeons, and engineers who enjoy their life's work. Robust curiosity can drive students with such intensity that they do not become discouraged at setbacks, but desire to excel and *persist toward mastery despite difficulties and frustrations*. Curiosity also can give students a burning drive *to continue lifelong education beyond formal schooling*—a trait that high-tech employers seek and prize.

Students are not vessels to be filled, but fires to be lit

Curiosity is also the *foundation of careful observation and experimentation*, pillars of the scientific method. Children will spend endless time observing what they find fascinating. Thus, from the earliest grades, science education should invite students to hone their naked-eye observations of the everyday natural world: types of clouds and change of seasons, tadpoles and cocoons, bean plants and ant farms and incubating eggs, schoolyard rocks and trees, changes in the position and phases of the moon or the direction of schoolyard shadows from morning to afternoon. With notebook and drawing pencil in hand for recording daily notes of changes they themselves observe, students can learn the basics of the scientific method: making careful regular observations, keeping meticulous laboratory notes.

Through their own personal experience, even the youngest students can discover the sheer accessibility of scientific questions, their personal capability and power to find answers, and the pleasure of discovery and wonder. Curiosity continues to be nurtured by the ever-present question of *I wonder what happens if...?*

Second, refocus K-12 science and mathematics instruction on experimentation, design, tinkering with physical objects, and logical problem-solving instead of simply lecture, textbook, and computer-simulation

Recommendation 1.
Suggested Steps for the Immediate Future

- Commission a study to identify *effective* best practices and resources for inspiring curiosity in K-12 students beginning with the earliest grades. Then communicate the results of the study to all school districts, schools, and teachers across Northeast Ohio.
- Develop a plan that will provide schools with laboratory facilities or other equipment, supplies and instructional materials for teachers to conduct experiments or demonstrate scientific principles in their classrooms. Include grades P-5. Laboratory equipment or measuring instruments do not have to be expensive or elaborate to be effective; in fact, consider how some can be constructed by students themselves from ordinary materials.
- Develop a plan that re-incorporates meaningful field trips into school curricula from K-12. Include in the plan simple "field trips" that occupy a single class period, such as explorations in the school yard to observe leaves, insects, clouds, changes of the seasons, phases of the moon, etc., which serve to hone students' powers of observation and fascination with science and nature permeating daily life.

presentation of abstract information. "We must focus on in-depth mastery of concepts rather than broad education," declared one Summit participant. "We need more inquiry-based activity and research experiences." Select curricula that emphasize problem-based, project-based approaches to investigating scientific questions, such as Project Lead The Way, [12] to the point of involving students in authentic research experiences. [13]

A young child's natural curiosity can be a powerful engine for learning

Cognitive learning theorists have long documented that child's play is the precursor to problem-solving. Young children instinctively tinker with ideas ("I wonder what would happen if I try…?") as well as with physical objects (cups, water, sand, Legos, and play dough). Older students can be challenged by problem-solving projects such as building a complete weather station (barometer, thermometer, anemometer, hygrometer, rain gauge, etc.) using plastic cups and straws, pie tins, human hair, and other household items. In so doing, they learn not only about weather systems, but also about construction of instruments, repeatable measurements, and calibration—essential concepts of the scientific way of knowing.

For example, one high point of physics classes in Lakewood High School, just west of Cleveland, is a cardboard boat regatta held each spring: the challenge is—using nothing more than packing tape and untreated cardboard—to design boats that are large and strong enough to hold two frantically paddling students for the length of the school's swimming pool before becoming waterlogged and sinking. [14]

Focused on such a real-world goal, students must—and more importantly, *want* to—learn about structures, materials, adhesives, stresses, efficient design, testing, and other important concepts in physics and engineering. They come to understand the process of questioning and testing competing hypotheses that are the essence of the scientific method and critical thinking. They also discover their own inventive capability. And creativity and innovation are among the "21st Century Skills" in such high demand by today's employers .

Third, emphasize how all the sciences and technology are fundamental to assessing and addressing some of the greatest challenges now facing humanity—with the message that students sitting in the classroom today are crucial to the resolution of many global issues. Many students are motivated not only by curiosity, but also by a desire to make a difference in the lives of other people, and help society and the world. The career of a doctor or surgeon, for example, usually emphasizes helping people or curing diseases rather than on the science and mathematics necessary as a prerequisite.

One Northeast Ohio Regional Summit participant reflected, "There is so much emphasis on [physical] science and technology [in STEMM] that I worry that we won't have enough people with backgrounds in the natural sciences. There is already a drought [in young natural-science graduates]. We need people who understand ecology, biology, and geology to work on issues related to climate change, sustainability, and natural resource management and conservation. For example, we are not going to have enough clean fresh water in the next 50 years." Such a global perspective is one of the 21st Century Skills in high demand by today's employers.

[1] Some articles from the special issue of *Educational Leadership* on the boredom crisis are online. See for example, "Turning on the Lights" by Marc Prensky, and "Testing the Joy Out of Learning" by Sharon L. Nichols and David C. Berliner, *Educational Leadership* (vol. 65, no. 6), March 2008, pp. 40–45; navigate to them online from the publications tab of the Association for Supervision and Curriculum Development site at http://www.ascd.org/portal/site/ascd/index.jsp/ .

[2] *Engaging Schools: Fostering High School Students' Motivation to Learn*, National Academies Press, 2003, p. 13.

[3] Secretary of Energy Advisory Board, U.S. Department of Energy, *Final Report of the Secretary of Energy Advisory Board's Science and Mathematics Education Task Force,* May 5, 2006 (online at http://www.seab.energy.gov/publications/SMETF-FRept_5-5d.pdf), p. 7; see also U.S. General Accounting Office, *Higher Education: Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends*, October 2005; U.S. General Accounting Office, *Higher Education: Science, Technology, Engineering, and Mathematics Trends and the Role of Federal Programs*, May 2006.

[4] Secretary of Energy Advisory Board, U.S. Department of Energy, *Final Report of the Secretary of Energy Advisory Board's Science and Mathematics Education Task Force,* May 5, 2006; online at http://www.seab.energy.gov/publications/SMETF-FRept_5-5d.pdf), p. 5.

[5] *Reality Check 2006. Issue No. 1: Are Parents and Students Ready for More Math and Science?* A Report from Education Insights at Public Agenda. A Public Agenda Initiative to Build Momentum for Improving American Schools, p. 8. Available at http://www.publicagenda.org/files/pdf/rc0601.pdf .

[6] *Engaging Schools: Fostering High School Students' Motivation to Learn*, National Academies Press, 2003, p. 13.

[7] Secretary of Energy Advisory Board, U.S. Department of Energy, *Final Report of the Secretary of Energy Advisory Board's Science and Mathematics Education Task Force,* May 5, 2006; online at http://www.seab.energy.gov/publications/SMETF-FRept_5-5d.pdf), p. 7.

[8] The actual quote, attributed to Plutarch, is "The mind is not a vessel to be filled, but a fire to be lit."

[9] Vision statement of the Ohio Academy of Sciences http://www.ohiosci.org/vision.htm . The Academy also maintains a website Heartland Science http://www.heartlandscience.org/ , which documents Ohio's legacy of contributions to science and technology.

[10] "Attributes of STEM Education: The Student, The School, The Classroom," TIES STEM Education Monograph Series, Teaching Institute for Excellence in STEM (TIES), August 2006, p. 2; available at http://tiesteach.org/documents/Attributes_of_STEM_Education.pdf . See also Bruce Duncan Perry, "Curiosity: The Fuel of Development," *Early Childhood Today*, at http://teacher.scholastic.com/professional/bruceperry/curiosity.htm . See also Charles R. Granger, "The Naturalistic Education Theory: In Search of a Unified Learning Theory for Instructional Methodology and Tactical Education," at http://www.umsl.edu/~sep/programs/net.html . See also "Curiosity vs. Curriculum" at http://www.engines4ed.org/hyperbook/nodes/NODE-54-pg.html . In robotics, there are attempts to program curiosity into artificial intelligence to increase functionality; see, for example, Pierre-Yves Oudeyer and Frederic Kaplan, "Intelligent, Adaptive Curiosity: a source of Self-Development," *Proceedings of the Fourth International Workshop on Epigenetic Robotics,* Lund University Cognitive Studies, 117, at http://www.lucs.lu.se/LUCS/117/oudeyer.pdf .

[11] See, for example, Ailish Hopper Meisner, "The Pleasures of Learning: Linking Parent and Child with MegaSkills," WashingtonParent.com, September 2004, at http://www.megaskillshsi.org/media/docs/pleasuresOfLearning.pdf . University of Minnesota even offers "Curiosity Camps," a continuing-education summer day camp for adults to reconnect with the pleasure of learning; see http://www.cce.umn.edu/curiosity/ .

[12] According to the Project Lead The Way website (http://www.pltw.org/index.cfm), research shows that schools practicing activities/project/problem-based learning experience an increase in student motivation, an increase in cooperative learning skills and higher-order thinking, and an improvement in student achievement. Information and resources about Project Lead The Way in Ohio appear at http://www.pltwohio.org/about_archives_fall2007.cfm .

[13] See, for example, http://quest.nasa.gov/ .

[14] The Lakewood High School physics teacher who runs the annual cardboard boat regatta is David Hille.

Recommendation 2:
Create a "line of sight" from school to careers

"Too many secondary educators don't understand the world of work. They understand only the world of education," observed one recruiter at the Northeast Ohio Regional Summit. "Just match the job want ads in the Cleveland *Plain Dealer* to any high school curriculum to see the discrepancy between what is taught and what skills are sought." Another participant commented that "even some graduates from four-year colleges are finding they must enroll in a community college to gain hands-on job training before they can be hired."

Not only high schools (some of which already offer required courses on career connections), but also K-8 grades must incorporate information about career paths into their curriculums. Today's children need early knowledge about possible careers, and how they might best prepare for various options while in school.

Not all students will enter a high-tech business or industry. But for the many that do, the single strongest recurring theme at the Summit was that business and industry must become active partners with Ohio schools. For continuity, it is imperative that the partnerships extend across P-20—from preschool through graduate school. These partnerships will provide teachers as well as students direct insights into individual scientific, technical, and medical professions and careers.

Not only high school, but also K-8 grades must incorporate information about career paths

First, invite individuals from hospitals, research laboratories, engineering companies, manufacturers, scientific publishers, and other high-tech workplaces into the classroom to give teachers and students a "real world" connection between teaching/learning and the world of work. This can be done via distance learning or over the web. Summit participants recommended that a workforce guest be asked to describe a day in the life of a research chemist, a surgeon, a NASA CAD engineer, a maintenance technician, a biochemist, a forensic pathologist, a technical writer, a radiologist, or member of another high-tech profession or trade, along with some concrete advice about how to prepare for such a career while still in school. Such speakers could address not only individual math and science classes, but also career classes, or even school-wide assemblies. After the formal presentation, allow ample time for questions and answers, as well as time for teachers and students to speak individually with a speaker about personal career interests or concerns.

Make a point of inviting such workforce guests to address students not only in high school, but also in middle and elementary grades as well. If possible, invite workforce guests not just once or twice a year, but at least once a month. To inspire the audience with a story of local success, look for workforce guests among the parents of current or former students, or alumni of Northeast Ohio schools. To share resources, school districts could create a speakers' bureau of the most dynamic high-tech professionals, who may also be willing to serve as ongoing informal advisors to teachers or students.

Second, workshops on science, technology, and medical careers targeted to school counselors. The career awareness workshop should target not only guidance counselors at the high school level and career centers, but also *counselors at the middle and elementary school level as well.* Although school counselors are

the principal audience, invite K-12 teachers and principals as well. High-tech career opportunities are continually growing and changing, so one purpose of the workshop would be to keep counselors current on high-tech trends and opportunities. Consider making the counselors' career workshop an annual event. After the workshop, continue to involve its session leaders and speakers as informal advisers to school counselors.

As early as middle school, students are seriously considering career choices

Third, invite students, teachers, and counselors to workplaces to experience a day in the life of various high-tech professions and trades. "We need more shadowing," exclaimed one Summit participant, referring to programs in various high schools where a student may apply to spend a day following an individual doctor, veterinarian, detective, research scientist, civil engineer, or other professional through a workday to observe what the daily work actually entails. In a field trip, a careers class or science club might visit a manufacturing plant, hospital, NASA Glenn research center, or other interesting high-tech venues. Virtual tours can be used as well.

A few Summit participants suggested employing various online career games for students, teachers, and counselors, citing resources available from the New Jersey Department of Education (http://www.state.nj.us/education/voc/resources/tools/exploration.htm). They also mentioned other gaming and virtual-worlds technology, such as Second Life, as a medium for allowing students to explore possible careers.

Fourth, partner with local businesses, laboratories, hospitals, and industries to offer students internships, mentorships, and apprenticeships. Several Summit participants pointed to the example of the Cleveland Metropolitan School District, which in 2008–2009 will inaugurate two regional high schools focused on science, technology, engineering, and mathematics, both closely tied to the world of work. The first, called MC^2 STEM, is housed on a corporate campus; students are partnered with mentors from industry, who introduce them to first-hand experiences

Recommendation 2. Suggested Steps for the Immediate Future

- Conduct a Northeast Ohio Regional Summit on the 21st Century STEMM Workforce. The Summit will bring together employers in healthcare and biomedical professions, advanced manufacturing, aerospace, and other high-tech businesses, as well as business, community, and political leaders for three purposes: to share efforts to meet their workforce needs now and in the future; to discuss ways to partner to achieve similar efforts and goals; and to discuss joint efforts aimed at encouraging P-16 students to consider scientific and technical careers and excite them about the necessary courses. Use the Idea Center and WVIZ/PBS and 90.3 WCPN *ideastream®* production facilities to produce related television and radio programs to broadcast to students, parents and guardians, and the general public

- Conduct a broader workforce exposition specifically designed to attract and encourage a diverse audience of "forgotten" workers (including youth not bound for four-year colleges, women, new immigrants, displaced workers, existing workers seeking retraining opportunities) to consider high-tech careers as various types of technicians. Include demonstrations, workshops, and displays by community colleges and other northeast Ohio institutions, as well as opportunities to speak with representatives from potential manufacturing and health-care employers. Such an exposition should have a focus on "how to achieve" career goals; it would also need to include funding agencies that can help provide means of supporting the "forgotten" workers' return to school through loans and scholarships. It would also address issues of adult literacy. [6]

- Create and maintain a website that features internship and summer and/or part-time student employment opportunities in northeast Ohio, as well as providing links to other websites elsewhere in Ohio that accomplish this same goal

- Promote the Educators in the Workplace summer program, which provides an opportunity for teachers to visit, observe, and participate at a different business on each day of a two-week program. The goal is for them to discover both technical and "soft" skills needed for various jobs so they can integrate job information into various course curricula. Educators in the Workplace programs have been running in various states for at least a decade; in Northeast Ohio, the Beachwood Board of Education began running the program in the summer of 2007 in collaboration with the East Suburban Business Advisory Council

- Develop a proposal for establishing a network and other resources to assist teachers with mentoring, shadowing and internships relevant to real life experiences. Identify challenges to address and solicit proposals to solve them.

with high-tech careers even while they are studying them. The second, called the Design Lab High School, housed in Cleveland's District of Design, allows students to take classes at both Jane Addams High School and Cuyahoga Community College, while working with instructors at the Cleveland Institute of Art and Design; the curriculum focuses on practical skills needed for a career in high-tech design. Another participant recommended more summer internships for high school students such as the extensive programs offered by the Cleveland Clinic.[1]

Students need more "shadowing" of working professionals

Fifth, produce and broadcast children's programming that is focused on the many science, technology, engineering, mathematics, and medical career paths available today. Several Summit participants suggested using a local education channel to feature programming for students, parents, and teachers that addresses opportunities and challenges to achieving success in high-tech careers. Follow the model of segments in such TV shows as "Bill Nye, The Science Guy" or "Mr. Roger's Neighborhood" that highlighted the work of individual scientists (geologists, biologists, etc.), doctors, engineers, or other professionals. Alternatively, create segments showing how a manufacturing plant creates some product of interest to K-12 students (e.g., how an iPod, digital camera, cell phone, or car), or how scientists or engineers design an amusement park rollercoaster. For a real hands-on opportunity, *involve students in the filming and editing of the programming*, so they become intimately familiar with the subject of the film.

Sixth, encourage collaboration of K-12 faculty with faculty at institutions of higher education. "The usual transition between high school and college involves almost a throwing-the-student-over-the-fence mentality," observed one Summit participant. "No wonder there is a 25-percent college dropout rate after the freshman year." To prevent that, two- and four-year colleges should be encouraged to work with high schools to provide opportunities (including transportation) for students in grades 9–12 to take or audit college courses and participate in labs so students get a feel for college-level science and mathematics education.

Seventh, engage with societies of professional scientists and engineers. "We [Northeast Ohio's schools] must engage in a meaningful way with the various professional organizations of scientists, engineers and researchers," declared one Summit participant. "STEMM education needs to begin in preschool. High school is too late!" added another participant. Amplifying that assessment is one conclusion from the DOE task force: "As early as middle school, students are seriously considering career choices."[2]

Already recognizing that science, mathematics, and engineering education is a serious pipeline issue facing technical fields, a number of professional scientific and engineering societies,[3] as well as the American Society for Engineering Education and the National Science Teachers Association[4] have launched pre-college outreach programs to inspire youngsters as young as kindergarten. Technical societies specifically for teens have also been founded.[5]

[1] The Cleveland Clinic's seven different internships for high school students appear at http://www.clevelandclinic.org/civiceducation/internships/ . Results of the 2007 summer internships for 140 high school students appear at http://my.clevelandclinic.org/media_relations/library/2007/860.aspx . College students can find internships in Northeast Ohio by searching the Cleveland Intern.net http://www.clevelandintern.net/content/ .

[2] Secretary of Energy Advisory Board, U.S. Department of Energy, *Final Report of the Secretary of Energy Advisory Board's Science and Mathematics Education Task Force,* May 5, 2006 (online at http://www.seab.energy.gov/publications/SMETF-FRept_5-5d.pdf), p. 6.

[3] See, for example, the K-12 educator/student pages for the American Association for the Advancement of Science (http://www.project2061.org/publications/2061Connections/2008/2008-03b.htm), the American Physical Society http://www.aps.org/programs/education/k12.cfm ; American Society of Mechanical Engineers (http://www.asme.org/Education/PreCollege/); the Astronomical Society of the Pacific http://www.astrosociety.org/education/activities/astroacts.html ; the Institute of Electrical and Electronics Engineers (IEEE) http://www.ieee.org/web/education/preuniversity/careerprep/ .

[4] American Society for Engineering Education (ASEE) EngineeringK-12 Center is http://www.engineeringk12.org/ ; accessible even to middle school students, it has games, guides, activities, and workshops for both students and teachers. See also the wealth of resources at the site of the National Science Teachers Association http://www.nsta.org/ .

[5] Primarily for high school students is the Journal Engineering Technical Society http://www.jets.org/ , which sponsors competitions and other events.

[6] For an explication of national concern about growing issues in adult literacy, see *Reach Higher, America: Overcoming Crisis in the U.S. Workforce* (National Commission on Adult Literacy, June 2008), http://www.nationalcommissiononadultliteracy.org/

Recommendation 3:
Give teachers authentic research experiences

The quality, competency, and vibrancy of the classroom teacher enormously influence the interest, performance, and outcomes of our students. That was a key recurring theme at the Northeast Ohio Regional Summit, a conclusion supported by various national studies. According to a report on higher education by the U.S. General Accounting Office (GAO), students who majored in STEM disciplines in college "associated their interests with [K-12] teachers who taught them good skills in mathematics or excited them about science," whereas teachers who "were unqualified and unable to impart the subject matter [caused] students to lose interest."[1]

The National Academies' Board on Science Education, in its study *Ready, Set, Science*, devoted much of its first chapter to discussing the importance of teaching science well, stating, "New research points toward a kind of science education that differs substantially from what occurs in most science classrooms today. This new vision of science education embraces different ways of thinking about science, different ways of thinking about students, and different ways of thinking about science education." [2]

All education majors, especially those planning to teach elementary grades, should be required to take college-level introductory science courses

Today's teachers need strong knowledge not only about the content of science, mathematics, and engineering, but also about the context in which science and technology is pursued in real life. As noted by the National Academies, "Sometimes scientists are seen as applying a 'scientific method' to get their results. They are perceived as removed from the real world, operating in an airy realm of abstraction. Studies of what scientists actually do belie these stereotypes. They approach problems in many different ways…"[3] Direct experience with science and scientists—either as science majors in college or during summer work fellowships—is the only authentic method of allowing teachers to learn for themselves about science, scientists, and the scientific enterprise, so they can teach in a way that makes science relevant and understandable to students, and inspires them to want to dig deep in learning. [4]

The Summit also emphasized that today's teachers also need tools and techniques for coaching students in the "soft" 21st Century Skills now demanded by many employers, such as interdisciplinary approaches, critical thinking, teamwork, and creativity. Thus, *the curriculum for pre-service teacher training may need modification* or addition, partnering with scientific research and engineering enterprises for relevant connections of scientific, mathematical, and technical knowledge.

First, develop a pool of STEMM teaching talent by creating new college scholarships for undergraduates and graduate students who pledge to teach grades K-12 in Ohio. One type of scholarship might be to provide an incentive and/or means for pre-service elementary, middle-grade, and secondary teachers to major or minor in mathematics and/or science. Scholarships might be applicable for any college or university in the nation, with the stipulation that the graduating student agrees to teach in some Ohio school system for some minimum time after graduation.

Another type of scholarship might be to provide incentives for STEMM majors to teach at the K-12 level in Ohio for some minimum time after graduation. In this

Recommendation 3. Suggested Steps for the Immediate Future

- Commission a study to identify programs, fellowships, and other opportunities and programs for Northeast Ohio teachers to work side by side with scientists and engineers as part of their professional development. Include the identification of programs in other states and nationwide, some of which may have travel grant opportunities, or may serve as models for setting up similar programs in Northeast Ohio.
- Identify, coordinate, integrate, and sustain community-based partnerships that have been designed to improve mathematics and science education in Northeast Ohio. NASA Glenn has a wealth of resources for teachers. The Center for Mathematics & Science Education, Teaching & Technology (CM/SETT, http://www.jcu.edu/cmsett/new_stuff/index.htm) at John Carroll University offers professional development workshops on communicating science and mathematics to students not only in middle and high school, but also as early as preschool and kindergarten.
- Promote partnerships and collaboration among Ohio schools and local and regional businesses, research centers, and hospitals. Invite businesses, research centers, and hospitals to contribute to the solution by being willing to open their doors to new ideas about education and high-tech careers directly involving teachers and students. Advised one Summit participant: "Build the house one board and one nail at a time."
- Convene a professional-development oversight committee to review current teacher professional development in mathematics and science and make specific recommendations centered on the needs of teachers in northeast Ohio.
- Identify opportunities for creating summer externships for teachers to work alongside scientists, medical researchers, doctors, engineers, and other high-tech professionals at NASA Glenn Research Center, University Hospitals, and manufacturing plants.
- Identify opportunities that may exist elsewhere in the nation (e.g., at the various national laboratories of the Department of Energy) that may serve Northeast Ohio, or that may serve as a model for starting similar programs in Northeast Ohio.
- Commission a study and proposal for working over the long term toward ensuring that all mathematics and science teachers at the middle and high school level have a major in the subject they are teaching.
- Develop a proposal on how to provide mathematics and science specialists at the elementary level to support existing science and mathematics teachers, and to expand the opportunities to deepen the knowledge, skills, and interest of existing students in science and mathematics.
- Assist or support individual school districts in creating and implementing a coherent, consistent science and mathematics curriculum across Northeast Ohio regardless of district. [6].

instance, careful thought will need to be devoted to how to construct the terms of the pledge—as well as the requirements of teacher training programs and of school systems—if the intention is also to attract STEMM majors who had originally intended to pursue other STEMM careers to consider K-12 teaching at least part time, without jeopardizing original career goals.

Consider incentives to recruit and retain STEMM teachers, including student-loan forgiveness programs for mathematics and science college graduates who become teachers.

Second, encourage close collaboration between every Ohio or college or university department of education with the departments of business administration, sciences, engineering, and pre-med. Summit participants strongly recommended that all education majors, especially those planning to teach elementary grades, should be encouraged or required to take a minimum number of college-level introductory STEMM courses (e.g., astronomy, biology, geology, pre-med, pre-engineering), such as survey courses offered for satisfying breadth or distribution requirements.

They also highly recommended that education majors take at least one introductory business course of the type that includes case studies of successful industries as well as a "how-to" introduction to teamwork, creative thinking, and other business skills. Such survey courses should introduce the education majors to fundamental principles both in science and business, and bring them up to date about current scientific research horizons and current best practices in business. *Col-*

leges and universities that have eliminated survey courses must seriously consider reinstating them.

Opportunities should be made available for education majors to pursue co-op or work-study employment during the summer or regular school year with scientific research or engineering departments on campus or with manufacturers or other businesses off campus. Part of the education requirements of pre-service teachers might include not only student teaching, but also a rotation for at least one academic quarter in some STEMM-related internship with a hospital, engineering company, research laboratory, high-tech manufacturer, or the like, plus another academic quarter in a business environment. The goal would be to expose and immerse pre-service teachers in authentic research and work environments so they can communicate their knowledge from experience to their eventual K-12 students. Care should be taken so that the education majors in mathematics and science are given meaningful tasks in a representative environment for an effective length of time.

Offer teachers summer fellowships to work side by side with research scientists or engineers

Third, provide practical learning experiences for already-certified teachers in scientific research laboratories, manufacturing plants, and businesses as part of their regular professional development. "Most [K-12] teachers have never set foot inside a manufacturing facility," exclaimed one Summit participant, "and when they do, they are just speechless, blown away by the sheer magnitude of the enterprise, as well as the variety of jobs available." As part of the regular professional development for Ohio educators, *have teachers go through a job shadow rotation* where they can shadow healthcare practitioners (physicians and surgeons, nurses, radiological or laboratory technicians, hospital administrators, psychologists, large- and small-animal veterinarians), engineers and technicians (civil, mechanical, electrical, aerospace, manufacturing), and other STEMM professionals in research, manufacturing, and business for an entire work day.

The primary goal of such shadowing would be for teachers to observe skills being applied in an arena other than formal education, and to provide a foundation for teachers to become involved in changing today's school curriculum. From such shadowing, teachers can observe the range of opportunities, the nature of the daily work, the requisite knowledge, and the expectations of business and high-tech environments. They would be able to (in one Summit participant's words) "make science and math cool" by sharing with their K-12 students their personal excitement from this behind-the-scenes experience. Such shadowing experiences for teachers will require partnerships between Ohio school systems and Ohio high-tech manufacturers, hospitals, and research centers.

Fourth, involve regional research scientists, engineers, and medical professionals in professional development for K-12 teachers. "Educators need support in content-rich professional-development opportunities," stated one Summit participant. "We cannot expect teachers to educate children in current science and/or mathematics without having an understanding of basic and more complex issues, as well as recent developments."

One approach might be to have regional practitioners offer current overviews of the latest developments and frontiers in science, engineering, and medicine, specifically designed for K-12 teachers.

Another approach might be to encourage teachers (through defraying costs and granting professional-development recognition) to take advantage of already-existing opportunities. One such opportunity is the annual "Mini Med School (for the Rest of Us)" lecture series offered each spring by Case Western Reserve University (see http://cme.case.edu/minimedschool); running two evening hours per week over half a dozen consecutive weeks, the sessions led by Case faculty experts update registrants on understanding how the body works and on current medical breakthroughs. Other opportunities might be individual lectures or a lecture series offered at the Cleveland Museum of Natural History or by various colleges and universities.

Another approach is to provide existing teachers *summer fellowship positions* that allow educators to work side by side with STEMM practitioners. "I don't think that many of our elementary and middle-school teachers have ever worked with a real scientist," commented one Summit participant. Summer fellowships of a week to a month at a local corporation, hospital, or research center would provide teachers with unparalleled inside views of the daily work and wealth of individual opportunities at greater depth than shadowing alone could provide. In the words of the Department of Energy task

force, such summer laboratory experiences have the potential to "transform science teachers into 'scientist-teachers,' by allowing them to discover the fascination of participating in authentic scientific investigation, so they can excite students with both up-to-date knowledge and personal enthusiasm." [5]

[1] U.S. General Accounting Office, *Higher Education: Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends*, October 2005, p. 33; GAO, *Higher Education: Science, Technology, Engineering, and Mathematics Trends and the Role of Federal Programs*, May 2006; Secretary of Energy Advisory Board, U.S. Department of Energy, *Final Report of the Secretary of Energy Advisory Board's Science and Mathematics Education Task Force,* May 5, 2006 (online at http://www.seab.energy.gov/publications/SMETF-FRept_5-5d.pdf, p. 7.

[2] Board of Science Education (BOSE), National Academies, *Ready, Set, Science: Putting Research to Work in K–8 Science Classrooms*, National Academies Press, 2008, p. 3.

[3] Board of Science Education (BOSE), National Academies, *Ready, Set, Science: Putting Research to Work in K–8 Science Classrooms*, National Academies Press, 2008, pp. 3–4.

[4] Many references to research on the quality of teaching can be found on the website of Mary Kennedy at Michigan State University at https://www.msu.edu/~mkennedy/publications/Index.htm .

[5] Secretary of Energy Advisory Board, U.S. Department of Energy, *Final Report of the Secretary of Energy Advisory Board's Science and Mathematics Education Task Force,* May 5, 2006 (online at http://www.seab.energy.gov/publications/SMETF-FRept_5-5d.pdf), p. 6. The first recommendation of this study was for the Department of Energy create a multiyear Scientist-Teacher Professional Development program for K-12 teachers, taking advantage of its nationwide network of 17 national laboratories to set up a program of summer laboratory experiences, to involve teachers in the scientific community by collaborating in four to eight weeks of actual research. See also the presentation by Ray Land, "Using Research-Teaching Linkages to Enhance Graduate Attributes," University of Strathclyde, (online at http://www.nairtl.ie/documents/LandR.ppt). Both NASA and the Department of Energy have long offered teachers summer opportunities to take classes and work alongside scientists and engineers in their various centers around the nation.

[6] The lack of a common national curriculum has been indicted as one cause of the United States' lagging behind nations leading in their educational systems. See, for example, the special issue of *American Educator* on "A Common, Coherent Curriculum: And the Cascading Benefits that Flow From It," (Summer 2002), articles accessible online from http://www.aft.org/pubs-reports/american_educator/summer2002/ ; especially relevant is the article "A Coherent Curriculum: The Case of Mathematics," by William Schmidt, Richard Houang, and Leland Cogan at http://www.aft.org/pubs-reports/american_educator/summer2002/curriculum.pdf .

Recommendation 4:
Offer students interdisciplinary and "soft" skills

One revealing comment at the Northeast Ohio Regional Summit dealt neither with academic content, nor with skills unique to science, technology, engineering, mathematics, or medicine. It concerned people skills: "If you read the newspaper, business leaders have been saying for many years that the number-one challenge they face is not taxes, foreign competition, or the environment – it's the workforce: the challenge of finding people who show up for work regularly, ready to work, able to collaborate with others, with a work ethic, and a true willingness and desire to learn. Business is desperate for that."

Offer business etiquette skills and practices throughout K-12.

Another participant concurred: "There is an almost magical belief that if you just get kids into college, somewhere along the line they assemble work skills."

Summit participants identified three different but related sets of "soft" skills that make a young graduate or employee stand out from the crowd in the world of work. One set is a host of abilities that Summit keynote speaker Ken Kay called "21st Century Skills." Closely related is a set of skills pertaining to interdisciplinary or holistic thinking, of viewing a challenge in context. The third set of skills is simple, basic business etiquette.

First, integrate "21st Century Skills" into the curriculum. Quite apart from technical knowledge of science or mathematics, success in today's high-tech work world requires that students possess a dozen "soft" people skills, including the ability to collaborate in teams, effective oral and written communication, initiative and creativity [see sidebar]. Several Summit participants recommended exploring such curriculum models as Project Lead The Way,[1] which makes a point of having students work in teams, give presentations, and practice other 21st Century Skills.

"Studies also show that science is fundamentally a social enterprise," noted the National Academies' Board on Science Education. "Scientists talk frequently with their colleagues, both formally and informally. Science is mainly conducted by large groups or widespread net-

"21st Century Skills"

A dozen "21st Century Skills" have been identified by the Partnership for 21st Century Skills (known as P21), a consortium of 21 leading advocacy groups, companies and education organizations (http://www.21stcenturyskills.org/); P21's president Ken Kay was a keynote speaker at the Northeast Ohio Regional Summit.

According to Kay's presentation plus P21's white paper *Are They Really Ready to Work?*, the "soft" people skills (in addition to "hard" technical skills) that today's students must master before graduating from high school are:

- Creativity and innovation
- Critical thinking and problem solving
- Oral and Written Communications
- Teamwork and Collaboration
- Information and Media literacy
- Flexibility and adaptability
- Social and cross-cultural skills
- Productivity and Accountability
- Leadership, Initiative, and Self-Direction
- Lifelong Learning
- Professionalism and Work Ethic
- Ethics and Social Responsibility

P21 is working with various states in guiding the redesign of high school curricula to incorporate these skills to ready students for the workplace. [3]

works of scientists."[2] Moreover, teams are common throughout business, industry, universities, and other workplaces. When every team member contributes thoughtful individual perspectives, innovative problem-solving, critical thinking, and maximum effort, the outcome can be greater than the sum of its parts. All too often in classrooms today some students learn that they do not need to work very hard because one or two enthusiastic group members prefer to shoulder the full task. Such a dynamic, if it becomes habit and survives into the work world, could spell a disservice to both sets of students because neither has learned genuine collaboration.

Second, integrate science and mathematics with the arts, literature, history, and other subjects to make more effective impact across the curriculum. Attention needs to be paid to finding ways to link science and mathematics to other disciplines without diluting the science and math content. Such interdisciplinary combination would achieve several important ends. It would emphasize that science is not isolated from the rest of culture; in the words of one Northeast Ohio Regional Summit participant, "In elementary-school reading classes, you have to read something—why not read about science?" Remarked another, "Art students may think science is scary at first, but when they hear a classmate describe how cool it was to be in an operating room or a laboratory, the art students may respond to the challenge of creating artistic interpretations of that experience." Other disciplines can provide an invitation to students whose primary interests lie more in the humanities and other non-technical fields.

Conversely, involving science students in activities seemingly unrelated to science or mathematics, such as a school play, may inspire them to engineer ingenious props and sets as well as master the concepts of basic machines (pulleys, wedges, levers) as well as introduce non-science students to those concepts. For science instruction itself, approaching science from a historical perspective connects students to the human personalities, times, and adventures of discoverers while also introducing more fundamental scientific concepts first.[4] Finally, such an interdisciplinary approach accustoms students to "thinking outside the box"—one of the 21st Century Skills in high demand by today's employers (see sidebar at left).

Third, offer basic business etiquette skills and practices in school from kindergarten to high school graduation. It used to be that work ethic, reliability, good attitude, social responsibility, self-discipline, and basic etiquette could be assumed to be taught at home. But not every student today has the advantage of such an "old-fashioned" upbringing.

Yet in this era of emphasis on customer service, such rudimentary social skills can make or break a job interview or the retention of a job past the first 90-day pro-

Recommendation 4.
Suggested Steps for the Immediate Future

- Make an interdisciplinary learning opportunity out of the annual summer three-day Ingenuity Festival in downtown Cleveland, a "weekend-long celebration of art and technology" sponsored by a collaboration of regional high-technology firms, colleges and universities, and internationally acclaimed artists.[6]
- Introduce arts and culture into science or mathematics classes (for example, highlighting mathematical relations devised by the Greeks and Moors for their beautiful architecture); conversely, introduce science and mathematics or non-stereotyped images of scientists and engineers into literature and history classes (for example, show the movie *Proof* [2005], based on the Tony Award-winning play by the same title by David Auburn, which successfully captures the avid excitement of the mathematician heroine [Gwyneth Paltrow] in deriving her mathematical discovery).
- Encourage cooperation between science or mathematics courses with history or English courses by joint term papers or other projects. For example, students might be asked to write a term paper on Galileo, Newton, or other famous scientist, exploring not only their scientific discoveries—possibly including reconstructing their experiments—but also exploring their context in history and religion and their effect on Enlightenment thought and art. Such a project could receive a double grade, one each for a history class and a science class.
- Invite an etiquette consultant into individual classrooms to discuss why and how the knowledge and skill of good manners gives confidence that contributes to a person's success throughout his/her lifetime, and coach K-12 students in this important area. Offer etiquette as a series of classes starting in the elementary grades and revisit it each year. Reinforce that manners are good habits by having teachers model the good manners, and reward students' mannerly conduct in class and on the school grounds.

bationary period.

Recounted one Summit participant who teaches a careers connections course, before students shadow at a workplace, participate in a field trip, or apply for an internship or apprenticeship, "we tell them they are going to a place of business, ask them what would be appropriate to wear, coach them how to introduce themselves to someone and suggest how to behave on the way there and at lunchtime."

Business etiquette classes could also help students learn to be resourceful and take responsibility in the event of a personal emergency. For example, noted another Summit participant, if the car doesn't start in the morning, then workable options include catching a bus, riding with a friend, or at least calling the boss. Several business etiquette consultants in Northeast Ohio specialize in teaching classes for children and teens as well as adults.[5]

[1] Project Lead The Way (http://www.pltw.org/index.cfm); see also Project Lead The Way in Ohio (at http://www.pltwohio.org/about_archives_fall2007.cfm).

[2] Board of Science Education (BOSE), National Academies, *Ready, Set, Science: Putting Research to Work in K–8 Science Classrooms*, National Academies Press, 2008, p. 4.

[3] For more information about 21st Century Skills, see P21's reports *Results That Matter: 21st Century Skills and High School Reform* (2008; available at http://www.21stcenturyskills.org/resultsthatmatter/) and *Are They Really Ready to Work? Employers' Perspectives on the Basic Knowledge and Applied Skills of New Entrants to the 21st Century U.S. Workforce* (2006; available from http://www.21stcenturyskills.org/documents/FINAL_REPORT_PDF09-29-06.pdf).

[4] An excellent example of cross-disciplinary research involving both science and the arts is the August 2008 symposium presented by the Cleveland Clinic and the Cleveland Orchestra at the Salzburg Music Festival in Austria, to examine the intersection of music and neuroscience, the impact of music on health and disease, and the social implications of the music-brain connection. See http://my.clevelandclinic.org/media_relations/library/2008/music_brain_connection.aspx and also http://my.clevelandclinic.org/media_relations/library/2008/music_and_the_brain_symposium.aspx .

[5] Among Ohio etiquette consultants are Catherine Holloway, Etiquette Consulting Services, Cleveland, etiquetteohio@yahoo.com ; another who does business in Northeast Ohio is Cathi Fallon of The Etiquette Institute of Ohio, Columbus http://www.magnificentmanners.com/ .

[6] More about the Ingenuity Festival, inaugurated in 2005, appears at http://www.ingenuitycleveland.com/ .

Recommendation 5:
Encourage learning opportunities outside the classroom

"Schools need to broaden the definition of science and engineering-related education to include activities beyond the classroom," said one participant at the Northeast Ohio Regional Summit. "Manufacturers can't find technicians, welders, and other specialized skilled workers, especially today when manufacturing facilities are under very tight budgets and challenged to be globally competitive," stated another. For example, a new generation of technicians is needed to maintain wind turbines and other green technologies.[1]

A third participant recommended providing stipends to staff members for before/after school programs so they can offer at least occasional activities related to science and mathematics.

Conversations about the importance of science and mathematics need to occur not only at school, but also at the dinner table

For that to happen, another Summit participant pointed out that schools need to work with parents more effectively: "Conversations [about the importance of science, mathematics, engineering, manufacturing, and medicine] need to occur not only at school, but also at the dinner table." Parents must be made aware of the issues so they can support the education of their children both in school and informally. "Too many parents think, 'I don't need science and math, so my children will be fine,'" one teacher observed. "We all parent the way we were parented unless something compels us to change by making us aware."

First, raise the awareness of students' wider family structures—parents, aunts, uncles, grandparents, and other guardians—so that the family structures encourage and support students' full participation in science and mathematics opportunities in school.

"Schools need to work with parents and guardians more effectively so they understand the consequences of their students' course selections and course sequences," observed one Summit participant. "We need to get parent buy-in or nothing significant will change," added another. "We need accountability for parents as well as for students and educators."

Their observations are backed by surveys and studies. According to a 2006 Public Agenda report, parents are "complacent"—indeed, "the number of parents who worry about whether local schools are teaching enough about math and science has declined since the mid-nineties."[2] For this reason, the first recommendation of the Ohio Board of Regents' Science and Mathematics Education policy Advisory Council (SAMEPAC) is: "Develop and carry out a multi-year, research-based public awareness campaign focused on the importance of mathematics and science education to Ohio's citizens, as well as the state's future economic growth and prosperity."[3]

Several participants recommended working through parent teacher associations and organizations and parent meetings at local schools. The biggest challenge, however, is "reaching out to parents who are not engaged," noted a third participant. Some area public high schools with a student body of more than 2,000 may have fewer than a dozen parents show up for a PTA meeting. In contrast, a substantial percentage of parents of students at private or parochial schools are actively involved in their students' education. For that reason, Summit participants felt it was important to involve Northeast Ohio private/parochial schools as well as

public schools. One innovative suggestion was to have science and mathematics professionals give lunch-hour talks to parents at various workplaces on opportunities and options for their students.

Second, partner with Northeast Ohio's many opportunities for informal science education, and encourage students and their families to take advantage of enjoyable science-related learning opportunities outside of school. Many informal science providers [see sidebar below] offer programs aligned with educational standards to promote science literacy of the community at large. Many are also members of RAISE (Regional Alliance for Informal Science Education), whose website offers a way parents and teachers can search for public programs by topic, grade level, date, or institution.[4] It is important to note that *many of these programs are free*, and accessible even to budget-conscious or low-income families.

Informal educators present science and technology disguised as fun

Northeast Ohio's Informal Science Educators

A few examples of Northeast Ohio informal educators include the Cleveland Botanical Gardens, the Cleveland Metroparks, the Cleveland Museum of Natural History (which includes a planetarium), the Cuyahoga Valley National Park (which also offers week-long summer programs for grades 4–8 focused on the environment through the Cuyahoga Valley Environmental Education Center), the Great Lakes Science Center (a major hands-on science center), the Holden Arboretum, the International Women's Air and Space Museum at Burke Lakefront Airport, the Lake Erie Nature and Science Center (which includes a planetarium), the Lake Metroparks, and the Visitor Center at NASA Glenn Research Center.

Nearby Akron includes Inventure Place, the Inventors' Hall of Fame and hands-on science center, and the Metro Parks Serving Summit County (whose Nature Realm offers nature programs).

In addition, several astronomical observatories in Northeast Ohio (including the Mueller Observatory at the Cleveland Museum of Natural History and the Stephens Memorial Observatory of Hiram College) have public observing nights where students can look through a telescope at various celestial objects and perhaps hear an astronomer talk about meteor showers or black holes.

Many of these organizations also offer children's activities, summer programs, lecture series, special and permanent exhibits, all presenting science or technology disguised as fun outside the classroom.

Some science programs offered by informal science organizations encourage students to get their hands dirty doing real science, such as the programs offered by the Cleveland Metroparks. Volunteers aged 12 and up are trained to help tag Monarch butterflies to track migration patterns. Cleveland Metroparks also offers a program of monthly "Home School Happenings"—and nature field trips for home-schooled K-12 students. Lake Erie Nature and Science Center offers an inexpensive three-year program (one Saturday every other month) for students in grades 7, 8, and 9 to learn to become naturalist's assistants. Inventure Place offers one-week summer Camp Invention programs for elementary and middle school students to inspire inventiveness in children.[5]

Third, encourage hands-on science and engineering, and promote local science fairs, robotics contests, and similar events and venues. "Schools and parent-teacher-organizations need to help fund hands-on science, and support extracurricular science and engineering activities just as much as they now support athletics," declared one Summit participant. Teachers, parents, and/or students should be encouraged to support or establish a science club in every Northeast Ohio school, beginning with students in the early elementary grades.[6]

Many middle schools and high schools already make provisions for students to create their own science fair exhibits as part of science classes. Students may compete for some $20,000 in prizes during a major four-day Northeastern Ohio Science and Engineering Fair that has been held annually since 1954.[7] Students may also apply to compete in the annual LEGO Olympiad, sponsored by the student chapter of the Society of Manufacturing Engineers club at Lorain County Community College, in cooperation with Nordson.[8]

Students, teachers, and parents alike should be encouraged to attend a competition or science fair to walk around and watch the fun whether they are entrants or not. In so doing, all will see how scientists and engineers can do "cool" things and be inspired by the ingenuity of fellow students in grades 7–12, absorb some basic scientific principles through observation, and be motivated to try projects at home. Encourage students to view Ohio's annual Science Olympiad,[9] Cleveland's annual FIRST robotics competition at Cleveland State University[10] and similar events[11] by awarding extra credit.

Recommendation 5. Suggested Steps for the Immediate Future

- Start a Northeast Ohio Paper Airplane Contest with divisions accommodating students spanning K-12. It is a low-cost extracurricular event using everyday materials plus ingenuity and fun, and likely to raise media interest, There does not appear to be any such contest in Northeast Ohio, although one has been held annually in Marietta since 1995.[15] The professional engineering organizations American Institute of Aeronautics and Astronautics (AIAA) and the American Society of Mechanical Engineers (ASME) have co-sponsored paper airplane contests for K-12 students in other states, and thus may be willing and able to offer practical suggestions.[16]
- Contact adult science hobby organizations, such as the Cuyahoga Astronomical Association (CAA) or the Astronomy Club of Akron[17] or the Northern Ohio Association of Herpetologists (NOAH),[18] for potential speakers who might visit a school science club, or for special events such as a public "star party" featuring telescopes for viewing the moon and planets.
- Encourage individual schools and teachers to announce and distribute information about various Northeast Ohio nature and science museums, parks, invention or curiosity camps, and other extracurricular opportunities for students and their families.
- Convene a one-day nature/science festival (in cooperation with RAISE, colleges, the Metroparks of various counties, science societies, nature artists, and other groups) featuring live animal demonstrations, booths of information, movies, and speakers to attract students and their parents to explore Northeast Ohio's wealth of nature and science recreational activities. Consider making the nature/science festival an annual event—another natural for media interest.
- Start a local science club or a technology club within every Northeast Ohio community. Programs could include field trips to local factories (e.g., Malley's Chocolates, *The Plain Dealer*), group projects (such as building a backyard weather station), and by "cool" young engineers, scientists, *and technicians* about what they do and why they chose their careers. Focus on careers in such emerging fields as nanotechnology and "green collar" professions.
- Contact various professional engineering and manufacturing societies and the Nuts and Bolts and Thingamajigs Foundation to explore setting up manufacturing summer camps for K-12 students in Northeast Ohio.

Fourth, get kids tinkering with hands-on hobbies. "Scientists and engineers need technicians," points out the Institute of Materials, Minerals, and Mining (IM^3). Despite the need and lack of skilled technicians, technician careers "are not desirable to youth," observed one Summit participant. For that reason, the IM^3 and other professional organizations are seeking to elevate the status of such positions.[12]

A generation or two ago, it was common for elementary, middle, and high school students to have such hobbies as building ham radio sets, stereo sets, telescopes, go-carts, kites, skateboards, and models of all types. Via such tinkering, they learned design skills, calculation and measurement, hand-eye coordination, skillful handling of tools ranging from soldering irons to lathes, and pride of invention and workmanship—all still much needed today in engineering and manufacturing. But the proportion of today's teens (whose hobbies tend to be related to a computer keyboard) with such hands-on expertise have sharply declined.

Get kids tinkering with hands-on hobbies to develop manual skills needed by industries and engineering practices

"To avert a growing crisis in America occurring because too few young people now develop the kind of manual skills required by industries, workshops, and engineering practices," manufacturing summer camps, mentoring, and education for K-12 students are now being offered by such organizations as the Fabricators and Manufacturers Association Foundation and the Nuts and Bolts and Thingamajigs Foundation.[13]

Fifth, connect with the media, and through them, the larger community. "We need to change the entire community culture of how parents as well as kids think about science and mathematics," stated one Summit participant. One way to do that, participants were convinced, was to "nurture relationships with local media."

One idea discussed was a major marketing campaign of wanting a future for Northeast Ohio's children through science and mathematics, disseminated through press

releases, newsletters, articles, TV advertisements, public service radio spots, local and regional newspapers, and educational TV and radio (WVIZ/WCPN *ideastream* in the Cleveland area). Other ideas included educational programs on workforce information through public access cable TV or educational TV, websites and internet blogs, community centers, public lectures, informal public events, student-focused events such as collaboration between schools, and streaming video. One participant recommended developing informational and career promotional materials similar to Ohio Mathematics and Science Coalition materials.[14]

[1] See, for example, Blake Nicholson, Associated Press, "Technicians, training needed for wind power jobs," July 27, 2008, http://www.cleveland.com/nation/index.ssf/2008/07/technicians_training_needed_fo.html and Ted Fackler, "Study finds 'green' job potential in Ohio high," *Toledo Blade*, June 13, 2008, http://www.toledoblade.com/apps/pbcs.dll/article?AID=/20080613/BUSINESS06/806130339 . The actual study to which the *Toledo Blade* refers is Robert Pollin and Jeannette Wicks-Lim, *Job Opportunities for the Green Economy: A State-by-State Picture of Occupations that Gain from Green Investments*, Political Economy Research Institute, University of Massachusetts, Amherst, June 2008, available from http://www.peri.umass.edu/fileadmin/pdf/other_publication_types/Green_Jobs_PERI.pdf .

[2] *Reality Check 2006. Issue No. 1: Are Parents and Students Ready for More Math and Science?* A Report from Education Insights at Public Agenda. A Public Agenda Initiative to Build Momentum for Improving American Schools, p. 6. Available at http://www.publicagenda.org/files/pdf/rc0601.pdf.

[3] Science and Mathematics Education Policy Advisory Council [SAMEPAC]. *Science and Mathematics: A Formula for 21st Century Success.* January 2007. p. 8. Available at http://regents.ohio.gov/samepac/reports/SAMEPAC_REPORT_FINAL_1-22.pdf .

[4] More about RAISE and its members appears at http://www.raiseohio.org/ ; the search page for public programs is at http://www.raiseohio.org/events.php .

[5] More about Inventure Place and its Camp Invention programs appears at http://www.invent.org/ and http://www.inventnow.org/ .

[6] Suggestions for founding a geology club for students as young as 7 or 8 years old can be found online at http://www.fossils-facts-and-finds.com/geology_activities.html .

[7] More information about Northeastern Ohio Science and Engineering Fair appears at http://www.neosef.org/ .

[8] More information on the LEGO Olympiad at Lorain Community College appears at http://www.lorainccc.edu/Community+Services/Lego+Olympiad/ .

[9] More information on Ohio's Science Olympiad appears at http://www.continuinged.ohio-state.edu/scioly/bgrnd.html .

[10] More information on FIRST robotics competitions at Ohio State University and elsewhere appears at http://www.osufirst.org/ . The mission statement of the national program FIRST (For Inspiration and Recognition of Science and Technology) is "To create a world where science and technology are celebrated… where young people dream of becoming science and technology heroes."

[11] Many other competitions are listed at http://www.tap2015.org/resource/month.html .

[12] For the perspective and efforts of the Institute of Materials, Minerals, and Mining, see http://www.iom3.org/content/need-technicians and http://www.iom3.org/content/need-technicians .

[13] Quote is from the Nuts and Bolts and Thingamajigs Foundation, http://www.nutsandboltsfoundation.org/About-Us.html . A list of 2008 Fabricators and Manufacturers Association Foundation manufacturing summer camps offered in various states—although none yet in Ohio—appears at http://www.fma-foundation.org/Manufacturing-Camps/Manufacturing-Camp-List.cfm .

[14] Many publications of the Ohio Mathematics and Science Coalition are available from http://www.ohiomsc.org/omsc/New.html .

[15] For newspaper coverage of the 2008 Paper Airplane Contest in Marietta, see http://www.newsandsentinel.com/page/content.detail/id/502658.html . The article implies, however, that the Marietta contest is done primarily for general community fun rather than as part of extracurricular informal science education. At least one website, however, has set up activities specifically designed for conveying the principles of flight through paper airplanes; see http://www.cyfernet.org/integrate/iowa/flying_things.html . Other references include books on flying origami and Gerry Mander's classic book on the Scientific American Paper Airplane Contest of 1967, which includes many patterns for paper airplanes.

[16] As just one example, for info about the AIAA contest co-sponsored with the University of Alabama at Huntsville, see http://www.aiaa.org/portal/index.cfm?adview=12&tcspageid=1463&getcomm=139 .

[17] Information about the Cuyahoga Astronomical Association appears at http://www.cuyastro.org/about.html . Information about the Astronomy Club of Akron appears at http://www.acaoh.org/ .

[18] The Northern Ohio Association of Herpetologists (NOAH), which does not appear to have a website, is headquartered in the Department of Biology at Case Western Reserve University.

Recommendation 6:
Think globally, act locally

"Stop talking and start acting," declared one participant at the Northeast Ohio Regional Summit. Participants agreed that it is time to bury the "rust belt" image of the past, and to focus on the future: Northeast Ohio's children and students in the twenty-first century.

"Our Northeast Ohio school systems need to develop a strategic plan to prepare students for the global economy," said another participant. "We need to formulate a plan complete with timelines, action plans, and outcomes."

As a starting point for such a regional strategic plan, one participant offered a succinct summary of the basic necessities discussed during the Summit: "1) Excite students' interest. 2) Start young. 3) Include experimental learning opportunities. 4) Provide a common curriculum. 5) Offer opportunities outside of the classroom. "

"We also need to create a regional plan to support economic revitalization through the creation of a highly skilled workforce," added a third participant. "Northeast Ohio must offer attractive opportunities to keep students in school—and devote a concerted effort to keeping the best and the brightest in the region after graduation." One step in this direction was taken in June 2008 with the announcement by the Chancellor of the Ohio Board of Regents of $100 million in scholarships to recruit and retain Ohio college students majoring in STEM or STEM education.[1]

Recommendation 6.
Suggested Steps for the Immediate Future

- Organize a blue-ribbon panel to visit other medium-sized middle-America cities comparable to Cleveland, which have brought themselves into the twenty-first century. Visit the downtown areas and the schools and meet with city leaders to learn how they have overcome past downturns to revitalize their downtown area, their educational systems, and their pride of community, how they retain talent in their areas, and where they still see principal challenges. Cities high on the list to visit should include Kansas City (Missouri), Little Rock (Arkansas), and Pittsburgh (Pennsylvania).
- Get started.

[1] The Ohio Board of Regents' scholarship announcement appears at http://regents.ohio.gov/news/press_releases/2008/OBRMediaRel26Jun08.pdf .

Appendix 1.
STEMM / 21st Century Skills Regional Summit Planning Team

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Appendix 2.
Funders, Presenters, and Panel

Funders

The Cleveland Foundation
WVIZ/PBS and 90.3 WCPN ideastream®
The Martha Holden Jennings Foundation
The Ohio Mathematics and Science Coalition
The SMART Consortium

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Panel

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STEMM / 21st Century Skills Regional Summit

The Northeast Ohio STEMM / 21st Century Skills Regional Summit (Science, Technology, Engineering, Mathematics and Medical)," held February 27–28, 2008 in the WVIZ/PBS and 90.3 WCPN ideastream® Idea Center™ at Playhouse Square in Cleveland, Ohio. The Northeast Ohio Regional Summit gathered together regional leaders from Northeast Ohio educational organizations , medical centers, NASA Glenn Research Center, teacher and labor unions, philanthropic groups, community mayors, and other groups to formulate a plan to carry Northeast Ohio's educational system into the 21st century.