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ENGINEERING THE K-12 CURRICULUM FOR TECHNOLOGICAL INNOVATION

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Panel #4 - "K-12 Education: Sparking Student Interest & Teacher Training"

The Museum of Science's goal is to introduce engineering and technology to schools—and at least one science center or informal education organization—in every state by 2015. Achieving this goal will help transform how children and adults understand and perceive technology and engineering, while inspiring young women and men to pursue careers in engineering and technology.

There is a concern that the nation's preeminence in innovation is eroding. To maintain the vitality and security of our country, we must expand our students' understanding of technology and engineering and broaden the pathways to engineering and scientific careers so that a diverse array of talented students can pursue these fields.

The key to educating students to thrive in today's competitive global economy is introducing them to the engineering design skills and concepts that will engage them in applying their math and science knowledge to solve real problems. This is the way to harness the creativity of young minds. This is also the process that fuels innovation of new technologies.

One problem is that most children and teachers think that engineers work mainly in construction or with information technology. They don't understand that a pen, windows, and water bottles are forms of technology, designed by engineers. Far beyond a facility with computers, "technological literacy" involves understanding what technology is, how it is created, and how it influences our lives. According to *Technically Speaking: Why All Americans Need to Know More About Technology* (National Academy Press, 2002), "Although the United States is increasingly defined by and dependent on technology … its citizens are not equipped to make well-considered decisions or think critically about technology." The report also said, "Neither the educational system … nor the policy-making apparatus has recognized the importance of technological literacy.

Until now, our country's school science curricula have focused almost exclusively on the natural world while ignoring the human-made one. Nineteenth century society was largely agrarian, and technologies were relatively primitive. There were no phones, plastics, automobiles, or computers. Obviously, our world has changed. But in the mid-1990s many teachers were still teaching a school curriculum largely reflecting a 19th century world. Most people spend 95 percent of their time interacting with products of the human-made world (technology). But few can explain the process by which these products are made (engineering).

There are many reasons to introduce engineering in K-12 schools:

First, engineering is rich in hands-on experiences. Children are born engineers, fascinated with building and taking things apart to see how they work. Describing these activities as engineering can help them develop positive associations with the field.

Second, engineering brings math and science to life, demonstrating that they are relevant and motivating students to pursue them. Engineering pulls together many other disciplines engaging children of differing abilities in problem-based learning, where teamwork is important.

Third, to create a technologically literate workforce, we need to foster engineering as a career choice. Relevance is particularly significant for girls and other underrepresented groups. Offering engineering early in schools makes it accessible to many more children who could enroll in necessary math and science courses.

The fourth and major reason to start engineering early is that technological literacy is basic literacy for the 21st century. We live in a technological world. We need to understand how human-made things like shoes and bicycles are created and how they work.

Understanding the importance of technological literacy and the need for trained engineers, the Museum of Science, Boston launched the National Center for Technological Literacy® (NCTL®) in 2004 to enhance knowledge of engineering and technology for people of all ages and to inspire the next generation of engineers, inventors, and scientists. Through the NCTL, the Museum is integrating engineering as a new discipline in schools via standards-based K-12 curricular reform and developing technology exhibits and programs. The Museum of Science is the only science museum in the country with a comprehensive strategy and infrastructure to foster technological literacy in both science museums and schools nationwide.

K-12 Initiatives

Recognizing that a 21st century curriculum must include the human-made world, the NCTL strives to introduce engineering in elementary school and continue it through high school, college, and beyond. For that reason, the NCTL strategy involves creation of educational products and resources, professional development, and advocacy.

A key goal of the Museum has been to examine and enhance K-12 engineering curricula. The Museum's online *Technology and Engineering Curriculum Review* includes instructional materials in a searchable database (http://www.mos.org/TEC). The most promising ones have been peer reviewed and mapped to national standards. The Museum is also creating curricular resources representing and engaging the 21st century world; both genders; and people of different colors, backgrounds, and cultures.

For example, the **Engineering is Elementary®** (EiE) project integrates engineering and technology with science, language arts, social studies, and mathematics via storybooks and hands-on design activities. Elementary teachers nationwide can use these curricular materials to teach technology and engineering concepts to children in grades 1-5. Each unit begins with an illustrated storybook in which a child from a different country uses the engineering design process to solve a problem.

This program has incorporated research, evaluation, and assessment into all aspects of its design. Students in grades 2-5 engaged in each of six EiE units completed a pre- and post-assessment. On more than 75 percent of questions, students performed significantly better on the post-assessment than on the pre-assessment. In most cases where a control sample was available, EiE students performed significantly better than the control. This was true for both genders and all racial/ethnic groups. Students demonstrate, among other things:

- a better understanding of the kind of tasks engineers working in a specific field might do for their job
- a better understanding that engineering involves design and teamwork
- a better understanding of the engineering design process
- an increased likelihood of understanding science content related to the unit
- a better understanding of what a process is and how it is a type of technology
- a better understanding of the criteria for judging the effectiveness of a technology

Engineering is Elementary professional development is also influencing teachers, who report large gains in their knowledge and understanding of the range of engineering disciplines, what engineers do, and the pervasiveness of engineering. Teachers report they are more knowledgeable about how engineering is practiced. They also report changes in their pedagogy after learning about EiE and teaching it in their classrooms. As of March 2008, Engineering is Elementary had reached over 5,562 teachers and 190,780 students in 46 states and Washington, DC. Materials are available at http://www.mos.org/EiE.

Building Mathematics*,* created with Tufts University, provides innovative practices for integrating engineering with math to help middle school students develop algebraic thinking. It has been pilot-tested in Massachusetts. Three-book series for grades 6-8 and teachers guides are available from Walch Publishing (www.walch.com).

The standards-based **Engineering the Future®** (EtF) curriculum engages high school students in hands-on design and building challenges reflecting real engineering

problems and encourages them to explore what engineering and technology are and how they influence our society. Preliminary studies show that students significantly increase their understanding in all four *Engineering the Future* units. The textbook is narrated by practicing engineers from various ethnic and cultural backgrounds. *Engineering the Future* textbook, *Engineers Notebook*, and *Teachers Guide* are available from Key Curriculum Press (www.keypress.com.etf). In 2005-2007, EtF reached 162 educators and 7,573 high school students in 102 schools in 10 states.

The NCTL's train-the-trainer approach to professional development helps teacher educators understand engineering and technology concepts, communicate them to other teachers, and run workshops. NCTL staff have worked with teacher educators from over 25 states and Washington, DC, during institutes and online courses to help them become familiar with engineering and lead professional development workshops in their region. In Massachusetts, the Gateway to Engineering and Technology Education project involved a network of 54 state school district leaders sharing best practices, experiencing hands-on engineering activities, and helping each other solve problems in order to implement the state's K-12 technology/engineering standards.

Lifelong Informal Education

The Museum of Science is also prototyping museum exhibits and programs that will inspire people to become technologically literate by exploring: 1) what technology is; 2) how it is created and used; and 3) how to make informed decisions about its development, use, and impact. Among the Museum's educational approaches are: 1) a "showcase" presenting new technologies and the latest research, 2) a "creativity workshop" for hands-on problem-solving with technology and invention, and 3) a "forum" focusing on developing critical thinking skills about science and technology issues. The goal is to help the public understand the innovation process—the skills of designing, building, and using technology—and the impact of science and technology.

Since 2003, Museum educators have engaged 50,000 young visitors in Design Challenges involving the engineering design cycle. Visitors may prototype a tiny bobsled or design a shelter for one of the Museum's live animals. Research shows that the challenges successfully guide visitors through the engineering design cycle. An exhibit nearby explores the stories of breakthrough engineering leaders, while guest scientists and engineers often join Museum experts to explain new advances.

In addition, *Star Wars: Where Science Meets Imagination*, the Museum's national touring exhibit, created with Lucasfilm Ltd. and funded in part by the National Science Foundation (NSF), has promoted technological literacy, reaching more than 1.25 million people since 2005. In 2005, the Museum of Science, in partnership with the Science Museum of Minnesota and the Exploratorium in San Francisco, was selected by the NSF to lead a $20 million effort to form a national Nanoscale Informal Science Education Network of science museums and research institutions.

Advocacy

In part because of the Museum of Science's advocacy: 1) the National Assessment of Educational Progress (NAEP) Science Framework for 2009 will be the first national test to include questions on technological design alongside those on scientific inquiry; 2) the National Governors Association STEM agenda calls for the adoption of technology and engineering standards and assessments; 3) the America COMPETES Act creates opportunities for technology teachers and engineering instruction at several federal agencies (not yet funded); and 4) the Higher Education Act expands the definition of "technological literacy" to include the engineering design process.

In 2001, Massachusetts was the first state in the nation to develop a K-12 curriculum framework and assessments for technology/engineering. The NCTL has been in contact with people interested in K-12 education in 46 states and Washington, DC, in various ways. Over 30 states now address technology/engineering through science standards and/or technology education.

Call for Action

If we are truly concerned about innovation and global competition, it is time for a major commitment to and investment in technological literacy. Please also consider the following as you pursue new education and innovation policies:

- Encourage states to adopt technology and engineering standards and assessments;
- Encourage states to include technology and engineering in the definition of "rigorous curricula" for high school graduation;
- Expand the No Child Left Behind (NCLB) definition and requirement for "technological literacy" to go beyond the *use* of computers to include the engineering design process;
- Include technology and engineering teachers alongside math and science teachers in all incentive programs to recruit, train, mentor, retain, and further educate teachers;
- Support after school programs that include technology and engineering activities; and,
- Remember science museums are excellent providers of teacher professional development. Be sure they are eligible participants in such programs.

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