Museum of Science

ENGINEERING THE K-12 CURRICULUM FOR TECHNOLOGICAL INNOVATION

Ioannis N. Miaoulis, Ph.D.

The Challenge

With an economy in crisis and a workforce at risk, educating the nation's future engineers and scientists and advancing technological literacy are more important than ever. We need a strong engineering workforce to remain competitive. To maintain our country's vitality and security, we must expand students' understanding of technology and engineering and widen the pipeline to careers in these fields so that a diverse array of talented students can pursue them.

The goal of the Museum of Science, Boston 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 technology and engineering, while inspiring young women and men to pursue careers in engineering and technology.

The key to educating students to thrive in this 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.

Lately, K-12 math and science education has received a lot of attention, while K-12 technology and engineering education has been largely overlooked. The problem is that the school science curricula still focus more on the natural, not the human-made or technological, world, and have taught little or no engineering. The beauty of engineering is that it is the connector that uses science and math to create the technological innovations that facilitate daily experience. Nineteenth century society was largely agrarian. No phones, automobiles, or computers. Obviously, our world has changed but most curricula have not, leaving a huge gap in students' learning. While most people spend 95 percent of their time interacting with technologies of the human-made world, few know these products are made through engineering. We need to add technology and engineering as standard subjects in U.S. public schools.

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.

However, according to *Technically Speaking: Why All Americans Need to Know More About Technology* (National Academy of Engineering/National Research Council, 2002, page 1), "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." Far beyond a facility with computers, "technological literacy" involves understanding what technology is, how it is created, and how it influences our lives. To paraphrase from *Technically Speaking* (page 4), a technologically literate person should:

• be able to recognize technology in its many forms
• be familiar with the engineering design process and basic concepts, including constraints, systems, trade-offs
• have a range of hands-on skills in using a variety of technologies
• recognize that there are risks and benefits in choosing to use or not use technology to solve problems
• be able to use math skills to make informed decisions about technological risks and benefits

Understanding the importance of technological literacy and the need for trained engineers, the Museum of Science 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 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. The Museum is helping states modify their educational standards and assessments to include engineering, developing standards- and research- based K-12 engineering curricula, and offering educators support and professional development.

A key goal of the Museum has been to examine and enhance existing 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 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 school 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.

EiE incorporates research, evaluation, and assessment into all aspects of its design and testing. During the development, pilot and field testing of EiE units, students completed pre- and post-assessments that measure pupils' understandings of engineering concepts, technology concepts, and science concepts. National, controlled studies indicate that children who engage with engineering and science through EiE learn engineering, technology, and related science concepts significantly better than students who study just the science (without engineering). This was true for both sexes and all racial/ethnic groups. Teachers also report that EiE curricular materials work well, whether students are low- or high-achieving, including those with cognitive, linguistic, and behavioral challenges, who are girls, children of color, or at risk in other ways.

Promising preliminary research indicates that EiE may be narrowing the achievement gap. In a national controlled study, thousands of students who participated in an EiE unit and related science instruction were compared to a control group that studied only the related science instruction. In two of the three units studied, the performance gap between low and high socioeconomic students was significantly smaller after participation in an EiE unit.

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. They also report changes in their pedagogy after learning about EiE and teaching. As of May 14, 2009, Engineering is Elementary had reached 15,660 teachers and 1,021,725 students in 50 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 reached teachers and almost 95,000 students in 40 states and Washington, DC. Awarded the 2008 Distinguished Curriculum Award as a math curriculum package by the Association of Educational Publishers, the 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 increase their understanding in all four *Engineering the Future* units. The textbook is narrated by practicing engineers from various ethnic and cultural backgrounds. The *Engineering the Future* textbook, *Engineers Notebook*, and *Teachers Guide* are available from Key Curriculum Press (www.keypress.com.etf). EtF has reached educators and high school students in over 39 states. In the last three years, professional development has been delivered to almost 500 teachers.

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 familiarize them with engineering and lead professional development workshops in their region. In Massachusetts, the Gateway to

Engineering and Technology Education project has involved a network of nearly 300 educational leaders from 58 school districts in sharing best practices, experiencing hands-on engineering activities, helping each other solve problems in order to implement the state's K-12 technology/engineering standards, and reaching 319,028 students.

Lifelong Informal Education

The Museum of Science is also prototyping museum exhibits and programs to 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 76,000 young visitors in hands-on Design Challenges. 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. 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. Forty (40) states now address technology education in their standards, and states are also moving to include engineering as a core academic subject. The NCTL has been in contact with people interested in K-12 education in 50 states and Washington, DC, in various ways.

Call for Action

There is a concern that our nation's preeminence in innovation is eroding. We need a strong, sustainable engineering workforce to remain competitive in the global economy. To attain that

goal and to maintain our country's vitality and security, we must expand students' understanding of technology and engineering and increase the attractiveness of careers in these fields so that a diverse array of talented students will pursue them.

If we are truly concerned about innovation and global competition, it is time for a major investment in technological literacy. Engineering education must move into the formal classroom so that all students learn the engineering design process and have the opportunity to explore careers in technology and engineering.

The U.S. Department of Education's “Race to the Top” funds provide an opportunity for states to adopt world-class standards and assessments that measures student technological literacy and innovation skills.

As Congress considers revising the Elementary and Secondary Education Act (ESEA), we recommend the following:

• Allow informal STEM education centers and other non-profit educational organizations to receive funds for teacher professional development;

• Expand and rename the Math/Science Partnerships to STEM Partnerships to include technology and engineering educators in teacher professional development opportunities;

• 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 engineering/technology teachers alongside math/science teachers in all incentive programs to recruit, train, mentor, retain, and further educate teachers;

• Remember science museums are excellent providers of teacher professional development and make sure they can participate in such programs;

• Support after-school programs that include technology and engineering activities as well as math and science activities.

The National Center for Technological Literacy stands ready to assist in re-engineering today's schools, inside and out. Join us. Visit www.nctl.org.

(Ioannis Miaoulis is president and director of the Museum of Science, Boston and former dean of Tufts University's engineering school. This article has been adapted and updated from a White Paper submitted by Dr. Miaoulis, who served as a panelist at the August 18 – 19, 2008, National Science and Technology Summit, Oak Ridge National Laboratory, Tennessee. The Office of Science and Technology Policy convened the summit, called for by the 2007 America COMPETES Act, on behalf of the President. The summit final report has been delivered to Congress.)

09-10-19