

2011 BROCK INTERNATIONAL PRIZE IN EDUCATION

NOMINEE

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President and Director

National Center for Technological Literacy
Museum of Science
Science Park
Boston, MA 02114

JUROR

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It is my pleasure to nominate Dr. Ioannis Miaoulis to receive the Brock International Prize in Education. Dr. Miaoulis is a leading authority on STEM (Science Technology Engineering and Mathematics) education, and is recognized as the foremost champion of K-12 engineering education in the United States. His model of engineering as a process for our understanding how the human-made world is created has been widely proclaimed as a necessary parallel to the teaching of science as a process for our understanding of the natural world.

K-12 engineering education contributions

Dr. Miaoulis's dream of introducing engineering in school curricula starts as early as kindergarten. His journey toward achieving his dream is described in detail in a book chapter that he authored. I present below, in some cases verbatim, part of the content of the chapter, as well as the timeline of his journey and specific major accomplishments that have led to significant changes in education at the national level. The chapter is presented in its entirety in the writing samples section.

We live in an engineered world. Engineering design creates the technologies that support our health, convenience, communication, transportation, living environments, and entertainment—our entire day-to-day life. We school our children so they can live a healthy, productive, and happy life. Our curriculum includes disciplines that prepare students to understand the physical and social world around them so they can be informed users, producers, and citizens. Social studies prepare students to understand human relations and dynamics. Mathematics prepares them to think in quantitative manners to model processes and to calculate. Language arts prepare them to communicate effectively and provide them with tools to learn other disciplines. Science prepares them to analyze and understand the physical world around them. Beginning in preschool, students learn about rocks, bugs, the water cycle, dinosaurs, rain forests, the human body, animals, stars and planets, chemical reactions, and physics principles. These are all-important topics, but they only address a minute part of our everyday life.

The science curriculum focuses exclusively on the natural world, which, arguably, occupies less than five percent of our day-to-day activities. The classical K-12 curriculum essentially ignores the other 95 percent, the human-made world. Prior to Dr. Miaoulis's efforts, the human-made world and engineering, the process of creating the human-made world, had not been part of the mainstream curriculum. Although students spent years in school learning about the scientific inquiry process, the process scientists use to discover the natural world, they never learned the engineering design process, which is responsible for most of the things that support their day-to-day lives.

The core academic topics that were taught until Dr. Miaoulis's movement were decided in 1893 by the "Committee of Ten," chaired by President Elliott of Harvard University. Dr. Miaoulis's chapter outlines why they did not include the human-made world and engineering as core topics. The last major effort to introduce engineering as a core discipline in K-12 took place around the same time and was led by C.M. Woodward, the Dean of Engineering at the Washington University in St. Louis. The effort failed, and the only outcome was the creation of "Industrial Arts" ("shop"), which is currently taught in

vocational schools and as an elective in some middle and high schools in the form of Technology Education.

The five major reasons that motivated Dr. Miaoulis to champion the introduction of engineering as a new core discipline are these:

1. Technological Literacy, understanding the human-made world and how it is made, is basic literacy.
2. Engineering integrates all disciplines and creates wonderful problem-solving activities where students work collaboratively in teams to solve real problems they care about.
3. Engineering makes mathematics and science relevant to students and motivates them to continue their studies in these areas.
4. Introducing engineering early on motivates students to consider engineering as a desirable career option, ensuring a much-needed robust U.S. technological workforce.
5. Engineering design builds students' skills and abilities to navigate in a three-dimensional world.

Dr. Miaoulis's K-12 outreach activities started in 1987 and for the first seven years focused on enhancing the traditional science instruction in grades K-8. In 1994, he realized the major omission in the core curriculum and launched an effort to introduce engineering in K-12 education.

A small number of K-12 engineering curricula were developed in the early to mid-1990s; however, their purpose was to motivate students to pursue careers in engineering. Most focused on a specific engineering area such as electronics or automotive engineering. "Project Lead the Way" offered the first sequence of high school engineering courses aimed toward students who planned to attend engineering schools. Many engineering colleges also started K-12 education outreach programs. Recruiting and community service were the main motivators. The first effort to introduce engineering to all children, starting in kindergarten, was undertaken by the School of Engineering at Tufts University in 1994 under the leadership of Dr. Miaoulis, who was then Dean of the School of Engineering. The Center for Engineering Education Outreach was established, and it created curricula and professional development programs for educators spanning all grade levels. The center also partnered with LEGO and created Robolab, the software that enabled the LEGO Mindstorm robotic kit to be used in classrooms.

While these breakthrough programs were very effective, they reached only a small number of schools and students. There was clearly a need for a systemic change in order for the K-12 engineering movement to gain momentum. An opportune moment arose in 1998, when the Board of Education in Massachusetts appointed a committee to re-write the Massachusetts curriculum framework and learning standards.

Dr. Miaoulis was appointed to the committee that would re-write the technology education component of the science standards. He worked with a team of K-12 educators, primarily K-12 Technology Education teachers and introduced the first

engineering curriculum frameworks and standards in the United States. The senior staff in the Massachusetts Department of Education did not have much appreciation for Technology Education standards at the time, and they saw the transformation of Technology Education standards to Technology/Engineering standards as a move in the right direction. The Technology Education teachers in the group also saw it as yet another evolution of their field and an opportunity for their professional position in the K-12 educator hierarchy to be upgraded and become more secure. On December 20, 2000, the Massachusetts Board of Education voted unanimously to adopt the new Technology/Engineering standards and to make them part of the state's assessment. Assessments at the elementary and middle school levels were revised so that science and technology/engineering comprised 20 percent. At the high school level, technology/engineering became one of the four end-of-course assessment options for graduation, the other three being biology, chemistry, and physics. Dr. Miaoulis describes the content of these standards in his chapter.

Although the vote of the board was unanimous, the new standards were not received enthusiastically by all members of the academic community. Many superintendents were against them because their districts did not have the necessary resources to implement them, and many technology education teachers were ambivalent because they saw the inclusion of engineering as a challenge to the traditional instruction. Fortunately, the commissioner of education was strongly behind the new standards and they survived. As a result, Massachusetts became the first state to have engineering standards and assess them at all levels.

College-level engineering education contributions

Parallel to his early work with K-12, Dr. Miaoulis also was changing engineering education at the college level. Engineering schools traditionally lose between 30-50 percent of their entering class. Students either drop out or transfer to liberal arts. When Dr. Miaoulis was first appointed Dean of the School of Engineering at Tufts University, 22 percent of the freshman class was transferring out of engineering. Dr. Miaoulis created an innovative curriculum that made Tufts the first, and still the only, school of engineering where, in most years, more students transfer from the School of Arts and Sciences into the School of Engineering than the other way around, resulting in an actual gain of students. Dr. Miaoulis wanted to determine the root of students' reasoning for transferring. He found that it was not due to the difficulty of the curriculum, but rather, that students didn't find engineering interesting. He knew that during their freshman year, students were loaded with core courses such as math and physics, which have little to do with true engineering. Dr. Miaoulis's concept was to introduce engineering early on, starting freshman year, in an engaging way. He raised funds and invited faculty members to create courses that stemmed from their personal interests and hobbies and were connected to a real engineering topic. He personally created two highly popular courses based on his two major hobbies: fishing and cooking. "Life in Moving Fluids" was a fluid mechanics course from the point of view of a fish, and "Gourmet Engineering" was a heat-transfer course where the laboratory was a state-of-the-art kitchen. Other courses included "Design and Performance of Musical Instruments" and "Microbrewery Engineering." His effort quickly became nationally known among engineering educators,

and a number of introductory engineering programs, focused on retaining first-year engineering students, followed.

Engineering schools have made significant progress in attracting young women during the last 20 years; however, the percentage of women engineering students has reached a plateau of about 19 percent. Along with the curriculum described above, Dr. Miaoulis worked to increase the percentage of women students by linking engineering with other disciplines such as art, drama/dance, music, child development, the health sciences, and law and diplomacy. Under his leadership, Tufts engineering students worked as partners with art and drama/dance students on interdisciplinary projects in the new minor in Multimedia. Mechanical engineering students were consultants to Steinway Pianos and Selmer Corporation in improving the next generation of musical instruments. Joint programs with Tufts Medical and Dental Schools prepared students to be solid engineers/physicians and engineers/dentists who can lead the development of future medical instrumentation. A unique program offered in collaboration with the Fletcher School of Law and Diplomacy prepared students for international engineering careers. The focus on introducing engineering early on, and the use of interdisciplinary partnerships to show engineering's relevance in day-to-day life, resulted in a 26 percent increase in the number of women engineering undergraduates at Tufts. Women now represent one third of the total undergraduate engineering population. Tufts is placed near the top (if not at the top) of engineering schools that are especially popular to women. Even more exciting, the retention of women is higher than the retention of men at Tufts, the reverse of the national trend.

These college-level-curricular innovations, which attracted national interest and are now replicated routinely, generated impressive results. They contributed to a record 100 percent increase in applications to Tufts University's School of Engineering from 1994-2002, Dr. Miaoulis's tenure as dean. While most engineering schools had experienced a decline, the average SAT score for enrolling engineering students at Tufts increased by 70 points, and their average high school rank order rose from the top 12 percent to the top 6 percent. The number of women students increased by 26 percent, and net retention exceeded 100 percent.

New K-12 Opportunities

Massachusetts' bold move in 2000 to become the first state to have engineering standards attracted the attention of the National Science Foundation, and it began to fund K-12 engineering education curriculum development and programs. The relevant activities in Massachusetts schools increased in scope and in number; however, no other state followed suit. It became clear that if the initiative were to spread nationally, it would need a focused champion organization. Such an organization could not be in competition with the partners needed to expand it to the national level. Universities tend to be very competitive, and so they would not be an ideal home for the lead organization.

In order to pursue his life mission of introducing engineering in K-12 schools, Dr. Miaoulis left Tufts University in January 2003, leaving behind a distinguished career as dean and tenured full professor, to join the Museum of Science in Boston as its president

and director. In 2004, a year after he joined the Museum of Science in Boston, he founded the National Center for Technological Literacy (NCTL). NCTL's mission is to introduce engineering in both schools and museums. Its philosophy is that in order to accomplish a fundamental change in attitude toward engineering, school curriculum must change, in conjunction with the attitudes and understanding of those responsible to implement the change. Dr. Miaoulis and his staff raised over \$65 million within three years from private and federal sources. They built the largest organization worldwide that focuses on enhancing technological literacy in both the formal and informal education spaces and on introducing engineering as a core discipline in schools, starting in kindergarten. Dr. Miaoulis determined that in order for such a major undertaking to succeed, it must focus on three areas: advocacy, curriculum development, and professional development. NCTL chose to take on those areas in the following ways.

Advocacy and Support

Although learning standards are centrally controlled in the vast majority of countries around the world, in the United States they are controlled at the state level.

State standards are influenced by standards developed by national groups, such as the National Research Council and the International Technology Education Association. The NCTL advocates for the inclusion of engineering in these national standards, in state standards nationwide and in all relevant federal legislation and assessments. It also provides support for states that decide to include engineering standards in their curriculum frameworks such as standards and assessment tool development. The NCTL is the foremost advocate for technology and engineering education nationwide. Here are some selected accomplishments in the advocacy arena:

- Dr. Miaoulis was a member of the steering committee that revised the science standards for the NAEP (National Assessment of Educational Progress). His efforts resulted in the inclusion of engineering (technological design) in the standards and assessments. State standards are guided in part by NAEP standards.
- The NCTL is recognized by the National Assessment Governing Board as a key driver in developing the new National Assessment for Education Progress (NAEP) Technology and Engineering Literacy Assessment for 2014. This is the first-ever national assessment that includes K-12 engineering. This assessment will also affect the development of state standards.
- Dr. Miaoulis and staff from the NCTL were instrumental in transforming the science and mathematics focus of the federal government to Science, Technology, Engineering, and Mathematics, advocating for the T and the E part of STEM. Dr. Miaoulis testified four times at various committees of the U.S. House and Senate. Meetings with President Obama's STEM advisors, Secretary of Education Duncan, U.S. House and Senate Education and Science committees, various federal agencies, and the National Governors Association influenced a number of important funding programs and legislations, including emphasis and prioritization of STEM education in the Race to the Top (RTTT) program, the Invest in Innovation program, the FY 11 education budget, and its Blueprint for reauthorization of the

Elementary and Secondary Education Act (ESEA). Both of the first states to win the RTTT competition include K-12 Engineering in their plan. Delaware chose curriculum developed by the NCTL as a component of their RTTT plan, and Tennessee has embedded engineering into the state's science standards and has used NCTL curricula to meet those standards.

- The NCTL was the very first to introduce a K-12 engineering education bill in the history of the United States in the U.S. House and Senate, the Engineering Education for Innovation Act. This legislation, which is gaining bipartisan support, was developed in response to the National Academy of Engineering report, "Engineering in K-12 Education." Current efforts focus on making this a part of the Elementary and Secondary Education Act.
- Dr. Miaoulis and his staff were instrumental in including technology and engineering in the solicitation for proposals for funding states by the National Governors Association (NGA) and are currently advising NGA on a number of STEM education issues.
- The NCTL is working with the Board on Science Education at the National Academies of Science, the National Governors Association, and the National Science Teachers Association in developing the first set of common core national standards in science that will include engineering.
- Dr. Miaoulis and NCTL staff worked with State Departments of Education and School Districts in numerous states on introducing engineering curricula materials, standards and assessments. The states include AL, FL, CA, AR, GA, TN, MA, MD, NC, ND, NJ, KY, ME, NH, VT, CT, OH, MN, TX, and VA.
- Dr. Miaoulis is a member NASA's Education and Public Outreach Advisory committee and was instrumental in focusing the new NASA K-12 funding program, Summer of Innovation on Engineering and Design.

Curriculum Development

Because engineering in K-12 is a new concept, there is a lack of relevant curriculum at all levels. Under the leadership of Dr. Miaoulis, NCTL has become the largest developer of K-12 Engineering curriculum in the world. Dr. Miaoulis and his staff develop K-12 engineering curriculum at all educational levels:

- Elementary – Engineering is Elementary
- Middle School – Building Math, design challenges supplemental units
- High School – Engineering the Future

Engineering is Elementary®

Engineering is Elementary (EiE) (www.mos.org/eie) integrates engineering and technology with science, language arts, social studies, and mathematics via storybooks and hands-on design activities. Each unit has an illustrated storybook, where a child from a different country uses the engineering design process to solve a community problem, and four lessons. Elementary school teachers use the materials to teach technology and engineering ideas to children in grades 1-5. As of January 2010, EiE had reached 16,829 teachers and 1,101,190 students in 50 states and Washington, DC.

According to the September 2009 NAE/NRC report, "Engineering in K-12 Education," (pages C-96, C-103), the EiE series "illustrates how a wide range of problems can be overcome through a systematic engineering design process that involves the application of math, science, and creativity." EiE materials are also "very attentive to issues of diversity." Promising preliminary research indicates that EiE may also 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 (http://www.mos.org/eie/research_assessment.php).

Teachers report that EiE curricular materials work well with students, whether low- or high-achieving, including those with cognitive, linguistic, and behavioral challenges, who are girls, children of color, or at risk in other ways. National, controlled studies also reveal that children engaging 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. 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.

Building Math®

Awarded the 2008 Distinguished Curriculum Award by the Association of Educational Publishers, Building Math, created with Tufts University, provides innovative practices for integrating engineering with math to help middle school students (grades 6-8) develop algebraic thinking. Three instructional units integrate inquiry-based math investigations and engineering design challenges. These challenges provide engaging contexts to learn and use mathematics and to develop teamwork, communication, and manual skills as well as helping students make informed design decisions. Building Math (<http://walch.com/building-math-text-books/>) has sold almost 1,900 units and reached almost 95,000 students in 42 states. According to the September 2009 NAE/NRC report (p. C-28), the units are "very deliberate in their use of contextual learning" to make math "more interesting, practical, and engaging." The materials are also "very consistent" in using the engineering design process to "orchestrate learning."

Engineering in Middle School

The NCTL is developing new middle-school supplemental units that meet technology/engineering and science standards by integrating science and engineering. Introduced by "WGBH Design Squad" reality TV shows, the hands-on units engage students in engineering design challenges informed by science topics. While tackling challenges, students in teams learn about engineers and scientists who work on similar projects in U.S. Department of Defense laboratories.

Engineering the Future: Science, Technology, and the Design Process™

In 2007, the NCTL launched its first school textbook publishing partnership with its standards-based Engineering the Future® (EtF) curriculum. It 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 society.

The 2009 NAE/NRC report (pp. C-119, C-120) notes EtF's focus on "people and story telling." The lab activities "are broken down into very small pieces that build upon one another in a very incremental manner." The "culminating design problems provide students a lot of latitude to be creative and to operationalize the problem in a way that capitalizes on their interests." Practicing engineers, female and male, from various ethnic and cultural backgrounds narrate the NCTL's standards-based high school engineering text. The 2009 NAE/NRC report (p.101) cites the text's effort "to portray engineering as an interesting and accessible career" for people of diverse backgrounds. The textbook, notebook, and teachers guide are at: (<http://www.keypress.com/etf>). EtF has reached educators and students in 39 states and Washington, DC.

Professional Development

Teacher Professional Development

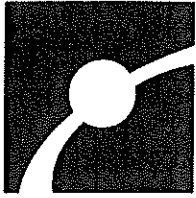
The NCTL supports educators through face-to-face and online professional development. Its train-the-trainer approach helps teacher-educators understand and communicate engineering and technology concepts to teachers by leading workshops in their region. NCTL has worked with teacher-educators in over 25 states and Washington, DC.

To address the national shortage of technology educators, the NCTL is making its curriculum materials and training available via an innovative online teacher certification program, **Closing the Technology & Engineering Teaching Gap**. This K-12 initiative integrates NCTL materials into the fully accredited online technology education programs of Valley City State University, North Dakota, to improve the technological literacy of K-12 teachers and prepare qualified teachers.

To help develop a more technologically literate teacher pipeline, the NCTL is also working with pre-service teacher education programs. Through the **Advancing Technological Literacy and Skills Project (ATLAS)**, three Mass. community colleges are modifying their pre-service elementary courses to educate future elementary teachers about engineering and technology. Faculty engage in engineering design challenges, connect technology/engineering concepts with science, mathematics, literacy, and other subjects, and learn about technical career options. They then modify their courses to include technology/engineering.

Gateway to Engineering and Technology Education involves school district leaders in hands-on engineering activities and best practices to implement K-12 technology/engineering standards. In Mass., the network of 58 school-district leadership teams has reached nearly 300 teachers and administrators and 341,560 students. The Gateway model is replicated in Maine and Texas.

In summary, Dr. Miaoulis has played a transformational role in technological and engineering literacy. His innovations at the college level and his leadership and tireless efforts to introduce engineering in the K-12 curriculum have had and will continue to have profound and everlasting effect in the United States. He not only has positively affected the education of millions of children, but has created a sustainable infrastructure, both at the national and state level, that will have a significant effect in workforce development and U.S. competitiveness.



National Center for
Technological Literacy®

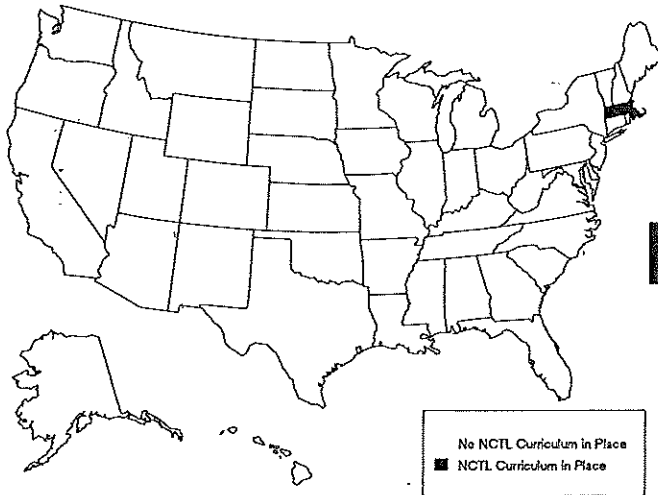
Museum of Science, Boston



Meteoric Growth

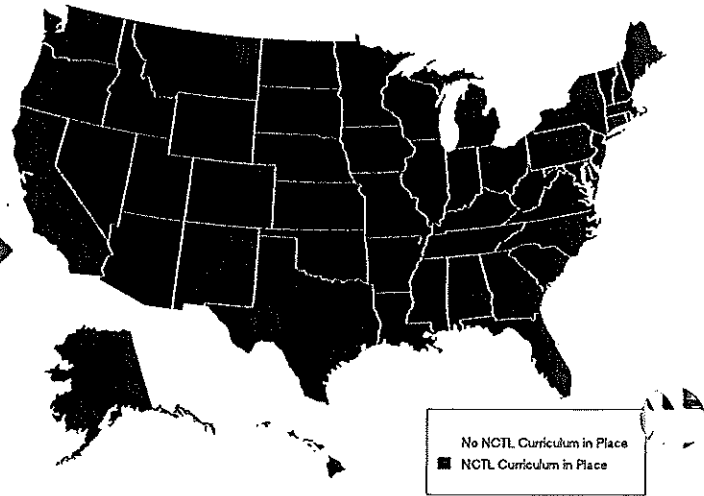
2004:

8 teachers and 200 students
1 state

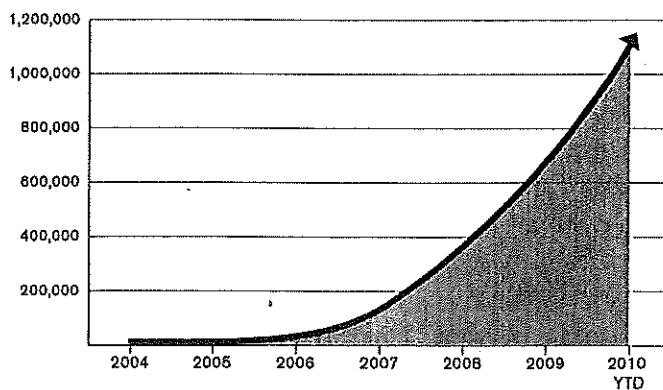


2010:

Over 20,000 teachers and 1,300,000 students
50 states and Washington, DC



Students Reached by Engineering is Elementary®



National Advocacy

- Engineering Education for Innovation Act
- STEM and Winning Race to the Top: Delaware and Tennessee
- 2014 National Assessment of Educational Progress in Technology and Engineering Literacy
- Common Core Science Standards to Include Engineering

Influencing the policy or strategy of the following:

- | | | | |
|------------------------|---|---|---------------------------------------|
| • The White House | • United States Department of Education | • National Science Foundation | • United States Department of Defense |
| • United States Senate | • National Governors Association | • National Aeronautics and Space Administration | • Numerous states |
| • United States House | • National Assessment Governing Board | | |



Information: mos.org/nctl

DR. IOANNIS MIAOULIS
President and Director, Museum of Science, Boston

On January 1, 2003, Ioannis (Yannis) N. Miaoulis, became President and Director of the Museum of Science, Boston. Originally from Greece, Dr. Miaoulis, now 48, came to the Museum after a distinguished association with Tufts University. There, he was Dean of the School of Engineering, Associate Provost, Interim Dean of the University's Graduate School of Arts and Sciences, and Professor of Mechanical Engineering. In addition to helping Tufts raise \$100 million for its engineering school, Miaoulis greatly increased the number of female students and faculty, designed collaborative programs with industry, and more than doubled research initiatives. Founding laboratories in Thermal Analysis for Materials Processing and Comparative Biomechanics, he also created the Center for Engineering Educational Outreach and the Entrepreneurial Leadership Program.

An innovative educator with a passion for both science and engineering, Miaoulis championed the introduction of engineering into the Massachusetts science and technology public school curriculum. This made the Commonwealth first in the nation in 2001 to develop a K-12 curriculum framework and assessments for technology/engineering. At Tufts, he originated practical courses based on students', and his own, passions for fishing and cooking: a fluid mechanics course from the fish's point of view and Gourmet Engineering, where students cook in a test kitchen, learn about concepts such as heat transfer, and then eat their experiments.

His dream is to make everyone, both men and women, scientifically and technologically literate. Miaoulis has seized the opportunity as the Museum's president to achieve his vision, convinced science museums can bring interested parties in government, industry, and education together to foster a scientifically and technologically literate citizenry. One of the world's largest science centers and Boston's most attended cultural institution, the Museum of Science is ideally positioned to lead the nationwide effort. The Museum drew over 1.5 million visitors in the fiscal period ending June 30, 2009, including 186,000 school children, and served over 100,000 more students in traveling and overnight programs. Receiving the Massachusetts Association of School Committees' 2005 Thomas P. O'Neill Award for Lifetime Service to Public Education, the Museum was also ranked #3 of the 10 best science centers in 2008 by *Parents Magazine*, one of the top two most visited hands-on science centers on Forbestraveler.com's "America's 25 most visited museums" list in 2008, and one of the top two science museums in the Zagat Survey's "U.S. Family Travel Guide."

With the Museum's Boards of Trustees and Overseers, Miaoulis spearheaded creation of the National Center for Technological Literacy® (NCTL®) at the Museum in 2004. Supported by corporate, foundation, and federal funds, the NCTL aims to enhance knowledge of engineering and technology for people of all ages and to inspire the next generation of engineers, inventors, and scientists. The Museum of Science is the country's only science museum with a comprehensive strategy and infrastructure to foster technological literacy in both science museums and schools nationwide. Through the NCTL, the Museum is creating technology exhibits and programs and integrating engineering as a new discipline in schools via standards-based K-12 curricular reform. The NCTL has been in contact with interested parties in 50 states. A 2006 \$20 million gift from the Gordon Foundation, established by Sophia and Bernard M. Gordon, endorses the Museum's vision to transform the teaching of engineering and technology. The largest single individual gift in the Museum's 180 years, the Gordon gift will help educate young people to be engineering leaders. The Museum has also been able to create the Gordon Wing, headquarters of the NCTL and home of the Museum's Exhibits and Research & Evaluation teams. Designed to be "green," the wing is the Museum's largest building project since 1987.

Recognizing that a 21st century curriculum must include the human-made world, the NCTL advances technological literacy in schools by helping states modify their educational standards and assessments, by designing K-12 engineering materials, and by offering educators professional development. The NCTL's *Engineering is Elementary* curriculum has reached over 18,800 teachers and 1.15 million students in 50 states and Washington, DC. In 2007, the Museum launched its first school textbook publishing partnership, introducing the *Engineering the Future*® high school course and reaching teachers and students in 39 states and Washington, DC. A *Building Math* middle school course, created with Tufts University, has reached

teachers and almost 95,000 students in 50 states and Washington, DC. The NCTL recently won the 2010 Smaller Business Association of New England Innovation Award. The Museum was one of two non-profits and six companies recognized for their innovation, growth, stability, and impact.

The Museum's approach to informal technology education calls for a Technology Showcase presenting the latest research and technology, a Creativity Workshop addressing hands-on problem-solving with technology and invention, and a Forum focusing on critical science and technology issues and decision-making. The Museum's *Star Wars: Where Science Meets Imagination* exhibition, created with Lucasfilm Ltd., and funded in part by the National Science Foundation (NSF), is touring museums nationally, promoting technological literacy to over 2 million people.

Miaoulis also leads the Museum's life sciences initiative, strengthening current offerings with exhibits like *Beyond the X-Ray* and *Human Evolution*, and testing prototypes for exhibits and programs related to advances in medical technology and research. All these efforts will be integrated into a landmark exhibit and activities. A 2006 \$2 million contribution from Genzyme Corporation to create the Genzyme Biotechnology Education Initiative is the largest single corporate gift in the Museum's history, the largest philanthropic gift in Genzyme's history, and the first major philanthropic commitment to the Museum's life sciences initiative.

Meanwhile in 2008, enlivening the Museum's natural history roots, Dr. Miaoulis oversaw the unveiling of one of the world's rarest dinosaur fossil finds, a near-complete *Triceratops*, which is on a seven-year loan from an anonymous Museum enthusiast. Another important element in Miaoulis's vision involves enhancing the overall Museum experience for everyone, paying special attention to attracting adults, females, and underserved audiences. Since 2003, the Museum has opened two new attractions: *Butterfly Garden*, filled with hundreds of live butterflies, and the 3-D Digital Cinema, as well as a renovated Mugar Omni Theater. He has also led the transformation of the Museum's eateries into a new Museum Café, supervised by its catering and food service provider, renowned chef-restaurateur Wolfgang Puck.

Under Miaoulis's leadership, the Museum has strengthened its financial position, diversifying its revenue sources and increasing its annual operating budget by 42 percent. 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 (NISE Network) of science museums and research institutions. In the fiscal period ending June 30, 2009, the Museum's Annual Fund exceeded \$2.4 million, individual/family/library membership income surpassed \$4.6 million, and member households reached 47,000. Gifts and pledges for NCTL-led formal and informal technology education initiatives have surpassed \$57 million, underlining the importance of the Museum's strategy for science, engineering, and technology education.

Exploring with national leaders how the Museum can help further to educate students, Miaoulis speaks often on science and technology literacy. Examples include testifying at a U. S. Senate Science, Technology, Engineering, and Mathematics (STEM) caucus and before the U.S. Senate Commerce Committee's Subcommittee on Technology, Innovation, and Competitiveness, as well as keynoting at numerous education reform conferences nationwide.

Miaoulis earned bachelor's and doctorate degrees in mechanical engineering and a master's in economics at Tufts, and received a master's degree in mechanical engineering from the Massachusetts Institute of Technology. He has published over 100 research papers and holds two patents. He has also been honored with awards for his research efforts and community service, including the Presidential Young Investigator award, the Allan MacLeod Cormack Award for Excellence in Collaborative Research, the William P. Desmond Award for outstanding contributions to Public Education, the Boston Jaycees Outstanding Young Leader Award, and a Mellon Fellowship. A former WGBH Trustee, Miaoulis has co-chaired the Mass. Technology/Engineering Education Advisory Board. Named in 2006 by President George W. Bush to the National Museum and Library Services Board, Miaoulis has also served on Mass. Governor Deval Patrick's Commonwealth Readiness Project Leadership Council and on the NASA Advisory Council from 2007 - 2009, and is presently on the NASA Education and Public Outreach Committee. Also serving on Gov. Patrick's Science, Technology, Engineering and Math Advisory Council, Miaoulis is a member of the Boards of Trustees of Wellesley College and Tufts University.

Ioannis (Yannis) N. Miaoulis

Born: July 24, 1961, Athens, Greece, U.S. Citizen

Married, Two Children

Academic Degrees

Ph.D. (Mechanical Engineering)	Tufts University	1987
M.A. (Economics)	Tufts University	1986
M.S.M.E	M.I.T.	1984
B.S.M.E. (summa cum laude)	Tufts University	1983
H.S. Diploma	Athens College/Greece	1980

Current Employment

President and Director	Museum of Science (Boston)	2003-present
Director	National Center for Technological Literacy	2003-present

Academic Appointments

Research Professor (Tufts Univ)	Mechanical Engineering	2003-2006
Associate Provost (Tufts Univ)		2001-2002
Dean (Tufts Univ.)	School of Engineering	1994-2002
Dean-Interim (Tufts Univ.)	Graduate School of Arts and Sciences	2001
Associate Dean (Tufts Univ.)	School of Engineering	1993-94
Professor (tenured-Tufts Univ.)	Mechanical Engineering	1997- 2002
Associate Professor (tenured-Tufts Univ.)	Mechanical Engineering	1993-97
Assistant Professor (Tufts Univ.)	Mechanical Engineering	1987-93
Visiting Scientist (M.I.T.)	Materials Science	1990-92
Visiting Asst. Prof. (Tufts Univ.)	Mechanical Engineering	1987-spring
Lecturer (Tufts Univ.)	Mechanical Engineering	1984-86
Lecturer (Tufts Univ.)	Experimental College	1985-Fall

Other Major Appointments

NASA Advisory Committee (NASA Board), 2007-2009
NASA Education and Public Outreach Committee, 2009-
Presidential Appointee to the National Board of Museum and Library Services, 2006-
Board of Trustees, Tufts University, 2006-
Board of Trustees, Wellesley College, 2007-
Board of Trustees, WGBH, 2003-2007
National Steering Science Committee for the National Education Assessment Progress, 2005-2006

Honors and Awards

Research-related awards

- Outstanding Career Award, Graduate School of Arts and Sciences, Tufts University, 2006
- Outstanding Achievement in Mechanical Engineering Practice Alumni Award, 1997
- Allan MacLeod Cormack Award for Excellence in Collaborative Research, 1995
- Presidential Young Investigator Award, awarded by two divisions (Chemical/ Thermal Systems, and Manufacturing) of the National Science Foundation, 1991
- Sigma Xi, The Scientific Research Society, Member, 1991
- Inventors Association of New England Annual Award, Inventors Weekend, Boston Museum of Science, 1990
- Mellon Grant/Fellowship Recipient for Fall 1990
- S.T.E.P. Award, American Society of Mechanical Engineers, 1984

- A.S.M.E. Regional Student Competition for Best Undergraduate Research Project in New England- First Place, Tufts Representative, 1983
- Tau Beta Pi - Engineering Honor Society, Member
- Burden Prize for Best Engineering Design Project- First Place, 1981
- Sigma Xi Research Award, 1981
- John Vakis Natural Sciences Award, 1980
- Listed in *Who is Who in the World, Who is Who in America*

Education-related awards

- Golden Key Honorary Society, Honorary Member, May 1994
- A.S.M.E. "Old Guard" Competition for the Best Undergraduate Research Project in the Nation- First Place, Project Advisor, 1988
- Society of Women Engineers, Best Undergraduate Research Paper Competition- First Place, New England Region; Fourth Place in the Nation, Project Advisor, 1988
- A.S.M.E. Regional Student Competition for Best Undergraduate Research Project in New England- First Place, Project Advisor, 1988
- Lillian Leibner Award for Excellence in Teaching, Nominee of the Mechanical Engineering Department, 1988
- G.T.E. "Engineering Teaching as a Life Choice" grant, 1985
- The Museum of Science's National Center for Technological Literacy® (NCTL®) in Boston won the "2010 Smaller Business Association of New England (SBANE) Innovation Award." Out of 170 companies, the Museum was one of two non-profits and six companies recognized by SBANE for innovation, growth, stability, and impact.

Community Service-related awards and recognition

- Fellow, Massachusetts Academy of Sciences, 2010
- PanCretan Association Annual Award, Boston, 2006
- Distinguished Fellow, Wheaton College, 2004-05
- Retirees School Volunteer Association (RSVA) recognition for enhancement of S.T.E.M. education, October 2004
- "Sophia" Award, Greek Institute, 2004
- Distinguished Alumni Service Award, Tufts University Alumni Association, May 2003
- Outstanding Young Leader Award, Boston Jaycees, June 1999
- Official Citation for Outstanding Contributions to the West Somerville Neighborhood School, Somerville School Committee, May 1997
- William P. Desmond Award for Outstanding Contributions to Public Education, June 1996
- Toastmasters International Community and Leadership Award, March 1995
- Outstanding Contribution in Elementary and Secondary Education Award, Clinton Area Educational Forum, May 1992
- Award for Contributions in Science Education at the Middle School level, Stow S.P.T.O., May 1991

Consulting Activity

National Governors Association

WGBH

Acton Discovery Museums

Dennison Manufacturing Co.

Devonrue Consulting Corp.

Galileo Electro-Optics Corp.

Kopin Corp.

Prentice Hall, Pearson

Research Interests and Activities

PreK-12 Science and Engineering Education

Founder of the Thermal Analysis of Materials Processing Laboratory (T.A.M.P.L.)
Director and founder of the Comparative Biomechanics Laboratory
Microscale Heat Transfer Phenomena
Modelling of Thermal Processing of Electronic and Fiber/Optical Materials
Management of Technology and Innovation
Air Pollution Control
Marine Biomechanics

Teaching Activity (at Tufts University)

Life in Moving Fluids (course originator)
Gourmet Engineering (course originator)
Comparative Biomechanics Laboratory (course originator)
Advanced Heat Transfer
Advanced Heat Conduction (course originator)
Heat Transfer
Project Laboratory
Thermodynamics
Applied Thermodynamics
Management of Technology and Innovation (course originator)
Entrepreneurship (course originator), Marketing (course originator)

Funded Research and Activities (at Tufts University)

"Integrating Algebra and Engineering into the Classroom," GE Foundation, (2002-2005)

"K-12: Distance Learning Program," Lockheed Martin Corp. and Lockheed Martin Foundation (2002-2005)

"Virtual Markets in Wireless Communications and Computational GRIDS," (2003-2005)

"Women in Engineering; Web Site and Electronic Community," G.E. fund (2001-02)

"Creation of an Entrepreneurial Leadership Program," Fidelity Foundation (2000-02)

"Engineering Fellows: a k-12 Resource for Integrating Technology, Mathematics, and Science," National Science Foundation, (1999-02)

"Infrastructure Development for Introducing Engineering into preK-12 Environments," Noyce Foundation (1999-01)

"Girls get SET (Science, Engineering, Technology) for life," Lucent Technologies Foundation, (1999-02)

"REU Site: Thermal Analysis of Materials Processing and Manufacturing," National Science Foundation, (1998-01)

"Microscale Reflectance Spectrometry of Biological Thin Films," National Science Foundation, (1997-99)

"Development of a Multimedia Laboratory," Panasonic Corp. (1997)

"Engineering Project Development Center; Equipment Support," Canon USA Inc. (1997)

"Development of Middle School Science Curricula," Prentice Hall (1997)

"Development of a Program in Engineering Educational Outreach," JSM Trust (1997-2001)

- "Tufts/RPI Thermal Manufacturing Research-Curriculum Development Program," National Science Foundation (1997-2001)
- "Investigation of Microscale Radiation Phenomena Affecting Thermal Processing of Patterned Wafers," National Science Foundation, (1996-99)
- "Research Experiences for Undergraduates," National Science Foundation (1997)
- "Girls in Engineering: Hands on Museum Exhibit Development for Middle School Students," National Science Foundation, (1996-98)
- "Development of a Minor in Interactive Multimedia," VIACOM Corp., (1996)
- "Creation of the Laboratory for Creative Exploration," Beveridge Foundation, (1996)
- "Women in Engineering Initiative," NYNEX foundation (1996)
- "Teaching Science Through Toys," Arthur D. Little Foundation (1995)
- "Development of an Engineering Presentation Preparation Laboratory," GTE Foundation, (1995)
- "Thermal Analysis of Diamond Film Processing," Department of Defence/Air Force and Raytheon Corp. (1994-95)
- "Exploring Technology; a Novel Introduction of Future Engineers and Teachers to Science and Technology," National Science Foundation (1993-95)
- "Understanding the Way things Work: An Innovative Approach to Early Science Education- Exploring Toys," Department of Education, Eisenhower Program (1995)
- "Teachers in Science Initiative," Pew Charitable Trusts (1992-96)
- "Testing of the Tufts Catalytic Converter Preheater," Cincinnati Environmental Protection Agency (1993-95)
- "Development of a Novel Catalytic Converter Preheater for Emission Reduction during Vehicle Cold Starts," U.S. Environmental Protection Agency / Tufts C.E.M (1992-94)
- "Understanding the Way things Work: An Innovative Approach to Early Science Education- Exploring the bicycle," Department of Education, Eisenhower Program (1993-94)
- "Understanding the Way things Work: An Innovative Approach to Early Science Education- Exploring the Bathroom," Department of Education, Eisenhower Program (1992-93)
- "A New Way to Teach Science to Middle School Students-Crossroads II program," Apple Computer Co. (1992-93)
- "Presidential Young Investigator Award," National Science Foundation (1991-96)
- "Experimental Investigation of the Solid/Liquid Interface of Thin Films During Thermal Processing," National Science Foundation (1990-93)
- "Development of a Novel Diesel Engine Preheater Using Exhaust Waste Heat," U.S. Environmental Protection Agency / Tufts C.E.M (1990-91)

"Experimental Investigation of the Convective Phenomena in the Optical Fiber Drawing Furnace," Galileo Electro-Optics Corp. (1990-91)

"Thermal Analysis of Zone-Melting-Processing of Thin Silicon Films," Mellon Fellowship (1990)

"Exemplary Engineering Laboratory awards," Apple Computer Corp. - Equipment Grant (1990)

"Heat Transfer Analysis of Transient Thermal Processing of Multilayer Thin Film Structures," National Science Foundation (1988-90)

"Research Experience for Undergraduates in Thermal Analysis of Materials Processing," National Science Foundation (1988-90)

"Thermal Analysis of the Isolated Silicon Epitaxy Process," Kopin Corp. (1988-90)

AT&T Bell laboratories- Equipment Grant (1988)

"Feasibility Study of the Use of Reversible Chemical Reactions for Thermal Energy Storage," Link Foundation and private industry (1987)

"Tufts Entrepreneurship Program," American Can Foundation (1986)

College and University Committee Appointments and Special Activities (at Tufts University)

Provost's Council	2001-02
University Research Council	1999-02
PreK-12 Education Council	1997-02
Tufts University Council	1994-02
Budget and University Priorities Committee	1994-02
Computer Facilities and Usage Committee	1994-02
Educational Policy Committee	1994-02
Faculty Research Awards Committee	1994-02
Faculty Research Support and Facilities Advisory Committee	1994-02
Tenure and Promotion Committee	1994-02
Undergraduate Admissions and Financial Aid Committee	1994-02
Arts and Sciences Policy Council	1993-02
Engineering Graduate Studies Committee	1993-02
Engineering Executive Committee	1993-02
Dudley Wright Center for Science Education Advisory Board	1990-02
Electro-Optics Technology Center - Member	1989-02
Laboratory for Materials and Interfaces- Member	1990-02
Director, Comparative Biomechanics Laboratory	1993-02
Chair, Arts and Science Committee on Undergraduate Admissions and Fin. Aid	1992-93
Materials Research Working Group	1992-94
University Committee on Tuition Benefits	1991-92
Strategic Planning Committee for the College of Engineering	1992-95
Director, Tufts Thermal Analysis of Materials Processing Laboratory	1990-95
Undergraduate Admissions and Financial Aid committee member	1990-93
University Presidential Search Committee	1991-92
Search Committee for the director of the Dudley Wright Center	1990-92
Educational Policy Committee (Arts and Sciences)	1988-89
Committee on Faculty Research and Facilities (Arts and Sciences)	1986-87
TEAM Tufts committee for under-represented middle school students	1991-93
Planning Committee for the PEW charitable trust A&S proposal	1991
Tufts Environmental Literacy Institute - Member	1990-93

"Experimental Investigation of the Convective Phenomena in the Optical Fiber Drawing Furnace," Galileo Electro-Optics Corp. (1990-91)

"Thermal Analysis of Zone-Melting-Processing of Thin Silicon Films," Mellon Fellowship (1990)

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Educational Policy Committee	1994-02
Faculty Research Awards Committee	1994-02
Faculty Research Support and Facilities Advisory Committee	1994-02
Tenure and Promotion Committee	1994-02
Undergraduate Admissions and Financial Aid Committee	1994-02
Arts and Sciences Policy Council	1993-02
Engineering Graduate Studies Committee	1993-02
Engineering Executive Committee	1993-02
Dudley Wright Center for Science Education Advisory Board	1990-02
Electro-Optics Technology Center - Member	1989-02
Laboratory for Materials and Interfaces- Member	1990-02
Director, Comparative Biomechanics Laboratory	1993-02
Chair, Arts and Science Committee on Undergraduate Admissions and Fin. Aid	1992-93
Materials Research Working Group	1992-94
University Committee on Tuition Benefits	1991-92
Strategic Planning Committee for the College of Engineering	1992-95
Director, Tufts Thermal Analysis of Materials Processing Laboratory	1990-95
Undergraduate Admissions and Financial Aid committee member	1990-93
University Presidential Search Committee	1991-92
Search Committee for the director of the Dudley Wright Center	1990-92
Educational Policy Committee (Arts and Sciences)	1988-89
Committee on Faculty Research and Facilities (Arts and Sciences)	1986-87
TEAM Tufts committee for under-represented middle school students	1991-93
Planning Committee for the PEW charitable trust A&S proposal	1991
Tufts Environmental Literacy Institute - Member	1990-93

Experimental College Course Selection Committee	1990-91
Committee on the Program in Engineering Management	1987-93
Experimental College Course Review Committee	1991-spring
Entrepreneurship Program Director	1986-88

Departmental Committees and Special Activities

Director, Graduate Program	1992-93
Graduate Program Committee (M.E. department)	1988-93
Laboratory Enhancement Committee (M.E. department)	1989-92
Committee on the Manufacturing Program (M.E. department)	1989-91
Advisor, Student section of the American Society of Mechanical Engineers	1988-92
Search Committee Chair/Member for various faculty/staff members	
Various projects on major purchases and space renovations	

Professional and Civic Activities

Massachusetts Governor's Science Technology Engineering and Mathematics Council, 2010-present
 Smith College, Member of the Engineering Advisory Board, 2002-present

Wheelock College, Member of the International Advisory Board

Sloan Foundation Cornerstone Project, Member of the Advisory Board

National Center for Engineering Education, Member of the Advisory Board

Reviewer/panelist for the

- National Science Foundation
- National Science Board
- International Science Foundation
- Journal of Heat Transfer
- Journal of Materials Research
- Journal of Thermophysics and Heat Transfer
- Journal of Applied Physics
- Journal of Fluid Mechanics
- Canadian Journal of Chemical Engineering
- National Governors Association

American Society of Engineering Education, member

American Society of Mechanical Engineers, member

ASME/Fluid Mechanics Division

ASME/Heat Transfer Division

Materials Research Society, member

Association of Science and Technology Centers, member

Science Museum Exhibit Collaborative, president (2004-2007)

Massachusetts Math and Science Advisory Council, member, elected by the State Board of Education (1995-1999)

Massachusetts Technology/Engineering Education Advisory Council, Chair, elected by the State Board of Education (1999- 2008)

Massachusetts Educational Frameworks Revision; Advisor to the Science and Technology Education Frameworks Revision Committee (1999- 2007)

Massachusetts Comprehensive Assessment System (MCAS) Performance Standards Committee, member, appointed by the Commissioner of Education, August 1998

U.S. Center for International Visitors-Scholars, Educational Advisor on Superconductivity (1987-89)

Sigma Xi Honor Society, member

Tau Beta Pi Engineering Honor Society, member

Tufts University Alumni Council, Elected Member (1993-2003)

Pompositticut School Council elected member (1993-1997)

Stow School System, Science and Technology Education Enhancement Program, founder, director (1988-1993)

Nashoba Area K-12 Regionalization Committee, Stow School Committee Representative (1990-91)

Hale Middle School, Science Program Advisor- Volunteer (1988-2002)

Central Massachusetts Regional Science and Engineering Fair Committee, Member (1989-1991)

Union 47 (Bolton-Stow) School Superintendent Search Committee, Chair (1993)

Athens College (high school) Alumni Association, Chairman of the Board, N.E. Section (1987-90)

Books, Patents, Articles, Reports, and Presentations

i) Books

1. Miaoulis, Ioannis, program author, **Science Explorer**, 16-book series on Middle School Science, Prentice Hall:

The Nature of Science and Technology; From Bacteria to Plants; Animals; Cells and Heredity; Human Biology and Health; Environmental Science; Inside Earth; Earth's Changing Surface; Earth's Waters; Weather and Climate; Astronomy; Chemical Building Blocks; Chemical Interactions; Motion, Forces, and Energy; Electricity and Magnetism; Sound and Light

2. Miaoulis, Ioannis 2010. K-12 Engineering—the Missing Core Discipline. In *Holistic Engineering Education: Beyond Technology*, edited by Domenico Grasso and Melody Brown Burkins, pp. 37-51. Springer Science & Business Media, LLC

ii) Patents

1. "Engine Preheating Process and System" I. Miaoulis, M. Selvidge*, U.S. Patent #4,991,644 (1991)

2. "Automotive Vehicle Auxiliary Component Preheating Method and System" I. Miaoulis, U.S. Patent #5,398,747 (1995)

iii) Refereed Articles

3. "Applications of Charging in Low Conductivity Fluids for Velocity Measurements, " B. Abedian and I. Miaoulis, in *Mass Flow Measurements*, FED-Vol 17, A.S.M.E. (1984)

4. "Heat Source Power Requirements for High Quality Recrystallization of Thin Silicon Films for Electronic Devices," I. Miaoulis and B. Mikic, **Journal of Applied Physics**, Vol. 59, 1658, (1986)
5. "Temperature Distribution in Silicon on Insulator Systems During Recrystallization Processing," I. Miaoulis and B. Mikic, **Journal of Applied Physics**, Vol. 59, 1663, (1986)
6. "Electric Charging in Laminar Pipe Flow," E. Potsdam⁺, I. Miaoulis and B. Abedian **International Journal of Physicochemical Hydrodynamics**, Vol.9, 589, (1987).
7. "Thermal Analysis of Zone-Melting-Recrystallization Processing of Multilayer Thin Film Structures," I. Miaoulis and J. Lipman*, in *Selected Topics in Electronic Materials*, M.R.S. EA-18 (1988)
8. "Zone-Melting Processing of Thick High-Tc Superconducting Films," I. Miaoulis, J Lipman⁺, D. A. Flodman⁺, P.Y. Wong⁺, M.W. Wolfson⁺, J. Barrett III⁺, A. Nelson⁺, **Journal of Physics D: Applied Physics**, Vol.22 (1989)
9. "A Novel Diesel Engine Cold Start Aid System Using Engine Waste Heat," M. Selvidge*, I. Miaoulis; in *Waste Heat Utilization*, A.S.M.E. HTD-Vol 118 (1989)
10. "Texture Enhancement of Thick High-Tc Superconductive Films by Zone-Melting," I. Miaoulis, J Lipman⁺, D. A. Flodman⁺, P.Y. Wong⁺, M.W. Wolfson⁺, J. Barrett III⁺, A. Nelson⁺; in *Collected Papers in Heat Transfer* A.S.M.E. HTD-Vol. 123 (1989)
11. "Numerical Simulation of the Radiation Effects in Graphite Strip Zone-Melting- Recrystallization," J. Lipman*, P. Wong*, I. Miaoulis, J. Im; in *Collected Papers in Heat Transfer* A.S.M.E. HTD-Vol 123 (1989).
12. "Evaluation of Reversible Hydration Reactions for Use in Thermal Energy Storage," M. Selvidge*, I. Miaoulis; **Solar Energy**, Vol. 44, 173 (1990)
13. "Parametric Study of the Zone-Melting-Recrystallization Process of SOI structures," J. Lipman*, I. Miaoulis, J. Im, in *Beam-Solid Interactions: Physical Phenomena*, M.R.S. Vol 157 (1990)
14. "Modeling of Localized Melting of Thin Silicon Films in Zone-Melting- Recrystallization," J. Im, J. Lipman*, I. Miaoulis, C. Chen, C.V. Thompson, in *Beam-Solid Interactions: Physical Phenomena*, M.R.S. Vol 157 (1990)
15. "Thermal Modeling of the Optical Fiber Drawing Process," H. Papamichael*, I. Miaoulis, in *Optical Fiber Materials and Processing*, M.R.S. Vol. 172 (1990)
16. "Thermal Analysis of Thin Film Zone-Melting-Recrystallization," I. Miaoulis, in *Recrystallization '90*, T.M.S. (1990).
17. "Electric Charging in Flow of Low Conductivity Liquids Through Screens: A Comparison of Theory and Experiment," I. Miaoulis, B. Abedian, and M. Darnahal, **Journal of Electrostatics** 25, 287 (1990).
18. "Theory for electric charging in flow of low conductivity liquids through screens," I. Miaoulis, B. Abedian, and M. Darnahal, **Journal of Electrostatics** 25, 295 (1990).
19. "A Passive Probe for Electrostatic Charge Density Measurements," I. N. Miaoulis, B. Abedian, **Review of Scientific Instruments** 61, 3416 (1990).

20. "Microscale Heat Transfer Phenomena in Multilayer Thin Film Processing with a Radiant Heat Source," P. Wong*, I. Miaoulis, P. Zavracky, in *Microstructures Sensors, and Actuators*, ASME Vol. DSC-19 (1990)
21. "A General Simulation Technique for the Cooling Stage of Optical Fiber Drawing," H. Papamichael*, I. Miaoulis, ASME paper 90-WA/EEP-11 (1990)
22. "Optical Effects of the Multilayer Structure of SOI Films During Transient Thermal Processing with a Radiant Line Heat Source," P. Wong*, I. Miaoulis, P. Zavracky, in *Surface Chemistry and Beam-Solid Interactions*, MRS Vol. 201 (1990)
23. "Scanning Speed and Supercooling Effects During Zone-Melting-Recrystallization of SOI Wafers," S. Yoon*, I. Miaoulis, in *Kinetics of Phase Transformations*, MRS Vol. 205 (1990)
24. "Thermal Modelling of Zone-Melting-Recrystallization processing of Silicon-on-Insulator Film Structures," I. Miaoulis, P. Wong*, J. Lipman*, J. Im, **Journal of Applied Physics** Vol. 69, 7273 (1991).
25. "Thermal Behavior of Optical Fibers During the Cooling Stage of the Drawing Process," H. Papamichael*, I. Miaoulis, **Journal of Materials Research**, Vol. 6, 159 (1991)
26. "Axial Heat Conduction Effects in the Cooling of Optical Fibres," H. Papamichael*, I. Miaoulis, **Glass Technology** Vol. 32 (1991)
27. "Thermal Analysis of Multilayer Thin Film Structure Processing with an Infrared Source; an Overview " I. N. Miaoulis, P. Wong*, S. Yoon*, R. Robinson*, C. Hess*, in *Heat Transfer in Thin Films*, A.S.M.E., HTD 184 (1991)
28. "Cross-Correlation Thermal Radiation Phenomena in Multilayer Thin Films Processing with a Radiant Heat Source," P. Wong*, L. M. Trefethen, I. N. Miaoulis, in *Micromechanical Sensors, Actuators, and Systems*, A.S.M.E., DSC Vol. 32 (1991)
29. " Mixed Convection Cooling Effects during the Drawing of Optical Fibers," H. Papamichael*, I. Miaoulis, in *Fiber Optics and Glass: from Science to Producibility*, S.P.I.E. (1991)
30. "Optical Effects of Multilayer Thin Films during Zone Melting Recrystallization with an Infrared Heat Source," P. Wong*, I. Miaoulis, **Journal of Applied Physics** 70, 7594 (1991)
31. "Numerical Simulation of Zone Melting Recrystallization of Thin Silicon Films with a Tungsten Halogen Lamp," R. D. Robinson*, I. N. Miaoulis, in *Phase Formation and Modification by Beam-Solid Interactions*, MRS Vol. 235, (1991)
32. "Solidification Interface Instabilities during Zone Melting Recrystallization Processing of Multilayer Thin Film Structures," S. Yoon*, C. Hess*, I. N. Miaoulis, in *Interface Dynamics and Growth*, Vol. 237, (1991)
33. "Thermally Controlled Morphological Features of a Solid-Liquid Interface of a Thin Gallium Film," R. D. Robinson*, I. N. Miaoulis, in *Interface Dynamics and Growth*, MRS Vol. 237, (1991)
34. "Thermal Effects of Heat Source Scanning Speed and Constitutional Supercooling during Zone-Melting-Recrystallization of Silicon-On-Insulator Structures," S. Yoon* and I. Miaoulis, **Journal of Materials Research**, Vol. 7, 124 (1992)
35. "The Cooling of Optical Fibres during the Drawing Process", H. Papamichael*, I. Miaoulis, **Glass Technology** Vol. 33, 136 (1992)

36. "Thermal Analysis of Zone-Melting-Recrystallization of Silicon-On-Insulator Structures with an Infrared Heat Source; an Overview" I. N. Miaoulis, P. Y. Wong*, S. M. Yoon*, R. D. Robinson*, C. K. Hess*, **Journal of the Electrochemical Society** Vol 139, 2687 (1992)
37. "Thermal Radiation Modeling in Multilayer Thin Film Structures", P. Wong*, C. Hess*, I. N. Miaoulis, **Int. J. Heat Mass Transfer** Vol. 35, 12 (1992)
38. "Thermal Effects of Isolated Step Perturbations within Thin Films during Processing with a Radiant Heat Source", C. K. Hess*, P. Wong*, I. N. Miaoulis, in *Transport Phenomena in Materials Processing and Manufacturing*, A.S.M.E., HTD-196 (1992)
39. "Thermal Energy Storage with Reversible Hydration of Lithium Bromide" I. N. Miaoulis, C.S. Thompson⁺, S. Kwak⁺, in *Topics in Heat Transfer*, A.S.M.E. Vol. 206-2 (1992)
40. "Effect of Scanning Speed on the Stability of the Solidification Interface during Zone-Melting-Recrystallization of Thin Silicon Films". S. M. Yoon*, I. N. Miaoulis, **Journal of Applied Physics** Vol. 72, 316 (1992)
41. "Cross Correlation of Optical Properties of Thin Films under Thermal Radiation" P.Y. Wong*, L.M.Trefethen, I.N. Miaoulis, **Journal of Applied Physics** Vol 72, 4884 (1992)
42. "Solidification Front Stability During Zone-Melting Recrystallization of Thin Silicon Films", S. M. Yoon* and I. N. Miaoulis, **Journal of Crystal Growth** Vol. 126, 275 (1993)
43. "Thermal Analysis of Incandescent Lamp Zone-Melting Recrystallization of Thin Silicon Films," R. D. Robinson*, I. N. Miaoulis, **Journal of Applied Physics** Vol 73 (1) (1993)
44. "The effects of Natural Convection and Conduction in a Zone-Melting Recrystallization Chamber" B.D. Heilman⁺, M.A. Marston⁺, P. Wong*, I. N. Miaoulis, **Journal of Materials Research** Vol. 8 (3) (1993)
45. "Microscale Radiation Effects in Multilayer Thin Film Structures During Rapid Thermal Processing," P. Y. Wong*, C. K. Hess*, and I. N. Miaoulis, *Proc. of Symp. on Rapid Thermal and Integrated Processing II*, MRS Vol. 303., (1993)
46. "Thermal Radiation Phenomena in Rapid Thermal Processing of Thin Film Structures," I. N. Miaoulis and P. Y. Wong*, *Proc. of 1st International Conference in Rapid Thermal Processing*, September 1993; and also presented in RTP'93 in Scottsdale, AZ, (1993)
47. "Real-Time Image Analysis and Control of the Solid/Liquid Interface During Zone-Melting Recrystallization of Thin Films," P. Y. Wong* and I. N. Miaoulis, *Proc. of Symp. on Sensors and Control for Microelectronic Processing*, Soc. Photo-Instr. Eng., 1993, and presented at Soc. Photo-Instr. Eng. meeting, September Monterey, CA, (1993)
48. "A Microscale Radiation Effects On Thermal Regulation Of Insects", B. Heilman* and I. N. Miaoulis, *Advances in Biological Heat and Mass Transfer*, edited by R. B. Roemer, *The American Society of Mechanical Engineers, Heat Transfer Division, HTD-Vol. 268*, 79-87, (1993)
49. "Insect Thin Films A Solar Collectors", B. Heilman* and I. N. Miaoulis, **Journal of Applied Optics** Vol. 33 (28) (1994)
50. "A Two-Dimensional Analysis Of The Viscous Problem Of A Glass Preform During The Optical Fibre Drawing Process," S. Rosenberg*, H. Papamichael* and I. N. Miaoulis, **Glass Technology** Vol. 35, No. 6 (1994)

51. "Thermal Parameters Affecting Low Temperature Zone Melting Recrystallization Of Thin Films," R. D. Robinson* and I. N. Miaoulis, **Journal of Applied Physics** Vol. 75 (3) (1994)
52. "A Comparative Study Between High And Low Temperature Thermally Controlled Crystallization Of Thin Films," R. D. Robinson* and I. N. Miaoulis, *Amorphous Materials Crystallization*, MRS Vol. 321 (1994)
53. "An Investigation of the Viscous Problem Associated with the Heating of the Glass Preform during Optical Fiber Processing," S. Rosenberg⁺, H. Papamichael* and I. N. Miaoulis, *Amorphous Materials Crystallization*, MRS Vol. 321 (1994)
54. "The Effect of Substrate Temperature on the Crystallinity and Stress of Ion Beam Sputtered Silicon on Various Substrates," C. G. Madras*, L. Goldman, P. Y. Wong*, and I. N. Miaoulis, MRS 1994, *Proceedings of the Materials Research Society Spring Meeting*, Vol. 338 San Francisco, CA (1994)
55. "Thermal-Radiation Absorption Characteristics Of Patterned Wafers During Rapid Thermal Processing", P. Y. Wong* and I. N. Miaoulis, *Proceedings of the Materials Research Society*, Vol. 342, Spring Meeting, San Francisco, CA (1994)
56. "Thermal Evaluation Of Zone-Melting Recrystallization Of Thin-Film Structures Over A Wide Range Of Melting Points," R. D. Robinson*, P. Y. Wong* and I. N. Miaoulis, **Journal of Materials Research**, Vol. 10 (4) (1994)
57. "Heat Recovery For Automotive Applications Using Reversible Hydration Reaction", M. A. Marston*, S. Armstrong* and I. N. Miaoulis, *Proceedings of ASME Winter Annual Meeting*, Chicago, Ill, 94-WA/HT-28 (1994)
58. "Processing Uniformity Issues During Zone-Melting Recrystallization Of Large Thin-Film Areas", P. Y. Wong*, R. D. Robinson*, and I. N. Miaoulis, *Heat Transfer in Thin Films*, A.S.M.E., HTD Vol. 293 (1994)
59. "The Effect Of Microscale And Macroscale Patterns On The Radiative Heating Of Multilayer Thin-Film Structures", P. Y. Wong*, B. D. Heilman*, and I. N. Miaoulis, *Microscale Heat Transfer*, A.S.M.E., HTD Vol. 291 (1994)
60. "Thermal And Deposition Stress Relaxation In Low-Melt-Point Substrates With High-Melt-Point Coatings", S. E. Rosenberg*, P. Y. Wong*, and I. N. Miaoulis, *Thermal Processing of Materials*, A.S.M.E., HTD Vol. 289 (1994)
61. "Hands-On Aeronautics for Middle School Students", Y.D. Pols, C.B. Rogers, I. N. Miaoulis, **Journal of Engineering Education**, Vol.83 (3) (1994)
62. "An Investigation of the Air Flow Patterns in the Heating Region of Optical Fiber Drawing," C. Pellon*, H. Papamichael* and I. N. Miaoulis, *Proceedings of the Symposium on Properties and Characteristics of Optical Glass III*, SPIE's annual meeting 94, San Diego California Vol 2287 (1994)
63. "Heat Transfer In The Heating Region Of The Optical Fiber Drawing Process," H. Papamichael* and I. N. Miaoulis, *Proceedings of the Symposium on Properties and Characteristics of Optical Glass III*, SPIE's annual meeting 94, San Diego California (1994)
64. "A Novel Automobile Preheating System For Cold Starts," Mathew A. Marston*, Steven Armstrong*, and Ioannis N. Miaoulis, *Society of Automotive Engineers, Paper #941995*, (1994)

65. "Implicit Modified Enthalpy Method with Application to Thin Film Melting", C. K. Hess*, and I. N. Miaoulis, **Int. J. Numerical Methods for Engineers** Vol. 5 (1995)
66. "A Theoretical Study of the Effect of Thermal Annealing on Curvature Changes in Multilayered Structures," S. E. Rosenberg*, P. Y. Wong*, and I. N. Miaoulis, **Thin Solid Films**, Vol 269 (1995).
67. "Analysis Of Deposition Stress During Thin-Film Growth On A Relaxing Substrate," S. E. Rosenberg*, P. Y. Wong*, and I. N. Miaoulis, **Journal of Applied Physics**, Vol. 77 (12) (1995)
68. "Measurement of the Effect of Temperature on Stress Distribution and Deformation in Multilayer Optical Thin Film Structures", C.G Madras*, P.Y.Wong*, L.M. Goldman, and I.N. Miaoulis, *Thin Films: Stresses and Mechanical Properties*, MRS Vol. 356 (1995)
69. "Coherent Thermal-Radiation Effects On Temperature Dependent Emissivity Of Thin-Film Structures On Optically Thick Substrates," P.Y. Wong*, C. K. Hess*, and I. N. Miaoulis, **Optical Engineering**, Vol. 34 (6) (1995)
70. "Transient And Spatial Radiative Properties Of Patterned Wafers During Rapid Thermal Processing," P. Y. Wong* and I. N. Miaoulis, *Rapid Thermal and Integrated Processing IV*, MRS Vol. 385 (1995)
71. "Thermal Radiative Analysis Of Rapid Thermal Processing Of Electronic Materials," P. Y. Wong* and I. N. Miaoulis, *Transport Phenomena in Electronic Materials Processing*, A.S.M.E. HTD Vol. 317-2 (1995)
72. "Microscale Reflectance Spectrometry Of Thin-Film Structures In Butterfly Wing Scales," P. Y. Wong* and I. N. Miaoulis, *Measurement Techniques and Instrumentation in Bio-Heat and Mass Transfer*, A.S.M.E., HTD Vol. 322 (1995)
73. "Rapid Thermal Annealing Of High-Melting-Point Films On Low-Melting-Point Substrates," S. E. Rosenberg*, P. Y. Wong*, and I. N. Miaoulis, **IEEE Transactions of Semiconductor Manufacturing**, Vol 9 (1996)
74. "Inelastic Effects in a Thermoplastic Adhesive Used for Bonding a Diamond Disk," C. G. Madras*, P. Y. Wong, and I. N. Miaoulis, **Optical Engineering**, Vol. 35 (1996)
75. "Numerical Modeling of Radiative Properties of Patterned Wafers with Submicron Features" J. Hoppert⁺, I. Miaoulis, P. Wong, *Rapid Thermal Integrated Processing V*, MRS Vol. 429 (1996)
76. "Viscoelastic Deformation during Thermal Cycling of Adhesively Bonded Optical Coatings," C. G. Madras*, P. Y. Wong, and I. N. Miaoulis, **Materials Letters**, Vol.35, No.8 (1996)
77. "Air Flow Paterns in the Optical Fibre Drawing Furnace " H. Papamichael*, C. Pellon*, and I. N. Miaoulis, **Glass Technology**, Vol.38 (1997)
78. "The Viscosity Of Germanium During Substrate Relaxation Upon Thermal Anneal," S. E. Rosenberg, C. G. Madras*, P. Y. Wong*, and I. N. Miaoulis, **Journal of Materials Research** Vol. 12 (1997)
79. "Prediction of Elastic Strains in Adhesively Bonded Diamond Optical Windows," C. G. Madras*, P. Y. Wong, and I. N. Miaoulis, **Glass Technology**, Vol.38 (1997)

80. "Selective Multilayer Thin-Film Development in Insects," I. N. Miaoulis, H. Tada*, S. E. Mann⁺, and P. Y. Wong, Proceedings of Session on Fundamentals of Microscale Biothermal Phenomena, *American Society of Mechanical Engineering, HTD, Vol. 355*, 1997
81. "Viscoelastic Behavior of Polymer Thin-Film under Thermo Stresses," S. D. Bluestein⁺, D. P. Y. Bramono⁺, I. N. Miaoulis, and P. Y. Wong, *Materials Research Society*, Vol. 445, pp. 185-190, 1997
82. "Microscale Radiative Effects in Complex Microstructures of Iridescent Butterfly Wing Scales," H. Tada*, S. E. Mann⁺, I. N. Miaoulis, and P. Y. Wong, *Materials Research Society*, Vol. 489 1998
83. "Effect of Surface Patterning in Thin Film Structures on the Thermal Radiative Properties During Rapid Thermal Processing," H. Tada*, A. R. Abramson*, I. N. Miaoulis, and P. Y. Wong, Session on Radiative Properties of Surfaces, particles, and Films at High and Low Temperatures, *American Society of Mechanical Engineering, HTD Vol. 361-2*, (1998)
84. "Butterfly Thin Films Serve as Solar Collectors," I. Miaoulis, and B. Heilman*, *The Annals of the Entomological Society of America*, Vol 91 (1998)
85. "Numerical Simulation of Radiant Thermal Processing of Bilayer Microcantilevers," H. Tada*, I. N. Miaoulis, and P. Y. Wong, *American Society of Mechanical Engineering, DSC Vol.66*, (1998)
86. "The Effects of Butterfly Scale Microstructure on the Iridescent Color Observed at Different Angles " H. Tada⁺, S.E. Mann⁺, I.N. Miaoulis, P.Y. Wong, **Applied Optics** Vol. 37 (1998)
87. "Partial Transparency Effects of Silicon During Rapid Thermal Processing," A. R. Abramson*, I. N. Miaoulis, P. Y. Wong, P. Nieva, and P. Zavracky, *Materials Research Society Symposium Proceedings*, Vol. 525, 1998
88. "Relaxation of Extrinsic and Intrinsic Stresses in Germanium Substrates with Silicon Films," C. G. Madras*, L. Goldman, P. Y. Wong*, and I. N. Miaoulis, **Thin Solid Films**, Vol. 320 (1998)
89. "MEMS as Temperature Sensors During High Temperature Processing," H. Tada*, A. R. Abramson*, I. N. Miaoulis, P. Y. Wong, P. Nieva, and P. Zavracky, *Proceedings of the Symposium on Microelectromechanical Structures for Materials Research, Materials Research Society, Vol. 518, pp. 161 – 166*, 1998
90. "Effect of Doping Level During Rapid Thermal Processing of Multi-Layer Structures," A. R. Abramson*, P. Nieva, H. Tada*, P. Zavracky, I.N. Miaoulis, and P. Y. Wong, **Journal of Materials Research**, (1998)
91. "In-Situ Measurement of Thermo-Mechanical Effects and Properties in Thin Film-Polymer," S. D. Bluestein⁺, E. K. Chan⁺, I. N. Miaoulis, and P. Y. Wong, **IEEE Transactions on Components, Packaging, and Manufacturing Technology** (1999)
92. "Temperature Measurements During Rapid Thermal Annealing Using MEMS," P. Nieva, P. Zavracky, G. Adams, H. Tada*, A. R. Abramson*, I. N. Miaoulis, and P. Y. Wong, *Proceedings of the 5th ASME/JSME Joint Thermal Engineering Conference*, San Diego, CA (1999)

93. "Effect of Doping Level During Rapid Thermal Processing of Multi-Layer Structures," A.R. Abramson*, P. Nieva, H. Tada*, P. Zavracky, I.N. Miaoulis, and P.Y. Wong, **Journal of Materials Research**, Col. 14, No. 6 (1999)
94. "Mechanical and Thermophysical Properties of Silicon Nitride Thin Films at High Temperatures," H. Tada*, I.N. Miaoulis, P.Y. Wong, P. Nieva, and P. Zavracky, *Materials Research Society Proceedings*, Vol 546, pp. 97-102, (1999)
95. "Determining the High Temperature Properties of Thin Films Using Bi-Layered Cantilevers," H. Tada*, P. Nieva, P. Zavracky, I. N. Miaoulis, and P. Y. Wong, *Materials Research Society Proceedings*, Vol. 546, pp. 39-44, (1999)
96. "Limiting the Effects of Thin Film Patterns on the Temperature Distribution of Silicon Wafers During Radiant Processing," H. Tada*, A.R. Abramson*, S.E. Mann*, I.N. Miaoulis, and P.Y. Wong, **Optical Engineering**, Vol.39, No.8 (2000)
97. "Novel Imaging System for Measuring Microscale Curvatures at High Temperatures," H. Tada*, A.E. Kumpel, R.E. Lathrop, I.N. Miaoulis, and P.Y. Wong, **Review of Scientific Instruments**, Vol.71, No 1 (2000)
98. "High-Temperature-Dependent Coefficient of Thermal Expansion of Silicon Nitride Films used in Microelectromechanical Systems," M. Bargmann+, A. Kumpel+, H. Tada*, I. N. Miaoulis, P. Y. Wong, P. Nieva, and P. Zavracky, *Materials Research Society Proceedings*, Vol. 605, pp. 235-240, (2000)
99. "Thermal Expansion Coefficient of Polycrystalline Silicon and Silicon Dioxide Thin Films at High Temperatures," H. Tada*, A.E. Kumpel+, R.E. Lathrop+, P. Nieva, P. Zavracky, I.N. Miaoulis and P.Y. Wong, **Journal of Applied Physics**, Vol. 87, No.9 (2000)
100. "Spectral Imaging, Reflectivity Measurements, and Modeling of Iridescent Butterfly Scale Structures," S. Mann*, I. N. Miaoulis, and P. Y. Wong, **Optical Engineering**, Vol. 40, No. 10 (2001)

+ designates undergraduate student of Prof. Miaoulis

* designates graduate student of Prof. Miaoulis

iv) Theses and Technical Reports

101. "A New Chabazite-Zeolite Solar Energy Storage System", I. Miaoulis, B.S.M.E. Thesis, Tufts University, (1983)
102. "Heat Transfer Analysis for High Quality Liquid-Phase Recrystallization of Thin Silicon Films for Electronic Devices," I. Miaoulis, S.M.M.E. Thesis and VLSI Report No. 84-210, M.I.T., (1984).
103. "Retail Sales Seasonal Adjustment using the Kalman Filter Algorithm," I. Miaoulis, M.A. Econ. special project report, Tufts University (1986)
104. "Experimental Investigation of Turbulence Spectra of Charge Density Fluctuations in the Equilibrium Range", I. Miaoulis, Ph.D. dissertation, Tufts University (1987)
105. "Thermal Issues of Optical Fiber Fabrication; a Review" I. Miaoulis, report to Galileo Electro-Optics Corp. (1989)

y) Presentations in Professional Conferences and other Similar Activities

- *American Society of Mechanical Engineers Winter Annual Meeting*, New Orleans, 1984

1. "Applications of Charging in Low Conductivity Fluids for Velocity Measurements"

- *Applied Mechanics Colloquium*, Yale University

Invited Presentation

2. "A New Technique for Measurement of Scalar Fluctuation Measurements in a Turbulent Jet"

- *Materials Research Society Fall Meeting*, Boston, 1988

3. "Thermal Analysis of Zone-Melting-Recrystallization Processing of Multilayer Thin Film Structures"

4. "Development of Thick Sr-Bi-Ca-Cu-O Superconductive Films by a Simple Screen Printing Technique"

5. "Grain Growth of Thick High Tc Superconducting Films by Zone-Melting Recrystallization"

- *Kopin Corp.*, Massachusetts, January 1988

Invited presentation

6. "Heat Transfer Analysis of Zone-Melting-Recrystallization of Thin Semiconducting Films"

- *American Society of Mechanical Engineers Winter Annual Meeting*, San Francisco, (1989)

7. "A Novel Diesel Engine Cold Start Aid System Using Engine Waste Heat"

8. "Texture Enhancement of Thick High-Tc Superconductive Films by Zone-Melting"

9. "Numerical Simulation of the Radiation Effects of the Zone-Melting- Recrystallization Process"

- *Materials Research Society Fall Meeting*, Boston (1989)

10. "Parametric Study of the Zone-Melting-Recrystallization Process of SOI structures"

11. "Modeling of Localized Melting of Thin Silicon Films in Zone-Melting-Recrystallization"

12. "Thermal Modeling of the Optical Fiber Drawing Process,"

- *Kopin Corp.*, December 1989

Invited Presentation

13. "Thermal Analysis of the Isolated Silicon Epitaxy Process"

- *International Conference on Recrystallization in Metallic Materials*, Wollongong, Australia, 1990

Invited presentation

14. "Thermal Analysis of Thin Film Zone-Melting-Recrystallization"

- *Inventors' Weekend*, Boston Museum of Science, (1990).

15. "A Rechargeable Thermal Battery for Diesel Engine Cold Starts"

- *American Society of Mechanical Engineers Winter Annual Meeting*, Dallas, Texas, 1990

16. "Microscale Heat Transfer Phenomena in Multilayer Thin Film Processing with a Radiant Heat Source"

17. "A General Simulation Technique for the Cooling Stage of Optical Fiber Drawing"

- *Materials Research Society Fall Meeting*, Boston, Massachusetts, 1990

18. "Optical Effects of the Multilayer Structure of SOI Films During Transient Thermal Processing with a Radiant Line Heat Source"

19. "Scanning Speed and Supercooling Effects During Zone-Melting-Recrystallization of SOI Wafers"

- *Galileo Electro-Optics Corp.*, March 1991

Invited Presentation

20. "Flow Visualization of the Convective Currents in an Optical Fiber Drawing Furnace"

- *American Society of Mechanical Engineers Winter Annual Meeting*, Atlanta, Georgia, 1991
 21. "Thermal Analysis of Multilayer Thin Film Structure Processing with an Infrared Source; an Overview "
 22. "Cross-Correlation Radiation Phenomena in Multilayer Thin Films Processing with a Radiant Heat Source"
- *OE/Fibers, Society of Photo-Optical Instrumentation Engineers*, Boston, Mass.(1991)
 23. "Mixed Convection Cooling Effects during the Drawing of Optical Fibers"
- *Schotts Fiberoptics Inc.* Southbridge, Mass. December 1991
Invited Presentation
 24. "Thermal Issues in Optical Fiber Processing"
- *Materials Research Society Fall Meeting*, Boston, Mass. , 1991
 25. "Numerical Simulation of Zone Melting Recrystallization of Thin Silicon Films with a Tungsten Halogen Lamp"
 26. "Solidification Interface Instabilities during Zone Melting Recrystallization Processing of Multilayer Thin Film Structures"
 27. "Thermally Controlled Morphological Features of a Solid-Liquid Interface of a Thin Gallium Film"
- *MIT Materials Science and Engineering colloquium*; February 1992
Invited Presentation
 28. "Thermal Issues in Multilayer Thin Film Structures"
- *Marine Benthic Ecology Meeting*, Newport, Rhode Island, March 1992
 29. "Drag Coefficient Variations of *Candylactus Gigantea* Sea Anemones in Periodic Flow Fields"
- *New England Environmental Conference*, Boston, Mass., April 1992.
 30. "Development of a Catalytic Converter Preheater for Emissions Reduction"
- *Kopin Corp.*, Taunton, Mass., May 1992
Invited Presentation
 31. "Microscale Heat Transfer Phenomena in Multilayer Thin Film Structures"
- *Eco World'92*, Washington DC, June 1992
 32. "A Catalytic Converter Preheater for Emissions Reduction During Engine Cold Starts"
- *National Heat Transfer Conference*, San Diego, August 1992
 33. "Thermal Effects Induced by Isolated Step Perturbations within Thin Films during Processing with a Radiant Heat Source"
 34. "Thermal Energy Storage with Reversible Hydration of Lithium Bromide"
- *Materials Research Society Fall Meeting*, Boston, Mass. November 1992
 35. "The Effect of Processing Conditions on the Thermal Gradients at the Solid/Liquid Interface in Zone-Melting-Recrystallization Using a Graphite Strip Heater"
- *Materials Research Society Spring Meeting*, San Fransisco, Calif. March 1993
 36. "Microscale Radiation Effects in Multilayer Thin Film Structures During Rapid Thermal Processing"
 37. "Solidification Front Stability during Zone-Melting Recrystallization of Thin Silicon Films"
- *1st International Conference in Rapid Thermal Processing*, Scottsdale,AZ, September 1993
Invited presentation

38. "Thermal Radiation Phenomena in Rapid Thermal Processing of Thin Film Structures"

- *OE/Fibers, Society of Photo-Optical Instrumentation Engineers*, Monterey, CA, September 1993

39. "Real-Time Image Analysis and Control of the Solid/Liquid Interface During Zone-Melting Recrystallization of Thin Films"

- *American Society of Mechanical Engineers Winter Annual Meeting*, New Orleans, LA, November 1993

40. "Microscale Radiation Effects on Thermal Regulation of Insects"

- *Materials Research Society Fall Meeting*, Boston, MA, November 1993

41. "A Comparative Study Between High and Low Temperature Thermally Controlled Crystallization"

42. "An Investigation of the Viscous Problem Associated with the Heating of the Glass Preform during Optical Fiber Processing"

- *Materials Research Society Spring Meeting*, San Francisco, CA, April 1994

43. "Development of a thermal battery for cold start emissions reductions"

44. "Thermal stress and creep modeling in thin-film structures on substrates with low melting temperature"

45. "The effect of film growth on the redistribution of stresses in Germanium substrates at elevated temperatures"

46. "Thermal-radiation absorption characteristics of patterned wafers during rapid thermal processing"

- *Raytheon Corp., Advanced Research Division*, Lexington, MA, April 1994

Invited Presentation

47. "Thermal Analysis of Thin Film Structures"

- *Sylvania Corp., Research Division*, Salem, MA, May 1994

Invited Presentation

48. "Thermal Analysis of Opto-Electronic Materials Processing"

- *SPIE Annual Meeting*, San Diego, CA, July, 1994

49. "An Investigation of the Air Flow Patterns in the Heating Region of Optical Fiber Drawing"

50. "Heat transfer in the heating region of the optical fiber drawing process"

- *American Society of Mechanical Engineers Winter Annual Meeting*, Chicago, IL, Nov. 1994

51. "Heat recovery for automotive applications using reversible hydration reaction"

52. "Processing uniformity issues during zone-melting recrystallization of large thin-film areas"

53. "The effect of microscale and macroscale patterns on the radiative heating of multilayer thin-film structures"

54. "Thermal and deposition stress relaxation in low-melt-point substrates with high-melt-point coatings"

- *Disney Corporation, EPCOT Center*, Orlando, FL, May 1994

Invited Presentation

55. "A Novel Approach to Science and Technology Education"

- *Materials Research Society Fall Meeting*, Boston, MA, November 1994

56. "Measurement of the effect of temperature on stress distribution and deformation in multilayer optical thin film structures"

- *American Society of Mechanical Engineers International Mechanical Engineering*

Congress and Exposition, San Francisco, CA, November, 1995

57. "Thermal radiative analysis of rapid thermal processing of electronic materials"

58. "Microscale reflectance spectrometry of thin-film structures in butterfly wing scales"
- *Materials Research Society Spring Meeting*, San Francisco, CA, April, 1995
 - 59. "Transient and spatial radiative properties of patterned wafers during rapid thermal processing"
 - 60. "Adhesion and thermal deformation of ceramic/polymer heterostructures"
 - *Materials Research Society Fall Meeting*, Boston, MA, November 1995
 - 61. "Temperature and Time Dependent Viscosity of Polymer Adhesives in Multilayer Structures"
 - *Helicon*, Cambridge MA, January 1996
 - Invited talk
 - 62. "Why Girls Shun Science"
 - *Materials Research Society Fall Meeting*, Boston, MA, November 1996
 - 63. "In Situ Measuring of Thermo-Mechanical Effects and Properties in Thin Film Polymers"
 - *Materials Research Society Spring Meeting*, San Francisco, CA, April, 1996
 - 64. "Numerical Modeling of Radiative Properties of Patterned Wafers with Sub-Micron Features"
 - *Citizens Educational Resource Center*, Worcester, MA, June 1996
 - Invited Talk
 - 65. "A Thematic Approach to Early Science Education"
 - *Biomedical Engineering Society Annual Meeting*, University Park, PA, October 1996
 - 66. "BioHeat Transfer in Butterfly Wings for Thermoregulation"
 - *Materials Research Society Fall Meeting*, Boston, MA, 1996
 - 67. "In-Situ Measuring of Thermo-Mechanical Effects and Properties in Thin-Film Polymers"
 - *Optical Society of America, Light and Color in the Open Air*, Santa Fe, NM, February 1997
 - Invited talk
 - 68. "Multifunctional Thin Films in Butterflies"
 - *Materials Research Society Fall Meeting*, Boston, MA, 1997
 - 69. "Microscale Radiative Effects in Complex Microstructures of Iridescent Butterfly Wing Scales"
 - *American Society of Mechanical Engineers International Mechanical Engineering Congress and Exposition*, Dallas, TX 1997
 - 70. "Selective Multilayer Thin-Film Development in Insects"
 - *Int. Symposium on Mechanics on Plants, Animals, and Their Environment*, San Diego, CA, January 1998
 - 71. "How Butterflies Optimize Solar Energy Absorption and Convective Heat Transport by Wing Design"
 - *Materials Research Society Spring Meeting*, San Francisco, CA, 1998
 - 72. "Effect of Wafer Partial Transparency During Rapid Thermal Processing"
 - 73. "MEMS as Temperature Sensors During High Temperature Processing"
 - *Materials Research Society Fall Meeting*, Boston, MA, 1998
 - 75. "Mechanical and Thermophysical Properties of Silicon Nitride Thin Films at High Temperatures"
 - 76. "Determining the High Temperature Properties of Thin Films Using Bi-Layered Cantilevers"

- *American Society of Mechanical Engineers International Mechanical Engineering Congress and Exposition*, Anaheim, CA, 1998

77. "Effect of Surface Patterning in Thin Film Structures on the Thermal Radiative Properties During Rapid Thermal Processing"

78. "Numerical Simulation of Radiant Thermal Processing of Bilayer Microcantilevers"

- *American Society of Mechanical Engineers/Japanese Society of Mechanical Engineers Joint Thermal Engineering Conference*, San Diego, CA, 1999

74. "Temperature Measurements During Rapid Thermal Annealing Using MEMS"

- *Materials Research Society Fall Meeting*, Boston, MA 1999

79. "High-Temperature Thermomechanical Properties of Silicon Nitride Films used in MEMS"

80. "Microscale Rapid Prototyping Using UV Curing Polymers"

vi) Presentations and Teacher/Student Workshops on preK-12 Science/Engineering Education

1. "Understanding How Things Work; an Innovative Approach to Early Childhood Science Teaching: Exploring the Bathroom" Series of one-day workshops for 60 teachers from 9 Massachusetts school districts (with K. Camara and C. Rogers), funded by the Massachusetts Department of Education, 1993
2. "Streamlining Early Science Education Curricula" one month workshop for 8 teachers and 15 Tufts students (with D. Alexander and C. Rogers), funded by the Pew Charitable Trusts, 1993
3. "Understanding How Things Work; an Innovative Approach to Early Childhood Science Teaching: Exploring the Bicycle" Series of one-day workshops for 60 teachers from 12 Massachusetts school districts (with K. Camara, C. Rogers, B. Chrochietiere) funded by the Massachusetts Department of Education, 1994
4. "Innovative Approaches for Early Science Education", GTE Gifts program; one day workshop for 150 selected math and science teachers (1994)
5. "Development of a novel preschool science curriculum" one month workshop for teachers from the Sunny Hill Preschool, funded by the Pew Charitable Trusts, (1994)
6. "Understanding How Things Work; an Innovative Approach to Early Childhood Science Teaching: Exploring toys" Series of one-day workshops for 80 teachers from 12 Massachusetts school districts (with K. Camara, and B. Chrochietiere), funded by the Massachusetts Department of Education, 1995
7. "Girls in Engineering Initiative" Month-long summer program for high school girls; funded by the Nynex foundation (with P. Wong) 1996
8. "Development of Engineering Elements in the science curriculum of an all-girl school" in collaboration with the Winsor School for Girls (1996)
9. "Girls in Engineering; Science Museum Exhibit Development", Collaboration with the Discovery Museums in Acton and five schools (with P. Wong and others) funded by the National Science Foundation (1997)
10. "Middle School Science Curricula Development" partnership with Prentice Hall to develop the new Middle School Science textbook edition (with M. Cyr) (1997-98)
11. "Infusion of Engineering in PreK-12 educational environments" funded by the Noyce foundation and the National Science Foundation (1999-present)

- 12 "Engineering Fellows" (with M. Cyr and D. Suvaine) partnership with Nashoba Regional School District to integrate engineering in grades K-10, funded by the National Science Foundation (1999-2003)
13. "Girls Get S.E.T. (Science Engineering and Technology) for Life – Interactive Museum Exhibit Development" for Middle School Girls, partnership with the Discovery Museums, Acton MA, funded by Lucent Technologies (1999-2002)

Invited Testimonies at US Senate and Congress

"Introducing Engineering in k-12; the Massachusetts Victory" Science and Education Committees of the House, and Education Committee of the Senate, Washington DC, April 2001

Testified before the US Senate Science, Technology, Engineering and Math (STEM) caucus and the US Senate Commerce Committee sub-committee on Technology, Innovation and Competitiveness, Washington, D.C., 2006

Testify before the Subcommittee on Research and Science Education, House Committee On Science and Technology, Washington, DC, 2009

Testify before the US Senate Committee on Commerce, Science and Transportation on reauthorization of COMPETES Act, Washington, DC, 2010

Selected Keynote speeches and invited talks on education reform and gender issues in education

"Why Girls Shun Science" invited talk, Worcester Public Schools, 1999

"Introducing Engineering in PreK-12 Educational Environments" Keynote Speaker, Technology Education Association of Massachusetts Annual meeting, Worcester, MA, 2000

"Introducing Engineering in PreK-12 Educational Environments" Northeast Tech Prep Conference, Cape Cod, MA, 2000

"Why Engineering is important in grades K-12?", Massachusetts Board of Education, Boston, MA, December 2000

"Introducing Engineering into the Massachusetts Public Schools; Next Go National," National Science Foundation leadership, Washington DC, February 2001

"Introducing Engineering into the Massachusetts Public Schools; Next Go National," National Academy of Engineering, Washington DC, February 2001

"Introducing Engineering in k-12; the Massachusetts Victory," Corporate Foundation Group organized by National Science Foundation, Washington DC, April 2001

Keynote speeches and invited talks on Introducing Engineering in K-12 Education

National Academy of Science, National Academy of Engineering, Institute of Medicine annual Presidents' circle event, Boston, MA, 2003

Secondary School Administrators Association meeting, Falmouth, MA, 2003

Annual Superintendents Conference, Falmouth MA, 2003

Technology/Prep. Roundtable, Falmouth, MA, 2003

Superintendents' Technology Forum, Southbridge, MA, 2003



Women, Leadership and the Workplace Conference, Federal Reserve Bank, Boston, MA, 2004

Advancing Technological Literacy Conference, ASME, Clearwater, FL, 2004

International Technology Education Association Annual Conference, Albuquerque, NM, 2004

Early childhood educators "Byte-Sized Education event," Revere, MA, 2004

Employer Education Forum, Bridgewater State College, MA, 2004

Technological Literacy Conference, National Academy of Engineering, Washington, DC, 2004

American Association of Museums Ann. Meet., Session on Innovation, New Orleans, LA, 2004

US Department of Education Summit on Assessment for High Schools, Boston, MA, 2004

Association of Science and Technology Centers, Session on University/Museum collaborations, San Jose, CA, 2004

New Jersey High School Summit to Reinvent High School Level Education, NJ, 2004.

Technology Education Association of Pennsylvania Annual Meeting Camp Hill, PA, 2004

National DOE High School Leadership Summit, Washington, D.C., 2004

New Hampshire High School Summit, Concord, NH, 2005

Massachusetts Cultural Leadership Conference: "The New Normal: Navigating a Changing World," Boston, MA, 2005

Arkansas High School Summit, Little Rock, AK, 2005

Rhode Island Governor's "Making the Grade" Conference, Providence RI, 2005

Department of Education Title I Dissemination Project, Hyannis, MA, 2005

U.S. Senate Science, Technology, Engineering, and Mathematics (STEM) Caucus, inaugural event, Washington DC, 2005

Guest panelist on Department of Education monthly TV program, Washington, D.C., 2005

NH Math, Science and Technology Coalition, Conference, Manchester, NH, 2005

Indiana High School Summit: "Redesigning Indiana High Schools," Indianapolis, IN, 2005

National Academy Foundation 21st Annual Institute for Staff Development, San Diego, CA, 2005

Vermont Department of Education, "Take the Helm" conference, Stowe, VT, 2005

New Jersey Department of Education, "Generation Next and Reading First" Conference, Atlantic City, NJ, 2005

Association for Supervision and Curriculum Development Conference on Teaching and Learning, San Francisco, CA, 2005

Annual State Conference of the Massachusetts Association of School Superintendents and Massachusetts Association of School Committees, Worcester, MA, 2005

New Hampshire Council for Social Studies, Manchester, NH, 2005

Optical Society of America, Washington, D.C., 2006

Committee on Workforce Development, Providence, RI, 2006

American Society of Engineering Education Regional Conference, WPI, Worcester, MA, 2006

T-STEM Technical Assistance Session, Dallas, TX, 2006

“What’s Working in Education” conference, Charlotte, NC, 2006

Intel International Science and Engineering Fair Educator Academy, Indianapolis, IN, 2006

Rhode Island Tech Collective Annual Award Dinner, Warwick, RI, 2006

New Hampshire Department of Education “Engineering Science Literacy for the 21st Century Summit, Manchester, NH, 2006

National High School Leadership Summit, Raleigh, NC, 2006

2006 William E. Mahoney Seminar, U Mass, Amherst, MA, 2006

Philanthropy Roundtable - K-12 Education Conference, Dallas, TX, 2006

Minnesota Rural Education Association, Alexandria, MN, 2006

T-STEM conference, Dallas, TX, 2006

MIT Innovation Summit, Cambridge, MA, 2006

Christa McAuliffe Technical Conference, Nashua, NH, 2006

NASA/Goddard Space Center Engineering Colloquium, Greenbelt, MD, 2006

eTech Ohio conference, Columbus, OH, 2007

Association of Science Museum Directors, Honolulu, HI, 2007

Philanthropy Roundtable, San Francisco, CA, 2007

Engineering Dean’s Institute, San Juan, Puerto Rico, 2007

BIO 2007 National Biotechnology Teacher Leader Program, Museum of Science, Boston, MA, 2007

Engineering our Future NJ Statewide Conference, Stevens Institute, Hoboken, NJ, 2007

US/UK STEM Conference, Keynote, Boston, MA, 2007



NSF Engineering Education Grantees meeting, Keynote, Arlington, VA, 2007

IDEAS Boston 2007, Panel Member, Federal Reserve Bank, Boston, MA, 2007

Partners in Education Appreciation Breakfast Launching Mobile's Engaging Youth in Engineering Initiative, Keynote, Mobile, AL, 2007

Today's Education, Tomorrow's Workforce: The Future of the Global Workforce", Panel member, Harvard Business School Publishing Conferences, Boston, MA, 2007

National Middle School Association, Annual Meeting, Keynote, Houston, TX, 2007

STEM Legislative Symposium, Keynote, Minneapolis, MN, 2007

Panel Member, A New Day for Schools; The Expanded Learning Time Summit, Massachusetts DOE, U Mass, Boston, 2007

Greater Boston Superintendents' Roundtable, Harvard Graduate School of Education, speaker, Cambridge, MA, 2008

Mass. Cultural Council Arts Education Advocacy Caucus, Opening Remarks, Boston, MA, 2008

Berkman Center for Internet and Society Luncheon Lecture Series, Harvard Law School, Cambridge, MA, 2008



Innovation Leadership Distinguished Lecture Series, College of Engineering and Computer Science, Florida Atlantic University, Boca Raton, FL, 2008

"Engineering Education: Achievement by Design" A Symposium Supporting the Engineering Academy Initiative for Alabama, Alabama STEM Coalition, Keynote, Birmingham, AL, 2008

State Science Supervisors Conference, Keynote, Boston, MA, 2008

National Science Teachers Association National Conference, Featured Speaker, Boston, MA, 2008

Student Transfer Symposium, opening remarks, Boston, MA, 2008

Massachusetts Association of School Superintendents Conference, panelist, Marlborough, MA, 2008

STEM Governor's Institute, Commonwealth of Pennsylvania Department of Education, Keynote, Hersey, PA, 2008

Opening Day of School, Andover Public School District, Remarks to teachers, Andover, MA, 2008

American Museum of Natural History/Carnegie Foundation Roundtable, panelist, New York, NY, 2008



Wayland Public Schools, Remarks to teachers, Wayland, MA, 2009

Google, Speech to staff, Cambridge, MA, 2009

New Jersey School Development Council's Annual Leadership Conference, Keynote, Rutgers University, New Brunswick, NJ, 2009

American Dental Society Dinner, Speech, Museum of Science, Boston, MA, 2009

Massachusetts Business Roundtable STEM Breakfast, Keynote, Museum of Science, Boston, MA, 2009

STEM Academy for Educators, Keynote, Lancaster, PA, 2009

Florida Engineering Society Annual Summer Conference, Keynote, Palm Beach, FL, 2009

Back-to-School Superintendent Conference, Keynote, Minneapolis, MN, 2009

CIO Strategy Exchange, Panel participant, New York City, NY, 2009

NASA Administrator Education Summit, Panel participant Washington, DC, 2009

Department of Defense, Education Summit, Keynote, Washington, DC, 2009

University of Rhode Island, Math and Science Learning Institute, Keynote and work session, Kingston, RI, 2009

Economic & Public Policy Breakfast Forum, Keynote, North Shore Chamber of Commerce, Ipswich, MA, 2009

Kenyon Bissell Grogan Symposium, "Innovations in Mathematics, Science, and Technology," Keynote, Brimmer and May School, Chestnut Hill, MA, 2010

Florida Engineering Society, "Engineering: A Powerful Force in Southwest Florida's Classrooms," Keynote, Florida Gulf Coast University, Fort Meyers, FL, 2010

National Space Grant Directors Consortium, Keynote, Washington, DC, 2010

"A New Vision for the Museum of Science—Integrating the Natural and Designed Worlds," Fox Hill Village, Westwood, MA, 2010

Federal Laboratory Consortium for Technology Transfer National Meeting, Panel participant, Albuquerque, NM, 2010

Commencement speaker, Boston University College of Engineering, May 2010

URL Links, Selected Testimony and Video Presentations

May 6, 2010: Testimony before U.S. Senate Committee on Commerce, Science and Transportation regarding the re-authorization of the America COMPETES Act.
<http://commerce.senate.gov/public/index.cfm?p=Hearings>

October 22, 2009: Testimony before U.S. House Research and Science Education Subcommittee, Committee on Science and Technology, regarding K-12 Engineering Education:
http://science.house.gov/publications/hearings_markups_details.aspx?NewsID=2639 (Click under "Webcast Video")

February 14, 2008: Speech on "Engineering in Education" at the Harvard Berkman Center for Internet & Society
<http://blogs.law.harvard.edu/mediaberkman/2008/02/14/ioannis-miaoulis-on-engineering-in-education-podcast-video/>



DEPARTMENT of COMPUTER SCIENCE

Dr. James Spohrer,

I am writing to strongly endorse the nomination of Dr. Ioannis Miaoulis for the Brock International Prize in Education.

A word about myself first to calibrate what I say below. From 1996 to 2007 I was on Leave from the University of Virginia to serve as the full-time (and then some) President of the US National Academy of Engineering (NAE). The NAE, together with its sibling, the National Academy of Sciences, is a private non-profit corporation, but it is chartered by the US Congress to advise the nation on issues of science and engineering. I made the improvement of STEM education a core value of my tenure, and that is how I came to know Ioannis.

You already have a copy of the nomination, so I won't repeat Ioannis' many contributions to STEM education – both at the university level and in K-12. I will only add to things: (1) it's all true, and (2) the nomination doesn't fully capture the energy and inspirational excitement that Ioannis brings to each of these activities. I say "its all true" because reading the nomination one might be tempted to think that no one could accomplish so much and that maybe the case is being overstated – but it's not. It's all true!

I frankly cannot think of another person that has contributed as much to STEM education as Ioannis has, or is more deserving of the Brock Prize.

Sincerely,

Wm. A. Wulf
University Professor, University of Virginia
President Emeritus, National Academy of Engineering

School of Engineering and Applied Science
151 Engineers Way PO Box 400740 Charlottesville, Va. 22904
(Phone) 434-982-2200 (FAX) 434-982-2214

Minnesota
**Department
of Education**

May 4, 2010

Dr. James Spohrer
IBM Almaden Research Center, G2-629
650 Harry Road
San Jose, CA 95120

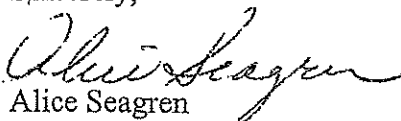
Dear Dr. Spohrer,

It is my pleasure to nominate Dr. Ioannis Miaoulis to receive the Brock International Prize in Education. Dr. Miaoulis is a leading authority on STEM (Science Technology Engineering and Mathematics) education, and our Agency has relied upon his expertise to guide the revision of our science standards to include engineering, K-12. We are proud to be the second state in the nation in 2008-9 to follow Massachusetts' example.

Dr. Miaoulis has been to our state many times to advise us and to speak to audiences of education, citizens and legislators about the importance of engineering education for all students.

We will always be grateful for the advice and consultation he has given to Minnesota as we advance the "T" and "E" of STEM. Speaking as the Commissioner of Education on behalf of our state, we believe that Dr. Miaoulis represents all that the Brock International Prize in Education embodies.

Sincerely,


Alice Seagren
Commissioner



State of Rhode Island and Providence Plantations

State House
Providence, Rhode Island 02903-1196
401-222-2080

Donald L. Carcieri
Governor

May 10, 2010

Dr. James Spohrer
IBM Almaden Research Center, G6-629
650 Harry Road
San Jose, CA 95120

Dear Dr. Spohrer:

It is with great pleasure that I write you this letter of support for Dr. Ioannis Miaoulis to receive the Brock International Prize in Education. He is a true leader and visionary on changing elementary and secondary science education to respond to the need for advancing student understanding and enthusiasm for learning engineering and technology concepts in this country.

At the outset of my first term as Governor, I created a Blue Ribbon Panel on Mathematics and Science Education comprised of business leaders and educators representing both K-12 and post secondary education. As part of the work of this council, we invited Dr. Miaoulis to speak at a statewide forum on this topic. His thoughtful insights and passionate delivery truly energized those present, the echoes of which are still resounding today.

Over the past few years, the Rhode Island Department of Elementary and Secondary Education has been working with educators to create for the first time K-12 Grade Span Expectations (GSEs), or content standards, in Engineering and Technology. While we already have science GSEs and a state science assessment that we collectively administer with Vermont and New Hampshire, it does not incorporate the "T" and "E" of STEM (Science, Technology, Engineering, and Mathematics) education. Benchmarked to the International Technology and Engineering Educators Association (ITEEA) Standards for Technological Literacy, Rhode Island's GSEs were developed as a means to identify the concepts and skills in technology, design, problem-solving, and engineering expected of all students. Founded by Dr. Miaoulis, our educators worked directly with the National Center for Technology Literacy (NCTL) in developing these standards and have utilized such NCTL resources as their Engineering is Elementary program. The Rhode Island Board of Regents, our state's governance body for elementary and secondary education, is poised to address these new standards in July.

Dr. James Spohrer
May 10, 2010
Page Two

I also have had the opportunity to participate in a number of national education initiatives and organizations including those of the National Governors Association and the Carnegie Commission on Mathematics and Science Education and I am on the Board of Directors for Achieve. Just last week at our state's Science and Technology Advisory Council, we heard a presentation from Dr. Jean Slattery of Achieve on developing the next-generation science standards. As states collectively move toward common core standards in mathematics and English Language Arts, the need to similarly address science is clear. Through the National Research Council and Achieve a conceptual framework for a common core of science standards will be created. Those standards will incorporate the "designed world" throughout the K-12 continuum.

The movement in this country, and within individual states, on recognizing and acting on the need to build engineering and technology content in our students early education is directly attributable to the unrelenting advocacy of Dr. Miaoulis. It therefore is with unstinting commendation that I support Dr. Miaoulis for the Brock International Prize in Education.

Sincerely,

A handwritten signature in dark ink, appearing to read "Donald L. Carcieri", with a long horizontal flourish extending to the right.

Donald L. Carcieri
Governor

David Driscoll Consulting

May 10, 2010

23 Cranmore Lane

Melrose, MA 02176

Dr. James Spohrer

IBM Almaden Research Center G2-629

650 Harry Road

San Jose, CA 95120

Dear Dr. Spohrer:

It is a great pleasure to write a letter of reference for Dr. Ioannis Miaoulis in connection with his nomination for the Brock International Prize in Education.

The success we have had in the improvement of student achievement across the board in Massachusetts over the past decade is clearly a team effort. Barely among the top ten States in NAEP testing in the early 1990's, Massachusetts scored the highest scale score on 2003 NAEP in all four tests – 4th and 8th grade reading, 4th and 8th grade mathematics – the first State to ever attain this feat. This remarkable accomplishment was repeated in 2005, 2007 and the recently released 2009 tests. I have often said publicly this is tribute to our historic Education Reform Law of 1993 and the collective effort of state leaders, school administrators, teachers, parents and even students themselves. The hallmark of our efforts was setting, and sticking with, high standards and expectations and a strong aligned assessment system that held students and educators accountable.

However, if there is one person who deserves to be singled out for his contribution it is Dr. Miaoulis. A longtime vocal advocate for higher standards for students dating back to his time as Dean of Engineering at Tufts University, Ioannis was in the midst of all of the initiatives to change this dynamic in Massachusetts. As Dean he noted how incoming freshmen, even at Tufts, had not been properly challenged in high school. He has this unique leadership style where he finds a way to get involved; and once involved is able to get people of very different perspectives to pull together for the greater good. This began with the National Science Foundation State Systemic Initiative in Massachusetts called PALMS (Partners Advancing the Learning of Mathematics and Science) where Ioannis helped develop standards and, provided leadership in what was to become the hallmark of Ed Reform in Massachusetts – strong challenging content presented in an engaging, motivating way. For too long, Educators argued over issues such as Whole Language and Phonics, Modern Math and Traditional drill as if they were mutually exclusive. The debates were detrimental to learning and Ioannis was the one strong voice and leader that was able to move educators away from Ideology toward the effective approach of combining facts and understanding within interesting lessons.

Too many people characterize our success in Massachusetts as resulting solely for our Standards and Assessment programs. As strong as those are, they are only tools and the real secret has been educators that make those high standards and subsequent test questions an integral part of their daily classroom work. Ioannis understood this better than anyone because it had been a part of his approaches his entire life as an Educator. Why did the number of engineering students increase during the time a class matriculated at Tufts where every other prominent school saw a decrease? Because Ioannis insisted that relevant courses in various disciplines be tied to Engineering Principles. Why do Schools and Districts flock to the Museum of Science and/or use their materials in their own settings? Because they are engaging materials and activities tied to the Massachusetts standards and their students experience success.

Ioannis asks why schools teach about dinosaurs and volcanoes and never anything about their car which they likely ride in every day. He asks why very young girls are given passive toys such as dolls where little boys are given trucks and balls creating investigation and curiosity. He rightly points out the disparity in male/ female Engineering students begins right there.

Like most States, we define one of the major content areas as Science and Technology. Unlike any other State our Curriculum Framework not only defines Technology Education in terms of Design and Robotics, but we have added Engineering as a specific discipline PreK – 12. That is a result of the singular effort and leadership of Ioannis Miaoulis. While he will give credit to others on the Committee, Ioannis was the Chair and it was his lifelong work in Engineering and the wonder of the man-made world as well as the natural world that was the catalyst.

Three years ago, Massachusetts chose to participate in the international Science test – T.I.M.S.S. The results were remarkable as Massachusetts students finished second to only Singapore in eight grade science. Those of us in Massachusetts that have been greatly involved in Education Reform know that these results would never have been achieved if it were not for the leadership, effort and involvement of Ioannis Miaoulis.

I am very pleased to tell at least part of the story of the extraordinary contribution of Ioannis Miaoulis, proud to be able to call him my colleague and friend, and honored to present his contributions to your attention.

Very truly yours,

David P. Driscoll

Former Commissioner of Education

Commonwealth of Massachusetts



National Science Foundation

4201 WILSON BOULEVARD, STE. 505, ARLINGTON, VIRGINIA 22230, USA
TEL: 703.292.8300 / FAX: 703-292-9013 / TDD: 800.281.8749

OFFICE OF THE
ASSISTANT DIRECTOR
FOR ENGINEERING

May 12, 2010

Dr. James Spohrer
IBM Almaden Research Center, G2-629
650 Harry Road
San Jose, CA 95120

Dear Dr. Spohrer:

I wholeheartedly support the nomination of Dr. Ioannis Miaoulis for the Brock International Prize in Education. Dr. Miaoulis is, without question, the national leader in the initiative to include fundamental engineering principles in the K-12 curriculum in the United States.

I first met Dr. Miaoulis in the late 90s, and have interacted with him in a number of ways over the past 10 years. First, we worked together often when he served as Dean of Engineering at Tufts University and I was Dean of Engineering at the University of Arizona. Through the American Society for Engineering Education (ASEE), we organized and participated in conferences for the engineering deans, many of which focused on this important issue of the pipeline for potential engineering students. He was a keynote speaker at an ASEE *Engineering Deans Institute*, focused exclusively on preparation of the pre-engineering student.

More recently, I have interacted with him and with his colleagues at the Boston Museum of Science as we both continue to try to advance this important issue of preparing American high school students for academic studies and professional careers in the field of engineering. After serving as Dean at Tufts, Ioannis went on to be the President of the Boston Museum of science. At about the same time, I completed my service as Dean and am now leading the Engineering Directorate at the National Science Foundation. At the NSF, a major priority for our education investments is enhancing the engineering pipeline and especially opening that pipeline to a more diverse population of student. I have worked closely with Ioannis and his colleagues to advance that objective. Recently, Ioannis and I testified together before the House Committee on Science and Technology on this important issue of K-12 engineering education. With strong input from the Boston Museum of Science, legislation has been proposed to include such materials in federal education guidelines.

Beyond this important work in K12 Engineering education, Ioannis and his colleagues at the National Center for Technological Literacy (NCTL) have developed a broad range of educational support materials for pre-college curricula. These materials assist the elementary, middle and high school teacher in their preparation for teaching technology-related topics. The NCTL

Engineering is Elementary materials introduce basic engineering design concepts in an integrated way (with social science, language, science and mathematics contexts) to children in grades 1-5. They have worked as well on a series of materials called *Engineering the Future* for use in high schools. Other projects that are part of NCTL include collaborations with WGBH in Boston on projects for middle school girls, development of professional development materials for teachers, and projects and workshops for education administrators, just to name a few.

In short, there is simply no other person more internationally recognized for his efforts in advancing K-12 engineering education than Ioannis Maioulis. He is an ideal recipient of the Brock International Prize in Education. I wholeheartedly and enthusiastically support his nomination.

Sincerely,

A handwritten signature in black ink, appearing to read "Thomas W. Peterson". The signature is fluid and cursive, with the first name "Thomas" being the most prominent.

Thomas W. Peterson

The University of Vermont

Office of the Vice President for Research
and Dean of the Graduate College

Domenico Grasso, Ph.D., P.E., DEE
Vice President and Dean



May 11, 2010

Brock International Prize in Education Selection Committee,

It is my great pleasure and honor to submit this letter in support of the nomination of Dr. Ioannis Mialouis for the Brock International Prize in Education. I have known Yannis for about a decade. Our paths first crossed when I became the Founding Director of the Picker Engineering Program at Smith College – the first engineering program at an American women's college and one of the few at a liberal arts college. In the formative stages of the Program, I explored curricula and approaches at several successful Schools of Engineering. At that time Yannis was Dean of Engineering at Tufts. Tufts was of particular interest to me because they were reporting low or negative student attrition in engineering compared to national averages of 40-60 percent. I came to learn that this was, in large part, due to innovative approaches in first year educational curriculum that were initiated by Yannis. His innovative contextualization of engineering principles in engaging and enjoyable subject matter served not only as inspiration, but also as role models for what eventually became Smith's Design for the Future course and subsequently our entire curriculum. Yannis' approach became infectious being adopted at many other institutions. Olin College, another exciting adventure in engineering education, developed a stream of activities called "passionate pursuits," not unlike Yannis' first year courses. There is no question that his efforts had a significant impact on our understanding of how best to attract, educate and retain engineering students.

The success of this approach led Yannis, while still Dean at Tufts, to realize the need and potential for introducing engineering and technology in the K-12 curriculum. Technology has become embedded the very fabric of everyday life. The need for all K-12 graduates to have a familiarity with the basic principles of technology is not only a potential source of future engineers, something that this country needs desperately, but also a *sine qua non* for success in the 21st century. Moreover, teaching of engineering and technology has been shown to provide a wonderful vehicle for better understanding to basic sciences and mathematics. His dogged determination and vision in requiring engineering education in the Massachusetts K-12 school curriculum has challenged, changed and improved the traditional educational paradigm and will most certainly provide long-term benefit to all humanity. What is truly remarkable about these efforts is that they were tangential to his core job – educating engineering students in college. His initiatives in this area were driven by the passion to do the right thing and make the world a better place.

Of course, it was not long that everyone in the United States knew of his success. Now many states are requiring or considering a technology competency to graduate. Yannis soon realized that he could be more successful and efficacious at a different venue. He became President of the Museum of Science in Boston and has used this new platform to supercharge his efforts, to

bring technology not only to K-12 education – although this is still vitally important and a major part of his efforts, but to bring technology, separate from basic sciences, to the masses through informal education.

Thomas Jefferson once noted – information is the currency of democracy. With so many of the issues that we face daily being technology laden, e.g. sustainability, computer security, energy crisis, medical advances, anyone that wishes to participate meaningfully in our society must have some familiarity with basic concepts of engineering and technology. Yannis is doing his best to see to it that future generations can be part of this important dialogue. He has, in no small fashion, contributed to making this a better planet.

You could not choose a more deserving recipient of this prestigious award.

Sincerely,



Domenico Grasso, Ph.D., P.E., DEE

KERN FAMILY FOUNDATION

May 10, 2010

Dr. James Spohrer
IBM Almaden Research Center, G2-629
650 Harry Road
San Jose, CA 95120

Dear Dr. Spohrer:

I fully support the nomination of Dr. Ioannis Miaoulis, President and Director of the Museum of Science in Boston, for the Brock International Prize in Education. His vision to include engineering education as part of a holistic K-12 education is transformational, and his tireless effort to bring about this educational change nationally will benefit generations of students for years to come.

As a young program director for a start up foundation with the vision to create "more and better" engineers, I was fortunate enough to connect with Dr. Miaoulis early on in my search for action-oriented solutions. Our founders, Robert and Patricia Kern, believe that engineering is "the artistic expression of math and science," and that an education is incomplete without some connection of how the academic rigors of math, physics and chemistry relate to our man-made world of engineering design. Engineering design impacts almost everything we interact with everyday including transportation, energy, and communications. Engineering design is creative, using math as a tool to predict what will happen when various solutions are proposed to an open-ended problem. Dr. Miaoulis has made it his mission to bring this understanding to students and teachers at all levels, and further, he has started to impact state structures that will make engineering education accessible and sustainable to all students into the future.

Dr. Miaoulis' success as the Engineering Dean at Tufts University would alone qualify him for this award. His creative courses, which made transfers into the engineering program from the liberal arts departments a common occurrence, were revolutionary and unmatched by others. However, what has impressed me most is that he left a secure, tenured position at Tufts to join the Museum of Science, Boston, and create the National Center on Technological Literacy, with the intent to transform K-12 education through some carefully crafted programs. He brought his incredible talent and energy to bear on what is often described as an entrenched and frustrating landscape of state educational systems so that younger children and their teachers could become part of the solution to improving America's global competitiveness. He has made this transition willingly and with good humor, understanding that America is at a crossroads in its education

trajectory, and that the time has to be now to bring engineering education into the halls of all our K-12 schools.

Dr. Miaoulis has done remarkably well in this endeavor and continues to impress. His achievements include developing engineering curricula and professional development models that are accessible for K-12 school districts, teachers and students across the country. He is the leading voice in advocating nationally and within states to include K-12 engineering education as part of a holistic education for our children. This requires being part of endless meetings on standards, assessments, and policies. There are a long list of results from his work, including legislation, state policy changes, significant recognition from the U.S. Department of Education's STEM education initiatives, and transformational developments in organizations from the National Governors Association to the National Assessment of Educational Progress.

At the heart of all this is Dr. Miaoulis' vision for a future where the application of math and science, though engineering habits of mind, is common for all students. That vision resonates with our Board of Directors, and has garnered a lot of traction nationally, in state agencies, in other non-profit organizations and in schools across the country because of his commitment and work every day. It's not something that many tenured faculty members would have undertaken as a mission. Dr. Miaoulis deserves recognition through the Brock International Prize in Education because he embodies the humanitarian spirit of the award as well as achievements that have led to innovative, transformational change in education. I fully support his nomination for this award.

Sincerely,

Karen Wilken

Karen Wilken
Program Director

THE NOYCE FOUNDATION

May 6, 2010

Dr. James Spohrer
IBM Almaden Research Center, G2-629
650 Harry Road
San Jose, CA 95120

Dear Dr. Spohrer:

I am writing to offer my enthusiastic support for your nomination of Dr. Ioannis Miaoulis for the Brock International Prize in Education.

I have known Dr. Miaoulis and followed his ever-broadening efforts on behalf of engineering education for the past fifteen years. Our early encounters came in the mid-1990's, when he was in the midst of transforming introductory college engineering courses at Tufts in order to increase retention and recruitment of engineering students and to increase the number of girls in engineering. How was he so successful? First, he's a great, enthusiastic communicator, so full of life and anecdotes that he draws people into his vision. By connecting engineering with music, cooking, medicine, fishing, and nature, he was able to make engineering the "ultimate liberal art" he talks about. Second, he empowers those around him to innovate. He raised funding to allow faculty members to create new courses and projects that linked engineering to their passions.

At the same time, Ioannis started the Center for Engineering Education Outreach at Tufts to increase the interest of young students, especially girls, in engineering. Besides the Logo Robotics work which has become an international movement, he led local projects that varied from a class for kindergarten teachers on the technology of toilets to a program to help middle school girls and their teachers design working exhibits for a local science museum.

In 1998, I was appointed head of a committee to revise the Massachusetts Science and Technology Curriculum Frameworks. We were faced with several contentious issues, one of which was the role of technology education in the framework. Traditionally, "tech ed" in Massachusetts had meant wood and metal shop. An earlier draft of the framework had asked technology teachers to address more areas, including the role of technology in society. But many found the standards vague, descriptive, and not particularly academic.

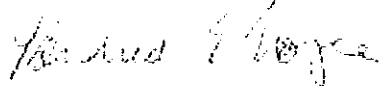
In repeated conversations, Ioannis convinced me that the most forward-looking way to address this problem was to introduce the concept of engineering in the early years. I knew this idea would be controversial, so I asked Ioannis to head a new, ad-hoc subcommittee on the notion. I introduced him to key decision makers at the Massachusetts Department of Education and

unleashed him to work his charm. With persistence, humor, good examples of student work, and patience, Ioannis brought the subcommittee, the committee, the Department of Education, and eventually technology teachers around the state to his point of view. Creation of the first state Technology/Engineering standards could absolutely not have happened without him.

Of course Ioannis didn't rest on his laurels. He began talking about engineering education standards all over the country. When he became President of the Boston Museum of Science, he brought his vision with him, convincing the trustees of a rather staid institution that a focus on technological literacy represented a new frontier for the museum. Methodically and strategically, he began bringing groups of teachers in to examine existing engineering curricula. He noted the absence of good materials in elementary school and launched the writing of the series *Engineering is Elementary*, which has now reached a stunning one million students. Next he worked on a high school engineering course that would meet the Massachusetts standard for graduation. He led the development of a supplemental course that links engineering and elementary algebra. Now the National Center for Technology Literacy is developing middle school engineering course units that link with the popular WGBH television program *Design Squad*.

To all this work, Ioannis has brought the same joyful missionary spirit, buttonholing anyone he can to share the vision of a population that understands where things come from, how they are made, and how innovation happens. He inspires, cajoles, invents, revamps, and makes sure everybody has fun along the way. I can't think of a more deserving innovator and evangelist for the idea of education as a tool that empowers us to understand and fix our world.

Yours sincerely,



Pendred E. Noyce, MD
Trustee, the Noyce Foundation



TUFTS UNIVERSITY

Alice and Nathan Gantcher University Professor

May 12, 2010

Dr. James C. Spohrer
Director, IBM University Programs (IBM UP)
IBM Almaden Research Center
San Jose, CA 95120

Dear Dr. Spohrer:

I was Provost at Tufts University from 1981 to 2001; in that capacity I appointed Ioannis ("Yannis") Miaoulis, then in his early thirties, as Dean of the College of Engineering. It was the best appointment I ever made.

Yannis took a good, gray, engineering college and in a few short years transformed it into a unique part of a complex university. He integrated engineering programs into medicine, dental medicine, community health, and the Fletcher School of International Relations. He paved the way for interdisciplinary degrees with six other schools at Tufts. Those programs are still working, long after he left Tufts.

This academic synergy would have, by itself, made Miaoulis part of the progressive history of the university. But, he did more than this. He led an often reluctant faculty to create a series of imaginative curriculum innovations that brought the Engineering College to the center of creative teaching at Tufts. Contrary to earlier history, engineering curriculum innovations became a model for other parts of Tufts that were also seeking style and substance in their classroom offerings. Other engineering schools and university administrators were calling me, asking what I saw in Miaoulis's vision that led me to appoint him Dean.

And he was still not finished. He took one look at a male-dominated profession and was determined to bring women into the engineering work force. Through a successful public relations plan that reached out to K-12 female students, he increased the number of women applicants exponentially; and they were successful. He brought females to the faculty, developed home-grown talent, and established the Tufts College of Engineering—later an independent School of Engineering, thanks to Yannis' leadership and political skills with the trustees—as a leader in the education of women.

He has had a positive impact wherever he has been: the curriculum of the Commonwealth of Massachusetts carries the Miaoulis stamp of approval; it has perhaps the only educational charter in the nation that includes engineering in the state requirements for education.

I made nineteen appointments to deanships for seven schools at Tufts during my tenure as provost. None has had the transformative impact on the community that equaled that of Yannis Miaoulis.

Please feel free to call or to write, should you require additional information.

Sincerely,

A handwritten signature in cursive script, appearing to read "Sol Gittleman".

/ Sol Gittleman



CHARLES RIVER
VENTURES

May 10, 2010

Dr. James Spohrer
IBM Almaden Research Center, G2-629
650 Harry Road
San Jose, CA 95120

I am writing as Chairman of the Board of the Museum of Science in Boston to support the nomination of Dr. Ioannis Miaoulis, the president of our institution for the Brock International Education Prize. The Science Museum was the pioneer of hands-on science education exhibits in the 1950s and 1960s which is now the basis science centers around the world. We believe that the engineering education concepts developed by Dr. Miaoulis will have a similar fundamental impact on technical education in the coming decades.

Many of the very best, most important innovations are quite simple and straight forward. Dr. Miaoulis recognized early in his career that we live in both the natural and the human made worlds and that students can be excited by learning about how the human made world works, the world they are most familiar with. On the surface this dichotomy is a theory that is easily understood, but it has profound implications for education long term.

Dr. Miaoulis' concept originated at Tufts University where he was appointed Dean of Engineering when he received his tenure. He turned around the Department by using actual, real life problems to interest students rather than beginning with the traditional theorems and formulas. The program became a great success with students transferring in to engineering from liberal arts. This led Dr. Miaoulis to realize that younger students could also be captured by engineering using the same approach.

The United States has been the world leader in innovation for nearly 200 years, but other countries in Asia and Europe have developed stronger engineering education programs and threaten the leadership of the US. They have done a better job creating an engineering culture; a culture where young people graduate from high school wanting to make things. Dr. Miaoulis understands these issues and joined the Museum of Science to implement his ideas on a nationwide basis. He proposed his program to the search committee before he was hired and after much deliberation our board realized this was a chance to have a fundamental impact on the future engineering education in the country.



Dr. James Spohrer
May 10, 2010

-2-

Dr. Miaoulis is an effective evangelist for engineering education and the program has been supported by leading education policy makers and funders. This has allowed the Museum to rise over \$60 million of support. Through his work many states have adopted the program.

The actual product is a unique K-12 engineering curriculum which is now in over 20,000 classrooms and being used by over 1.5 million students. First graders are taught to read with books about windmills, filters and pumps rather than dogs chasing balls and cats. It has proven to be very popular.

Dr. Miaoulis understands that young students are inherently interested in how the man made devices around them work and the curriculum pioneered the idea that young students can be taught the basic mechanics behind the world built by humans. Approaching STEM education from this point of view brings a freshness and reality to the classroom that has a much greater chance of capturing the student's imagination.

At the Museum of Science we believe these new ideas have the potential to excite a new generation of engineers and fundamentally shift the way technical subjects are taught. If you have any questions I can answer please contact me.

Sincerely,

Richard M. Burnes, Jr.
General Partner

MBR

May 13, 2010

Jim Spohrer
Director, Almaden Services Research
IBM Almaden Research Center
spohrer@us.ibm.com

RE: Reference Letter for Dr. Ioannis Miaoulis

Dear Dr. Spohrer:

This is to provide a reference letter in support of Ioannis Miaoulis' (Yannis) nomination for the Brock International Prize in Education. I have known Yannis for nearly 10 years and strongly believe he is a unique, positive force in K-12 education and especially in Engineering education.

I have served the Museum of Science as a Trustee for the past 12 years and have been an active supporter of Science, Technology, Engineering and Math (STEM) education causes for more than 20 years. I have chaired the Massachusetts Business Roundtable Education Task Force for the past 5 years and Yannis has been a strong voice on the committee. I also have been appointed to the Governors STEM Advisory Council, as has Yannis. So I know Yannis well and especially his leadership and action orientation on behalf of Engineering education.

It is clear to many of us in the Massachusetts (and national) education community that Yannis has created, driven and executed major changes in Engineering education in the New England area and the nation. Beginning before he was a professor and later vice provost at Tufts University and blossoming further while President and CEO of the Museum of Science, Yannis is a seminal voice for transforming K-12 learning to include Engineering and technological curricula. He pioneered and then helped implement the Massachusetts state Engineering curriculum program. As President of the MoS, he championed the National Center for Technological Literacy (NCTL) which has had national impact in not only drawing attention to technological literacy, but providing tangible programs to increase awareness and competency among students and adults alike.

I am sure you are aware of many of his other contributions to Engineering education, technological literacy and STEM advocacy, but I want to add my voice as an admirer and co-worker in this important cause. He is a clear leader; creative, articulate, forceful and achievement oriented. He is also a pleasure to work with and a great team member when he needs to be. I am fully supportive of his nomination.

Sincerely,



Gary DiCamillo
Chairman, Massachusetts Business Roundtable Education Task Force

*Chris Rogers
Dept. Mech. Engng.
Tufts University
Medford, MA 02155
crogers@tufts.edu*

5/6/10

Recommendation for Ioannis Miaoulis

It is a definite pleasure to nominate Yannis for the Brock Award. I have known Yannis for 20 years - and he continues to be an inspiration for me. In my mind, he is one of the largest contributors to changing the face of education in America. The best way to demonstrate this and recommend Yannis is through the footprint he has left: at Tufts, in Massachusetts, and nationally. That is, if Yannis had stayed in Greece rather than move to the US, how might have things been different?

At Tufts, his footprint is readily apparent. As a professor, he was really responsible for starting undergraduate research in our department. Although previously, one or two students got involved with a faculty member, Yannis institutionalized it and it continues today (just last week about $\frac{1}{3}$ of this year's graduating class presented research results). He also led the effort to make the classes more project-based and relevant. As a result, most of the junior and senior level courses now have some sort of final project. Finally, he started the K-12 engineering education outreach efforts of the department by starting collaborations with various school systems in the area.

As dean, he continued to promote project-based learning and instituted the " $\frac{1}{2}$ courses" - a set of freshman seminar courses that allowed faculty to teach around their hobbies (from cooking to robots) and students to understand the need to a solid background in math and science. As a direct result of these courses, our retention of engineers went from about 80% to almost 100%. These courses still exist and now the current dean just presented a plan to grow them into year-long, hands-on, design experiences. These courses have been emulated at other universities as well. Yannis also led the effort to separate the engineering departments from the school of arts and sciences, and thereby started the Tufts School of Engineering. He led the formation of the new biomechanics department at Tufts, building a department around a research paradigm. He began the effort to increase research funding and he placed a significant effort in pre-college engineering education. As part of that effort, he helped start the Center for Engineering Education and Outreach (which I now direct) - which currently supports 6 faculty members, 20 graduate students and staff members along with around 40 undergraduates.

He was also instrumental in starting the Tufts interdisciplinary doctoral program in engineering education (one of the first in the country).

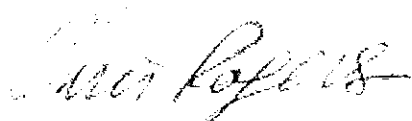
Even while at Tufts, he had significant influence outside of Tufts. I am most familiar with his work in K-12 engineering education where his work has been truly extraordinary. After helping establish one of the first programs in engineering education, he went to the Massachusetts Department of Education and convinced them to develop the first standard in engineering education in the US. Since then, Massachusetts students (my children included) have had standardized tests in engineering - causing more and more schools to think about how to bring hands-on, problem-based learning into their classrooms. Yannis left Tufts to run the Museum of Science and has been instrumental in bringing engineering to the Museum as well as starting the National Center for Technological Literacy there. The museum reaches out to over a million visitors annually and works with hundreds of local schools.

At the national level, Yannis has continued to push his K-12 agenda, starting with his work with Prentice Hall to develop engineering education curriculum as part of the middle school science books. Since he moved to the Museum, this work has flourished, with the success of the elementary school curriculum (Engineering is Elementary) and the new middle and high school curricula. He is on numerous advisory boards, including NASA's education board and has repeatedly presented to congress (he was down testifying in front of the senate yesterday). He has worked with many states to convince them to bring engineering into their curriculum, with New York, Minnesota, Texas, California, and others already taking steps in that direction.

In summary, Yannis has changed the way we do engineering education at Tufts and led the formation of a doctoral program to study how best to teach engineering at all age levels. His work rapidly started to affect all educational institutions in the state as he led the efforts in defining the MA engineering standard. With his move to the Museum, his reach into Massachusetts schools increased and extended across the nation. I think he is a perfect fit for the Brock prize in that he has had a tremendous impact on students across the state and is having more of an influence on students across the nation. He has successfully led the effort to bring the completely new field of engineering into the K-12 classroom and we are already starting to see the benefits. Benefits like kids previously turned off of math and science coming in during recess to do "more engineering." Benefits like teachers changing the way they teach, moving toward a more open-ended, project-based classroom. Benefits like students learning how to work in teams and how to fail - and learn from it. Finally, I think what Yannis has started in MA will eventually be adopted across the US (and in other countries) and will help ensure that the future voter will understand some of the scientific and engineering underpinnings of the policies they are asked to vote on. Armed with this knowledge, maybe we can (as a country) effectively tackle problems like global warming, energy sustainability, and drinkable water. I am pretty sure that if we do not continue to promote engineering (all of STEM)

education for all students, we will continue to have a voting population that think Intelligent Design is a science or that can be fooled by perpetual motion machines and other pseudo-science/engineering. I hope that through awarding the Brock Prize to Yannis, you can help give him the visibility he needs to improve our school systems at a national level. Please contact me if there is anything else I can do to support Yannis' nomination.

Sincerely,

A handwritten signature in cursive script, appearing to read "Chris Rogers".

Chris Rogers
Director, Center for Engineering Education & Outreach
Professor, Mechanical Engineering
crogers@tufts.edu

Domenico Grasso
Melody Brown Burkins
Editors

Holistic Engineering Education

Beyond Technology

 Springer

WRITING SAMPLES

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Chapter 4

K-12 Engineering – the Missing Core Discipline

Ioannis Miaoulis

Ioannis Miaoulis is President and Director, Museum of Science, Boston, Massachusetts, USA

The Missing Core Discipline



We live in a human-made world. From the moment we wake up until we lie down to sleep, we are immersed in technologies. The faucet we use to wash our face, the toothbrush we use to clean our teeth, the clothes we wear, the car we drive, our office or school, our home, and even the mattress we sleep on are all the results of engineering processes. The water we drink has undergone an engineered purification process. The food we eat is the result of countless engineering technologies. If you are reading this inside a building, take a moment to look around. Imagine how your environment would look without any human-made things. Almost nothing you see or experience would be present – no electricity, no chair, no walls, no book, and maybe no YOU. Without human-made pharmaceuticals and sanitation processes, the life expectancy would be 27 years.

We live in an engineered world. Engineering design creates the technologies that support our health, convenience, communication, transportation, living environments, and entertainment – our entire day-to-day life. We school our children so they can live a healthy, productive, and happy life. Our curriculum includes disciplines that prepare students to understand the physical and social world around them so they can be informed users, producers, and citizens. Social studies prepare students to understand human relations and dynamics. Mathematics prepares them to think in quantitative manners to model processes and to calculate. Language arts prepare them to communicate effectively and provide them with tools to learn other disciplines. Science prepares them to analyze and understand the physical world around them. Beginning in preschool, students learn about rocks, bugs, the water cycle, dinosaurs, rain forests, the human body, animals, stars and planets, chemical reactions, and physics principles. These are all important topics, but they only address a minute part of our everyday life.

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e-mail: imiaoulis@mos.org

D. Grasso, M.B. Burkins (eds.), *Holistic Engineering Education*,
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The science curriculum focuses exclusively on the natural world, which arguably, occupies less than 5% of our day-to-day activities. The classical K-12 curriculum essentially ignores the other 95%, the human made world. Technology is not part of the mainstream curriculum. In most academic environments the term technology is used to describe electronic devices. Most people do not understand that everything human made, other than some forms of art, are technologies. Although students spend years in school learning about the scientific inquiry process, the process scientists use to discover the natural world, they never learn the engineering design process, which is responsible for most of the things that support their day-to-day lives.

When I first realized this blatant omission, I was shocked. There are so many brilliant people working in K-12 education fields, so many higher education institutions that prepare educators and curricula, and many committed government leaders that care about education. How, then, have we reached the ridiculous point where one may be considered illiterate if she does not know how many legs a grasshopper has, yet is considered perfectly fine in not understanding how the water comes out of a faucet? Students in middle school can spend weeks learning how a volcano works, and no time understanding how a car works. How often will they find themselves in a volcano?

Understanding the natural world around us is essential, but ignoring the other 95% is simply wrong. I was curious to learn the reason that the human-made world is not part of the curriculum. I discovered that one of the most significant moments in American education was the publication of the report of the "Committee of Ten" in 1893. Charles Elliott, the president of Harvard University at the time, led this impressive group of education leaders. They used a quite rational approach to determine which disciplines students should be taught in K-12 schools in order to be prepared for productive work or college entrance. First, they decided what students need to know by high school graduation, then they looked at the things that typical students learn at home, and by subtraction, they decided what should be taught in schools to cover the difference. Fields such as biology, chemistry, physics, and earth science are typically not covered at home and they made the list. Yet technology was left out. Think of the state of technology in 1893. Not only was it quite basic and simple, but most of it focused on farming. And since the majority of school children were living in agrarian areas, they were learning "technology" at home. So the committee determined that it was not necessary to include technology in the regular curriculum. In addition, the committee was likely influenced by the bias of its leader. President Elliott was not a friend of "applied knowledge." He closed Harvard's Engineering school because he deemed Engineering to be too mundane for Harvard. The "Committee of Ten" report was used as a template to create textbooks and curricula and thus technology and engineering were omitted. As technology advanced to become a major influence on our lives, the core curricula and textbooks never caught up.

There was a parallel, yet not as successful movement to create "manual schools," led by the C.M. Woodward, the Dean of Engineering at the Washington University in St. Louis. This movement focused more on vocational education versus basic

technological literacy for all. Industrial arts emerged as an elective discipline in some schools in the early 1900s, but also focused on the vocational side of technology. Industrial arts' aim was to train students to become technicians, such as builders and plumbers. Industrial arts gradually evolved to technology education (Tech Ed) which leans closer to engineering, but in most cases it was still viewed as "shop." Tech Ed teachers are not high in the prestige hierarchy in the K-12 academic world. Although in the beginning of the 1900s, Tech Ed programs were developed by engineering schools, schools of education gradually took over the discipline. Many Tech Ed programs are now in colleges and universities which have no engineering programs. This trend inhibited growth in the field that would parallel the explosion of engineering and technology, with a resulting focus on the vocational, rather than the academic. At present, technology education is either a small part of the student's education or simply an elective. In tough economic times, these are the first areas to be cut from the budget. As a result only a small number of students are afforded an opportunity to learn even that limited part of the human made world.

Why Should Engineering Be Part of the Core Curriculum?

Technological Literacy is Basic Literacy

How can one claim to be literate if she does not understand how 95% of her environment works, or how it was made? Technological literacy is simply *basic* literacy. It is no less important than understanding US history or trigonometry. Understanding how an engineer designs is just as important as understanding how a scientist thinks.

Engineering Promotes Problem Solving and Project-Based Learning

The engineering design process starts by identifying a need or a problem. It follows an organized path to arrive at one or more solutions that satisfy the need or solve the problem. Problem solving skills are far more valuable than many of the other skills that are the focus of our K-12 educational systems. I use my engineering training constantly to solve problems far removed from engineering, such as dealing with personnel issues or fundraising. Engineering provides a life skill that can be used in everyday life and in any occupation.

Engineering pulls other disciplines together, enabling students to work as a team to solve a problem they are passionate about. Imagine a second-grade engineering team trying to solve the problem of how to keep their classroom pet bunny rabbit at the school, even though one of their classmates is allergic to it. This problem presents a welcome opportunity for the students to apply the skills they have gained from other disciplines to solve a problem they personally care about. In order to build an outdoor habitat for their rabbit, students have to use their math to figure

out the measurements of the hutch so the bunny can comfortably live in it and enter and exit, while not allowing the neighborhood raccoon to move in. They have to use their science knowledge, including the fact that heat flows from hot to cold, while insulating the habitat so the bunny can be comfortable during the cold winter months. They even have to use their art skills to make the habitat appealing. While doing this, they sharpen their team and collaborative learning abilities.

Engineering Makes Math and Science Relevant

Why do students lose interest in math and science in the middle school years? Some blame teacher quality and preparation. That may be a factor; however, I believe it is primarily because curriculum content is disconnected from the content of the students' daily lives and interests. In elementary school years, students love science because they learn about rocks, bugs, dinosaurs, and rain forests. These topics are exciting in elementary school, but quickly lose their appeal as the students reach puberty. In middle school, science begins to become more abstract, rocks become earth science, bugs become life science, and physical science deals with forces, energy, and other things that are "invisible" to students. These "natural world" topics are not so natural for children that live in inner-city, urban environments with few opportunities to travel and enjoy the natural world.

The "lack of relevance syndrome" continues at the college level. About half of the students that enter engineering school quit or transfer to liberal arts. Granted, some of these students are not adequately prepared in math and science and are challenged to the point where exit is the only solution, but many of them do quite well in math and science, yet they decide to switch. All colleges and universities, even the elite ones, lose a large portion of their first-year engineering class to liberal arts. When I became Dean of the School of Engineering at Tufts University in 1994, I learned that 22% of the first-year engineering students transferred to liberal arts. What I found even more disturbing than the sheer number of transfers was the grade point average of these students was a B+, with average math plus verbal SAT scores was close to 1400! Lack of preparation was not the reason.

Why, then, were students switching at such great rates? I held a number of focus groups in order to understand the reasons. The number one response was "I did not find Engineering interesting." What I found interesting was that they had not yet taken any engineering. The first-year curriculum was filled with math and science, along with some computer programming and perhaps a basic design course. The magic and excitement of engineering was just not part of their experience. As a result, we changed the curriculum to not only include engineering earlier, but also to include it in an engaging way. We introduced engineering courses for first-year students that stemmed out of faculty's personal hobbies and interests and we opened the courses to liberal arts students as well. There were courses in Acoustics and Chemical Engineering under the titles "Design and Performance of Musical Instruments" and "Microbrewery Engineering." I developed two courses stemming out of my fishing and cooking hobbies. My fishing-related course was called "Life

in Moving Fluids.” It was an introductory fluid mechanics course, but from the point of view of a fish or a tree. The laboratory looked more like a biology lab than an engineering lab with live fish, sea anemones, and plants, along side liquid and air tunnels. The other course was called “Gourmet Engineering” where transient heat conduction-related differential equations would come alive in a state-of-the-art kitchen laboratory. Finite cylinders took the form of meat roasts, instrumented with thermocouples that would monitor the temperature to show if the math really worked. All these courses were designed in a way that made math and science relevant. The experiment worked. Within a year, Tufts became, and still is, the only school in the country where in some years more students transfer from liberal arts into engineering versus engineering to liberal arts.

Engineering makes math and science relevant which is critical in the middle school and high school years. Relevance is particularly important for retention of girls in science fields. Girls gravitate toward science disciplines that have an evident benefit to society. Half of the medical school students are women, and women comprise the majority of students in the life sciences. In some highly competitive veterinary schools, more than 80% of the students are female. Ability is clearly not the limiting factor. Engineering in K-12 can make science relevant and improve student interest, especially among girls.

Engineering as a Career

There has been considerable discussion and expressed panic for the prospective lack of engineers in the United States. Some skeptics argue that the gap between demand and supply of domestic engineers could be covered by outsourcing work to foreign engineers for less money and, in some cases, better work quality. While there are some engineering jobs that could, and probably should be outsourced, there are others that must remain domestic. If these jobs were outsourced, the security and culture in the United States would suffer.

Engineering jobs related to local infrastructure are prime examples. The design, construction, and maintenance of buildings, roads, power plants, airports, electric grid systems, etc., are best accomplished by engineers who are familiar with local conditions. Engineering jobs related to our national defense systems also cannot be outsourced. Would you be comfortable being protected by weapon systems imported from another country?

The United States has always been the center of innovation. Innovation, driven by US engineers, has made this country special and has attracted some of the best minds to immigrate here. This innovation has created the products, services, and wealth that still make living in the United States better than most countries. If this innovation culture gets eroded or outsourced, the entire character and culture of our nation will be affected dramatically.

In order to preserve the innovation culture in the United States, numerous committees have issued reports calling for an increase in support of K-12 mathematics

and science education. What these reports have missed is that the connector between math, science, and innovation is engineering. Unless this connection is made in school, the number of future engineers will continue to fall short of the current and future demands.

The United States would have a lot more engineers if young people knew what engineers do. Approximately seven out of ten engineers in this country have had a relative that was an engineer. There are few other non-trade professions that are connected like this to family. Unfortunately, school career guidance counselors are typically uninformed about engineering. The general public is similarly uninformed and confused about what engineering is and what engineers do. In China, Europe, and India the engineering profession is better understood, and Engineering is considered a very prestigious career choice. Some of the most competitive admissions to European universities are for engineering majors. Almost half of the members of China's politburo have an engineering background.

As the demographics of our country change, and the percentage of Caucasians decreases, so, too, will the number of engineers. In African-American communities, most young adults that attend college focus on education, medicine, and law, largely because these were culturally considered respectable professions. These are the professions that their community has encouraged them to enter and thrive in – since African-Americans have historically been shut out of many professions including engineering. Given that the engineering profession is overwhelmingly comprised of Caucasians, and given the strong link between the engineering career choice and relatives in the profession, the numbers are bound to decrease.

Here in the United States there is confusion about the term "engineer." We call train drivers, radio station sound technicians, and janitors engineers, along with the traditional college educated engineers. It is not uncommon to see the doors of high school janitor closets lettered with signs saying "ENGINEERING." Even the janitor's closet at the National Academy of Engineering's old building had a sign saying "ENGINEERING." If you have a problem with your toilet in a hotel and you call the front desk for help, they may tell you "we are sending the *engineer* up right away."

The role of engineers could be better understood if public media represented the profession more prominently and accurately. Engineers are largely absent from mass-market television, where both kids and adults get their information. News programs could be encouraged to solicit input from engineers on topics such as cutting-edge technologies, port designs, earthquake prevention, and heart stents. Newspapers could include more statements from engineers when new designs succeed (vs. during failures). The nation has missed great opportunities to celebrate engineering achievements and to excite young people to pursue engineering careers. When NASA's Rover made it to Mars, the press called it a "science miracle." When something went wrong with it, the press called the event an "engineering error." There are no prime time TV shows with engineering heroes or main characters.

Unless the United States makes an effort to teach students about engineering early and to present the engineering profession in a realistic light, there is little chance of improving the career-choice statistics.

Navigating in a Three-Dimensional World

We live in a three-dimensional world and we should be able to conceptualize it as such. At times we all have to imagine and sometimes sketch things in three dimensions for considering optimal designs, for example when we redesign a kitchen or set up a warehouse.

Most engineering schools have a course on engineering design which is required for all first-year students. A significant component of this course focuses on 3D visualization skills. A surprising phenomenon that schools throughout the country once noted was that young men entering the engineering school were more capable tackling 3D challenges than their female counterparts. Both men and women had comparable college entrance test scores, high school grades, and in some cases, were from the same family. The phenomenon could not be attributed to some genetic factor, since after the design course, the 3D gap would close and both men and women could tackle these challenges with similar abilities and skills.

Researchers in Michigan studied the phenomenon and came to the conclusion that the reason for the differential performance between young men and women in 3D skills was attributed to the toys that they played with during their growing years. I was fascinated by the study and wanted to take a personal look at the different toy availability for boys and girls. I went to a large chain toy store and spent a few hours with the gender bias in mind. I was fascinated! There was an abundance of toys for boys that sharpened 3D visualization skills such as LEGOs, Lincoln Logs, construction sets, and lathes. The availability of such toys for girls was a different story. Most girl toys focused on nurturing and fantasy. Barbie's aisle was loaded with toys such as "Teen Talk Barbie" which once said "Will I ever have enough clothes?" and "Math class is Tough!" "My Little Pony" was another top seller which featured a plastic little horse with a fuzzy tail and a plastic comb. I quickly understood the validity of the Michigan study and realized that toys stemmed this inequity.

Currently, I am more worried that what used to be a boy versus girl issue has become a boy *and* girl issue. Children now spend most of their discretionary time in front of 2D screens, televisions, video games, laptops, MP3 players, and mobile phones. Building, tinkering, and other activities that primarily engage boys are no longer the preferred pastime. We have started creating generations of people that will not be able to visualize and design in three dimensions. This will not only affect the abilities of future engineers, designers, and architects, but also deprive people from a basic life skill. By introducing engineering in K-12 schools we will remediate this issue for both boys and girls.

These are the five driving issues that created the "call for action" to introduce engineering as a new discipline in the K-12 curriculum. This discipline should be parallel and equal to language arts, mathematics, science, and social studies. I recall someone once saying, "Introducing a new discipline in K-12 education is as challenging as moving a graveyard." I am beginning to see the truth in that statement.

The Transformational Moment

A small number of K-12 engineering curricula were developed in the early to mid-1990s; however, their purpose was to motivate students to pursue careers in engineering. Most focused on a specific engineering area such as electronics or automotive engineering. "Project Lead the Way" offered the first sequence of high school engineering courses aimed toward students that planned to attend engineering schools. Many engineering colleges also started K-12 education outreach programs. Recruiting and community service were the main motivators. The first effort to introduce engineering to all children, starting in kindergarten, was undertaken by the School of Engineering at Tufts University in 1994. The Center for Engineering Education Outreach was established and it created curricula and professional development programs for educators spanning all grade levels. The center also partnered with LEGO and created Robolab, the software that enabled the LEGO Mindstorm robotic kit to be used in classrooms.

While these breakthrough programs were very good, they only reached a small number of schools and students. There was clearly a need for a systemic change in order for the K-12 engineering movement to gain momentum. The opportunity was created in 1998, when the Board of Education in Massachusetts appointed a committee to re-write the Massachusetts curriculum framework and learning standards. I was appointed to the committee that would re-write the technology education component of the science standards. I worked with a team of K-12 educators, primarily K-12 Technology Education teachers and introduced the first engineering curriculum frameworks and standards in the United States. The senior staff in the Massachusetts Department of Education did not have much appreciation for Technology Education standards at the time and they saw the transformation of Technology Education standards to Technology/Engineering standards as a move in the right direction. The Technology Education teachers in the group also saw it as yet another evolution of their field and an opportunity for their professional position in the K-12 educator hierarchy to be upgraded and become more secure. On December 20, 2000 the Massachusetts Board of Education voted unanimously to adopt the new technology/engineering standards and to make them part of the state's assessment. Assessments at the elementary and middle school levels were revised so that science and technology/engineering comprised 20%. At the high school level, technology/engineering became one of the four end-of-course assessment options for graduation, the other three being biology, chemistry, and physics.

At the elementary level, the engineering standards focused on distinguishing between the natural and human made world, such as comparing tools with animal body parts, e.g., scissors vs. lobster claws and dog paws vs. rakes. Material properties and the basics of the engineering design process were also included. They are intended to be covered by the mainstream classroom teacher, who also covers all other core subjects. At the middle school level, the standards focus again on the engineering design process and also on five technology areas: construction, manufacturing, communication, transportation, and bio-related technologies.

The middle school curriculum is intended to be covered primarily by technology education teachers and science teachers, if technology education teachers are not on staff. At the high school level the standards include more advanced content, including topics such as fluid mechanics and heat transfer.

Although the vote of the board was unanimous, the new standards were not received enthusiastically by all members of the academic community. Many superintendents were against them because their districts did not have the necessary resources to implement them, and many technology education teachers were ambivalent because they saw the inclusion of engineering as a challenge to the traditional instruction. Fortunately, the commissioner of education was strongly behind the new standards and they survived. As a result, Massachusetts became the first state to have engineering standards and assess them at all levels.

Expanding to the National Level

Massachusetts' bold move attracted the attention of the National Science Foundation and it began to fund K-12 engineering education curriculum development and programs. The relevant activities in Massachusetts schools increased in scope and in number; however, no other state followed suit. It became clear that if the initiative were to spread nationally, it would need a focused champion organization. Such an organization could not be in competition with the partners needed to expand it to the national level. Universities tend to be very competitive and so they would not be an ideal home for the lead organization.

In 2004, a year after I joined the Museum of Science in Boston, it became home to the new National Center for Technological Literacy (NCTL). NCTL's mission is to introduce engineering in both schools and museums. Its philosophy is that in order to accomplish a fundamental change in attitude toward engineering, school curriculum must change, in conjunction with the attitudes and understanding of those responsible to implement the change. In order for any program to succeed with this philosophy, it must focus on three areas: advocacy, curriculum development, and professional development. NCTL chose to take on those areas in the following ways.

Advocacy and Support

Although learning standards are centrally controlled in the vast majority of countries around the world, in the United States, they are controlled at the state level. State standards are influenced by standards developed by national groups, such as the National Research Council and the International Technology Education Association. NCTL advocates for the inclusion of engineering in these national standards, in state standards nation wide and in all relevant federal legislation and assessments. It also provides support for states that decide to include engineering

standards in their curriculum frameworks such as standards and assessment tool development.

Curriculum Development

Because engineering in K-12 is a new concept, there is a lack of relevant curriculum at all levels. NCTL develops K-12 engineering curriculum at all educational levels where it has identified gaps in existing curricula.

Professional Development

NCTL provides professional development programs for in-service teachers and administrators. Using a "train the trainer" model, NCTL partners with states; so that the professional development capacity can meet the demands according to the level of need in each state. In addition, NCTL works with universities to assist them in curriculum and program development for pre-service teachers.

At the national level, significant progress has been made. The National Assessment for Educational Progress (NAEP) science assessment now includes standards in "technological design." It is unfortunate that it is not called what it is: "engineering design," but still there is progress. The K-12 grant program from the National Governors Association explicitly encourages applicants to include K-12 engineering in their proposals and plans. There is now explicit language in many bills about technology and engineering education. The majority of states now include engineering standards of one form or another, most of them still calling them technology standards. Thousands of schools throughout the country have adopted some form of engineering curriculum. The curriculum produced by NCTL alone is used by over 1,000,000 students in all 50 states.

Challenges

Changing curriculum on a national scale is not easy, particularly when it must be accomplished one state at a time. Over time, NCTL and other advocates have made significant progress. However, we continue to be faced with significant challenges.

Current K-12 curriculum is packed with traditional material, some of it necessary and some not. Turf issues inhibit serious revisiting of what, and to what extent, students need to learn. The turf issues extend beyond the local level. When learning standards development committees are formed at the state level, each member advocates for more standards in their specialty area. Engineering is the newcomer and threatens the each member's "piece of the pie." Similar turf issues occur when developing educational standards at the national level.

Fear is always a consideration when implementing change and the thought of teaching a new topic has proven to be intimidating to many teachers, especially at the elementary levels. Some educators are intimidated by science alone. If teachers have a background in a discipline, or have ready access to professional development

courses in that area, they have the ability to increase their knowledge, thus reducing their fear and minimizing their resistance. Unfortunately, colleges of education do not currently prepare prospective teachers for engineering and design. In addition, state-level certification programs do not require content knowledge in engineering for elementary teachers, so few teachers have even the slightest background in engineering education.

When properly presented, most educators react positively to the idea of introducing engineering in K-12 schools. Areas of STEM (science, technology, engineering, and mathematics) education are enjoying widespread support amongst school administrators, federal department of education officials, and National Research Council appointed committee members. However, when implementation and funding opportunities arise, all the attention is focused on the S and the M part of STEM. Many reports advocate for supporting math and science in schools in order to foster innovation in our economy. What they do not realize is that the connector between math, science, and innovation is engineering. The vast majority of school administrators misunderstand the term technology and they assume that technology means computers. Computers are just a small part of technology. Some school districts feel that they offer technology to their students simply because they teach them word processing and spreadsheet skills.

Education is a cyclical process. Students learn, and then some grow to be teachers and teach what they know. When a new discipline is introduced, in-service teachers must learn something new during their busy, professional lives. For this reason, there are few qualified to teach engineering at the middle and high school levels. The teachers that graduate from technology education programs are qualified to teach the technology components of the curriculum, but in many cases are under-prepared in mathematics and science, which provide the basis for engineering. Engineering schools have not stepped up in encouraging their graduates to pursue teaching careers, and certification requirements have made the process of switching from engineering to teaching cumbersome.

College admission requirements have also presented a challenge to the effort of early engineering education. It is ironic that most engineering colleges do not accept a high school engineering course as equivalent to science. They typically look more favorably at an applicant who has taken an advanced placement course in a science area that may have nothing to do with engineering, than a candidate who has taken an engineering course. This discourages students from taking engineering in high school and schools from offering it.

The final hurdle for the introduction of K-12 engineering exists due to the applied nature of the discipline. Engineering education requires new facilities and equipment. When school budgets are tight, administrators are hesitant, if not unable, to open new budget line items.

Moving Forward

In order to maintain the momentum, we should focus our attention on six key areas.

Standard Development and Assessment

The most significant step toward inclusion of engineering in the curriculum is to introduce engineering learning standards at the state and federal level, along with regular assessments of student performance. Technology education teachers, engineering professional societies, and industry members should be strong advocates for the creation of such standards and assessments.

Funding

As mentioned above, funding has focused on the science and mathematics part of STEM, but employment opportunities are predominantly in engineering and technology. For instance, the ratio of engineers to scientists on the NASA payroll is 12:1. NASA's mandate is to educate and motivate young people to enter professions relevant to NASA's mission, yet most of the education funds flow toward science. It is time to directly fund the engineering and technology portions, so they can come up to speed with, and help enforce the others. Funding initiatives that encompass engineering education are not likely to succeed without the aforementioned changes to the learning standards.

Teacher Preparation

Engineering must be inserted into the education cycle, so that teachers are prepared and excited about including the engineering discipline in their curriculum. In order to accomplish this, college programs must be modified. Technology Education teacher training should include more mathematics and science, as well as the engineering design process. Additionally, engineering schools should offer a new track-major that focuses on engineering education. Graduates of such programs would have a broad understanding of engineering, as well a good hands-on project building background. The curriculum should include teaching methods courses. A partnership between the college of engineering and the college of education, at the same or neighboring schools, would facilitate this. Graduates would be prepared to teach both science and technology/engineering courses. Certification requirements should be updated to better reflect the new engineering standards, and also make the career transition from engineer to teacher easier. Elementary school teacher preparation programs should include at least one course in design and understanding the human-made world.

Facilities

The lack of facilities can be overcome if state programs that fund school renovation and construction require schools to have facilities dedicated to technology and engineering. At the elementary school level the facilities may be "take apart"

tables with simple tools. Middle and high schools should have design and building facilities, including power tools for prototype development.

Textbooks

Science textbook publishers should include engineering content and activities in their new editions, connecting the traditional science to technology. Engineering is by nature “hands on.” This blends well with science textbooks that focus on inquiry. It is more challenging to integrate engineering in traditional science texts. However, more and more publishers now include engineering components. The technology education textbooks should also be modified to emphasize the engineering design process and to include contemporary technologies such as bio-related technologies and nano-technologies.

Changing the Culture

Informal education channels such as museums and science centers, as well as popular media should include more programs on engineering, technology, and relevant careers. Such changes would not only create a more technologically literate population, but would also inspire children to pursue relevant studies, and motivate parents to encourage their children as well.

Conclusion

Understanding how the human made world works, and how it is developed, is an essential component of contemporary basic literacy. Although the value of this understanding was largely ignored in K-12 schools until the mid-1990s, significant progress has been made. Engineering and technology standards are being included in many state curriculum frameworks. Federal legislation and national assessments now also include technology and engineering, and thousands of schools in all 50 states are using engineering curricula. This is a long road, but at the end we will have a nation of technologically literate citizens. This vision continues to fuel the momentum to ensure that K-12 Engineering will emerge as the essential new core discipline.

Acknowledgments I would like to thank John Hall, Beth Miaoulis, Yvonne Spicer, and Anderson for their useful input.

The Boston Globe

THURSDAY, JANUARY 11, 2007

Opinion

A boost for high-tech literacy

By Ioannis Miaoulis

DURING HIS campaign, Governor Deval Patrick sparked a grassroots effort showing that inspiration can drive change. Now he has the opportunity to mobilize citizens on critical issues. Technological literacy should be one of them.

Understanding what technology is, how it is created, and how it shapes and is shaped by society is not new. It is at the heart of the state's leadership in scientific research, biomedical innovation, and nanotechnology. Up until now, however, school curriculums have focused more on the natural, not the humanmade or technological world. Schools have taught little or no engineering — the connector that uses science and math to create the technologies that facilitate 95 percent of our daily experience.

Concerned about math and science test scores, leaders in government, business, and education worry that our preeminence in technological innovation is eroding. One key to preparing students for today's competitive global economy is introducing them to the engineering skills and concepts that engage them in applying their math and science knowledge to solve real problems and inspire innovation. This is a critical step in moving toward technological literacy.

While some may doubt the educational value of the MCAS, a new MCAS testing requirement will make technology/engineering as prominent as math or English language arts. Starting with the class of 2010, high school students must pass an MCAS test in science and technology/engineering

to graduate. Students in grades 9 and 10 are now eligible to take a test in biology, chemistry, introductory physics, or in technology/engineering in June 2007. While 2010 may seem far off, the current ninth-grade class is the class of 2010; ninth-graders enrolled in a science and technology/engineering course who want to take the June test must be offered one; 10th-graders

taking one of these courses must also take a corresponding test. Students will need to order these tests in January 2007.

Thirty-seven states offer technology/engineering, technology in science, or technol-

ogy education standards in their academic curriculums, but only Massachusetts has a whole test assessing technology/engineering in the same way it does biology, chemistry, and introductory physics. While the state has made strides in math and English MCAS testing, we must focus on the new science and technology/engineering requirement. Educators and school administrators need resources to prepare their students to meet the testing requirement. The time to act is now.

Massachusetts organizations should support technology/engineering education programs at schools, whether via a donation of equipment, funding, or expertise. At Tufts University's Center for Engineering Educational Outreach, graduate students are working with Boston College Lynch School of Education and University of Massachusetts-Boston faculty to integrate engineering into the Boston Public Schools Active Physics curriculum. Every university or college re-

ceiving state funding should sponsor at least one area high school and establish mentoring or after-school programs in technology/engineering education.

We can go beyond practical incentives such as increased tax credits for companies that commit to supporting a school or after-school program. Patrick could encourage industry to support partnerships strengthening technology/engineering programs such as the PowerUp! Project. Funded by the National Science Foundation, this professional development program involves 25 industry partners; six high schools; Bunker Hill, Quinsigamond, and Northern Essex Community Colleges; the Tech Prep Network; and the Museum of Science. PowerUp! offers programs for educators on renewable energy and integration of academic and engineering concepts.

At Peabody Veterans Memorial High School, for example, PowerUp! teachers designed a new science course on renewable engineering applications and involved students in building a hydrosolar panel. PowerUp! also collaborated with the Boston Society of Civil Engineers and the Institute of Electrical and Electronics Engineers to provide training for engineers interested in working with schools.

We need to signal students that technological literacy is important because it gives citizens tools to participate thoughtfully in a technological world, thus fostering civic engagement.

There will be many demands on the Patrick administration and many issues vying to be at the top of his list. Technological literacy must be one of them.

Ioannis Miaoulis is president and director of the Museum of Science.

MOON LANDING

A giant leap . . .

An adventure that spawned wide discoveries

By Ioannis N. Miaoulis

Some events are forever etched in our collective memory. Sept. 11, 2001. The assassination of President Kennedy. The fall of the Berlin Wall. Martin Luther King's "I Have a Dream" speech. The Beatles' debut on "The Ed Sullivan Show."

Americans know exactly where they were at those pivotal moments, whether tragic or joyful. Among such milestones was Apollo 11, the first NASA mission to land a human on the moon. On July 20, 1969, shortly before 11 p.m. EDT, when Neil Armstrong first stepped onto the dusty lunar surface, the United States reached a pinnacle of scientific exploration enabled by engineering ingenuity. We will mark the 40th anniversary of that historic event tomorrow.

We benefit every day from innovations developed by NASA engineers and astronauts. President Obama recently credited the Apollo program with technologies improving kidney dialysis and water purification, energy-saving building materials, and sensors to test for hazardous gases.

Other inventions derived from NASA research span computer programs that monitor air quality and provide Internet access, flat-screen televisions, trash compactors, weather-forecasting tools, shock-absorbing running shoes, medical devices from voice-controlled wheelchairs to laser angioplasty, and safety equipment including lightweight oxygen tanks used by firefighters.

But times have changed. Teachers no longer usher students into auditoriums to watch wide-eyed as the space shuttle takes flight. Today, many kids

dream of being pop stars when they grow up, not astronauts.

It is no secret that here in the United States, we are not doing enough to motivate the next generation of scientists and engineers or to engage the public in conversations about the impact of science and technology on society, the environment and daily lives.

Perhaps we need to take a look back in order to move forward.

The urge to invent and to push the limits is part of the American spirit. In the 1800s, pioneers looking for a better life drove west with their families and a few possessions in covered wagons.

In 1903, two brothers challenged gravity on the dunes at Kitty Hawk, N.C. — convinced that human beings could fly. Others have penetrated the far reaches of the universe with the Hubble Space Telescope. Just last month, a new robotic vehicle successfully reached the deepest part of the world's oceans to investigate some of the richest geological and biological systems on Earth. Now we are working to harness the wind and the sun to power our homes, developing new therapies to fight disease, and driving cars that rely on alternative energy sources. But there is more to be done.

I believe that molding the explorers and inventors of tomorrow hinges on engaging children today in science, technology and engineering — igniting and then fostering their natural curiosity about how things work.

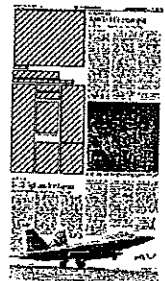
Happily, children practically emerge from the womb fascinated by engineering and the principles of functional design. However, to encourage those activities, parents, schoolteach-

ers and educators everywhere must embrace their inherent role as influencers.

I hope the 40th anniversary tomorrow of Apollo 11's historic mission will remind us all of the need to inspire our children to probe, to question, to challenge, to create.

Ioannis N. Miaoulis is president and director of the Museum of Science, Boston, a member of the NASA Advisory Council and also a former dean of Tufts University's engineering school.

President Obama recently credited the Apollo program with technologies improving kidney dialysis and water purification and sensors to test for hazardous gases.



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New Hampshire leads in science education, but can do more

ON JUNE 1, the New Hampshire Department of Education convened more than 125 education and business leaders from across the state for an important educational summit in Manchester — Engineering "Science Literacy" for the 21st Century. The goal was to discuss ways to work together to ensure that the state's high school students are prepared to be productive citizens of the 21st century.

Why is this important? Our children know how to operate iPods and digital cameras, yet have little understanding of how these technologies are created or that hay, faucets and cars are also technologies. Technology shapes almost every aspect of our lives, but our schools' curriculum includes little or no engineering — the process of using science and math to create technologies that fill human needs.

In May, the federal Department of Education reported that high school students' science test scores on the National Assessment of Educational Progress are falling. While 83 percent of New Hampshire's fourth graders scored at the basic level or better, to bring science to life we must update the curriculum — much of which is more than 100 years old — to include the human-made world. We need to introduce engineering as early as elementary school and continue it throughout high school, college and beyond.

Furthermore, our nation's dependence on foreign engineering skills and innovations poses significant economic, policy and security challenges. To graduate students who can succeed in a competitive global economy, we must give them the right tools. Engineering skills — identifying a problem, designing a solution, testing and improving the design — are among the most important of

ANOTHER VIEW

Ioannis Miaoulis

these tools. Fortunately, New Hampshire is to be commended for taking concrete steps to make its students' education relevant in our changing technological world.

This last year, with support from the National Center for Technological Literacy (NCTL) at the Museum of Science, Boston, New Hampshire revised its Framework for Science Literacy K-12 so that the standards include technological literacy and engineering design as a critical part of scientific literacy. Given the high level of achievement expected in technical education today, New Hampshire is also revising its Career and Technical Education Core Technical Competencies.

As one of the NCTL's first major outreach efforts and its closest state partner, the Gra-

nite State has become a model for educational reform in other states. Led by New Hampshire Commissioner of Education Lyonel Tracy, the state's efforts epitomize NCTL goals — to introduce engineering as a new discipline in schools nationwide and inspire the next generation of engineers, scientists and innovators.

This year, while New Hampshire teachers, district leaders and state officials have been revising the standards, other educators have been field-testing Engineering the Future, a high school course developed by the NCTL. This year, students at Woodsville, Peterborough and Laconia high schools have been working on hands-on engineering challenges. Projects include designing and building models of emergency lighting and wireless communication systems and adjustable-speed fans. Woodsville High School teacher Scott Edwards says his

11th and 12th graders like the course's hands-on activity. "Engineering also puts math, science and writing skills in a package with real-world applications," he says.

There are plans to revise and bring Engineering the Future to more schools in the state. In addition, teachers will field-test the new technology and engineering curricula with up to 500 students in the next school year to see how effective the new materials are. The NCTL also plans to map all the curricular resources it has collected and tied to the national Standards for Technological Literacy (ITEA 2000) to New Hampshire's new standards so that educators can learn to use and apply these resources.

For students to achieve both scientific and technological literacy, we must work together. There is a role for everyone. In addition to offering financial support, industry leaders can

invite students to intern at their companies and volunteer in schools to share what engineers do and why it matters. Educators can learn about the revised standards, online tools and library resources in professional development workshops while trying out new curricula in class. As parents, we all can challenge our government officials to provide adequate federal and state funding for this critical educational reform.

Together, we have an opportunity in New Hampshire to make a real difference — to show the rest of the country the importance of engineering and technology to our schools and to our understanding of the world. Let's build off this great momentum.

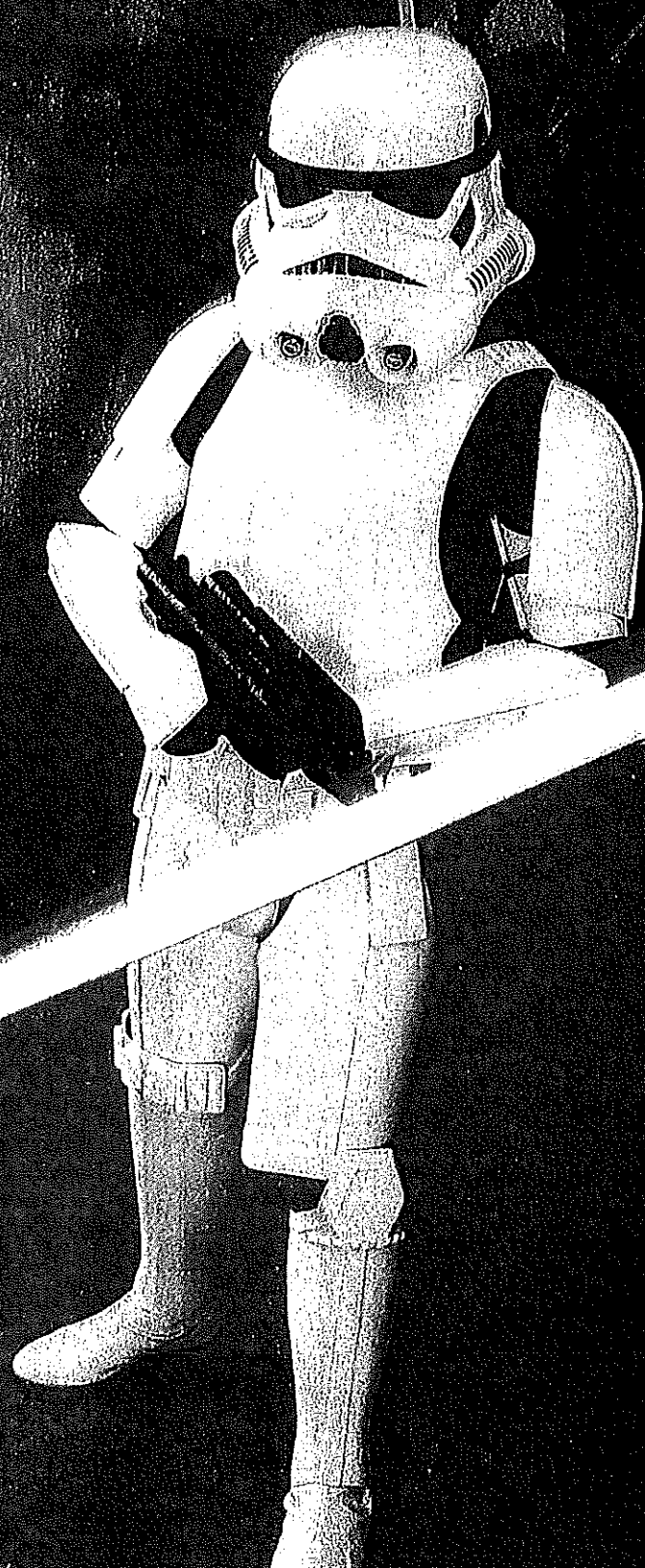
Ioannis Miaoulis is president and director of the Museum of Science, Boston.

Ioannis Miaoullis
brings a new vitality
to the museum with
a engaging Star
Wars exhibit.



A Powerful Force

SUPPORTING MATERIALS



By Alice Daniel

Photograph by Steve Marsel

Whether it's cozying up to stormtroopers or the state legislature, Boston Museum of Science's Ioannis Miaoulis will stop at nothing when it comes to introducing engineering to children in Massachusetts.

TALK ABOUT ELECTROMAGNETIC FORCE! Ioannis Miaoulis, president of the Boston Museum of Science (MOS), believes that engineering should be a part of everyone's education—and he means everyone. He's as enthusiastically wedded to this vision as some people are to Star Wars, a relevant analogy considering the museum recently opened an exhibit that uses the Star Wars culture as an entrée to understanding technology. The \$5-million exhibit, *Star Wars: Where Science Meets Imagination*, was co-produced by Star Wars creator George Lucas and includes props and costumes from all six films, including Luke Skywalker's gravity-defying "landspeeder," which, yes, teaches visitors about electromagnetic force. Rows of Star Wars androids are utilized to help explain advances in robotic technology.

This is just one of the many multidisciplinary approaches Miaoulis advocates to make America less technologically illiterate. Without widespread public engineering education, the United States will soon lose its international prominence to countries like China, Miaoulis says. "We are producing generations of people who don't understand how the things they use on a day-to-day basis actually work," he says. Nor are kids as readily able to visualize building, constructing and manipulating 3-D objects, a skill that is lost due to time spent in front of the computer or television.

Miaoulis first realized how little students were learning about the way the modern human world was designed when he visited public schools as the dean of the School of Engineering at Tufts University, a position he held from 1993 to 2003. "Kids spent about a month learning how volcanoes work and no time learning how cars work," he says. "How often do you find yourself in a volcano compared to a car?"

One reason for the lapse was a science curriculum based on standards set in 1883, a time when agriculture was the mainstay for most of the population, the life expectancy was 47 years and there were no televisions, no planes, no cars and no phones. That year, a committee at Harvard created statewide standards for science education that focused almost solely on the natural world, standards that were still being used at the turn of the next century.

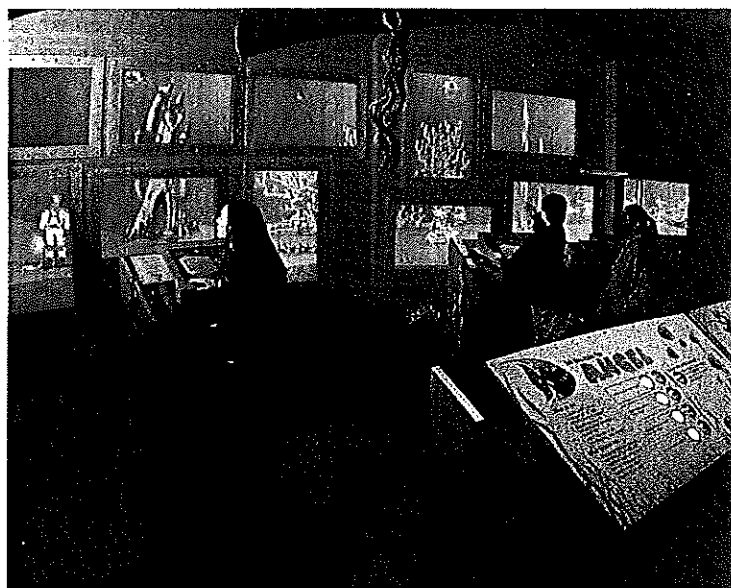
In an effort to tackle this problem, the Athens, Greece, native armed himself with statistics and headed straight for the state board of education. Miaoulis convinced them that engineering is a great way to make science and math more engaging to youngsters, and in 2001 he spearheaded the introduction of engineering into the Massachusetts K-12 science and technology curriculum, a move unprecedented in state education. Currently, all fifth and eighth graders in Massachusetts are being tested in engineering, and starting in 2008, an engineering test will be among four science options high school students must pass in order to graduate.

"Some people think you need to know all science and math to do engineering, but you can do it at different levels," Miaoulis says. "Engineering is a wonderful way to implement project-based instruction." Second graders, for instance, can design and build an outdoor habitat for a pet rabbit, an engineering problem that involves math for measurements, science for climate control, teamwork and participation. It's a notion that's readily demon-

strated at MOS where a new program called Design Challenges lets children solve basic engineering problems, such as building a proper habitat for a ferret with a variety of materials. The solution is then tested and the results are e-mailed to the kids.

The museum has always been active in trying to educate children about technology. More than 250,000 schoolchildren visit the museum each year, making up about one-sixth to one-eighth of its total annual attendance. The museum, Miaoulis realized, was the perfect platform to take his campaign beyond state lines. He left academic research in 2003 to become the president of the museum and to embark on an even more ambitious effort to introduce engineering into schools nationwide by 2014.

"He's an engineer at heart, and engineers like to solve problems," says Christine Cunningham, who worked with Miaoulis at Tufts and is now the vice president of research at MOS. "It's become the engineering problem he wants to solve in his life. He imagined different solutions and designed a system that's working." That system is the largest of its kind in the country, the National



FUN AT THE BOSTON MUSEUM OF SCIENCE: Up close at the butterfly garden; a demonstrati

Center for Technological Literacy. Headquartered at MOS, the center has 50 employees who develop and teach curricula, provide workshops for teachers, partner with universities and museums nationwide and establish hubs in different states to work with teachers and legislators on introducing engineering into public education.

A Little Engineering, A Little Eating

"Miaoulis is good at mixing disciplines to create significantly improved learning experiences," says MOS Chief Operating Officer Wayne Bouchard, who also worked with Miaoulis at Tufts and has seen him use his own hobbies to parlay engineering principles. In fact, when Miaoulis first became dean at Tufts, he was faced with an attrition challenge. Tufts was losing about a fifth of its engineering students to liberal arts after the first year. Students

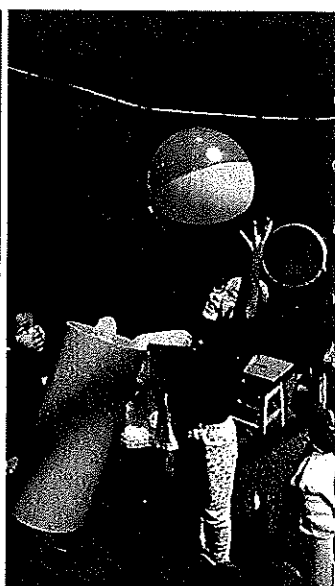
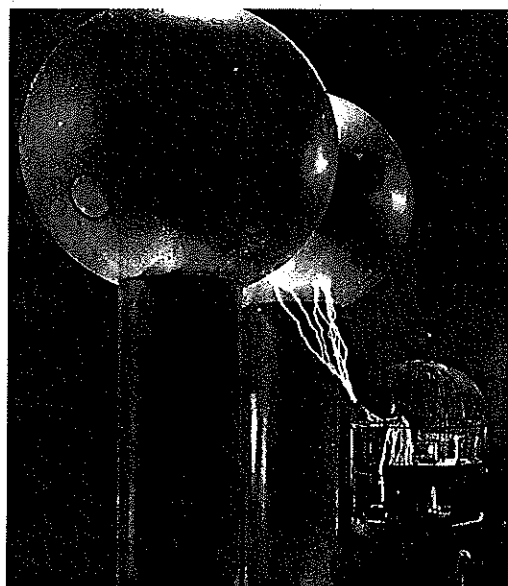
said they just didn't find engineering interesting, which was ironic considering the only courses they had taken were math and science. To address the lethargy, Miaoulis and his faculty created 60 playful introductory courses based on their own passions and interests, such as designing musical instruments and microbrewing.

Miaoulis, who grew up fishing, taught *Life in Moving Fluids*, a fluid mechanics course from a fish's point of view. He also taught a heat transfer course that took place in a kitchen lab. An epicure who checks out the Zagat guide online before any trip, Miaoulis always appreciated the end of each session, when students got to eat the experiment. "These courses made math and science relevant," he says. "We became the only engineering program where more students were transferring into engineering from liberal arts than the opposite." And many of these students were women. Under Miaoulis' tenure as dean, the number of female students increased by 26 percent and the number of women faculty members tripled. In a parallel development, Miaoulis also founded the Center for Engineering Educational Outreach at Tufts, which offers profes-

sional gain, later cooking it for his students.

It's this inherent enthusiasm that carries over to Miaoulis' public-education goals. When researchers at the Center for Technological Literacy did an initial engineering curricula search, they found very little was available for elementary students, even internationally. The best solution, Miaoulis concluded, was for the museum to create and publish in-house storybooks with engineering themes from different parts of the world. For instance, in one story, an engineer solves a drinking water problem in India by building a filtration system, a task that young students can do on a smaller scale in the classroom. The literacy center also publishes a book for high schools that satisfies all of the technology standards and 80 percent of the physics standards in Massachusetts schools. A quarter of the state's schools now use the book, which offers in-depth profiles of 32 engineers who have interesting jobs and includes laboratory work that's exciting to youngsters, such as designing a better running shoe.

Miaoulis' ambition to infuse engineering into public school



he the theater of electricity; playtime at the discovery center.

sional guidance for teachers to take engineering to the classroom.

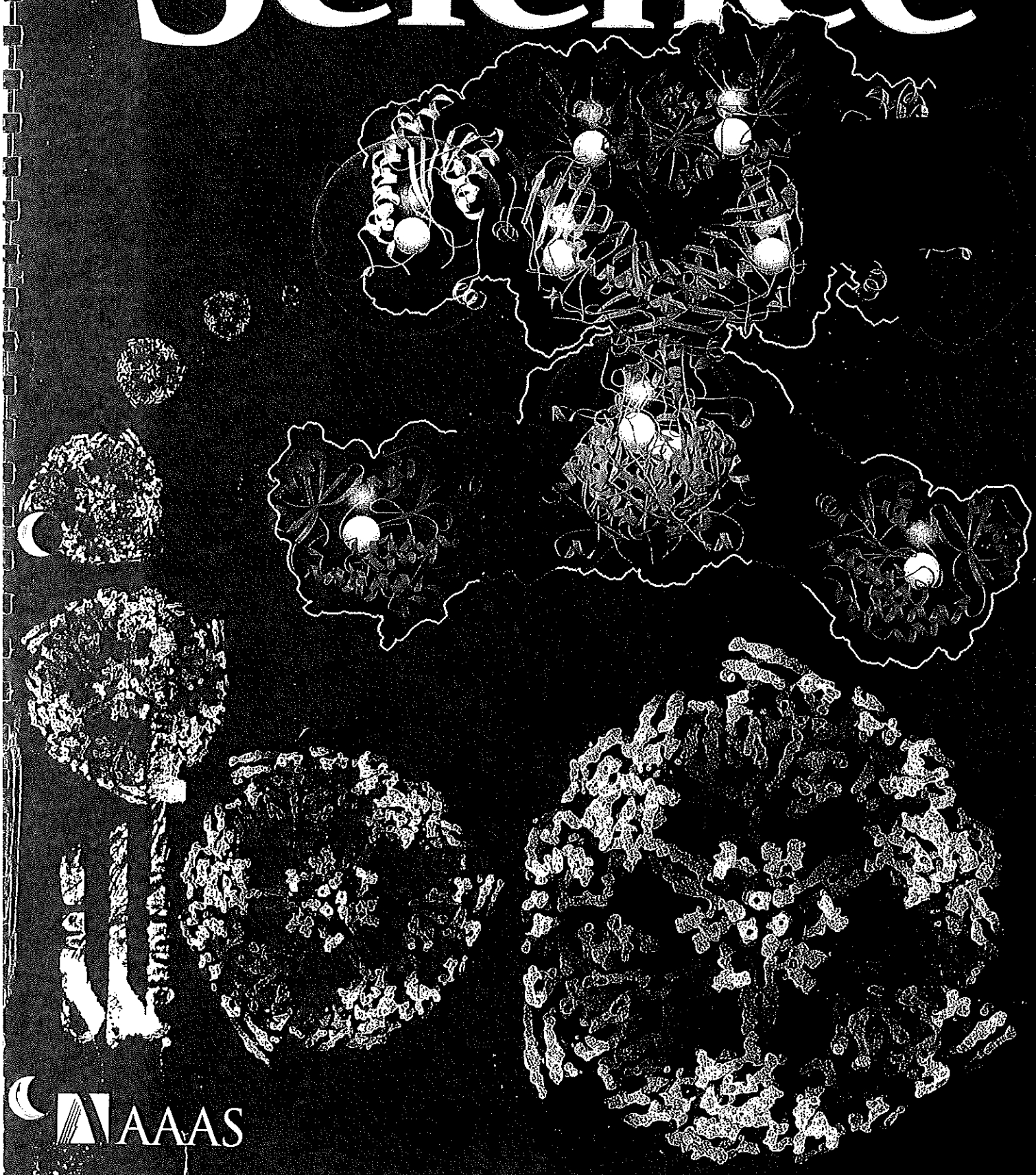
"Miaoulis had extremely high expectations of all of his students, but at the same time he was very collegial, always inviting us over for dinner, having parties," says Alexis Abramson, a Tufts graduate and mechanical engineering professor at Case Western Reserve. While Abramson always enjoyed the food, the high academic expectations hit home one cold New England fall day when Miaoulis required her to become scuba-certified. Abramson was managing the biomechanics lab at Tufts, and Miaoulis wanted her to help collect specimens off the Massachusetts shore. Miaoulis had a scientific license, and he and his team would go diving in the spring and early fall to collect lobsters, crabs, sea urchins and starfish. On one occasion, Abramson says, Miaoulis' passion for fine food and his enthusiasm for mixing disciplines took over and he would grab a bit of seafood for per-

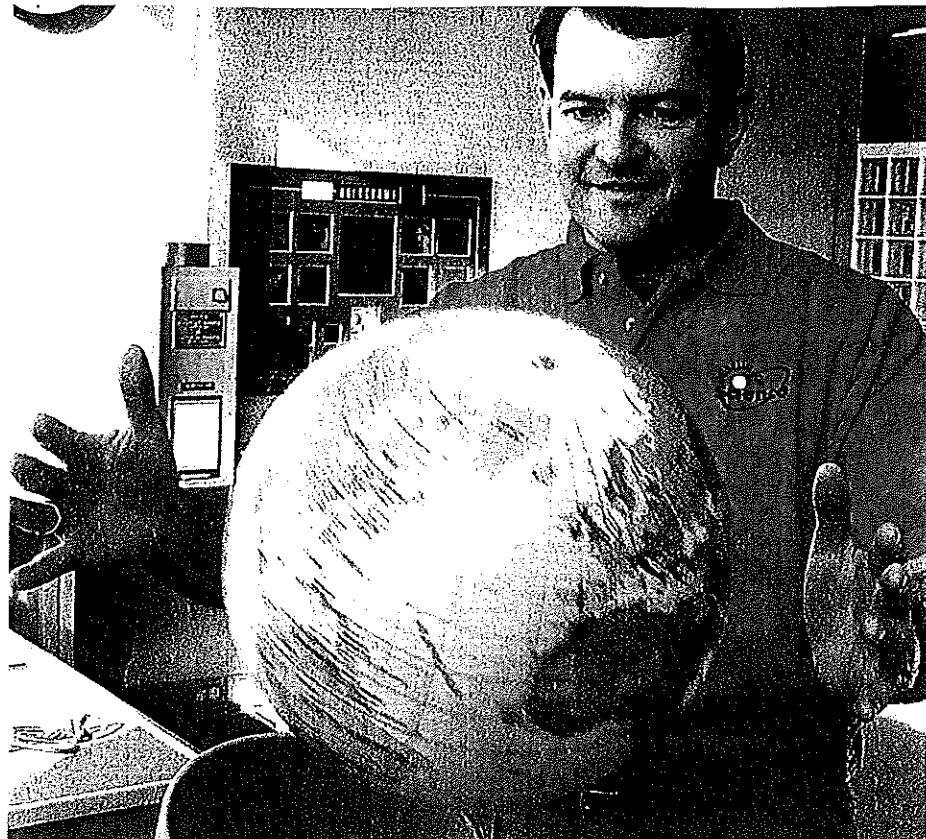
education is gaining momentum nationally. Several states in New England are considering significant curriculum changes as are Arkansas, Indiana, New Jersey and Pennsylvania. Ideally, Miaoulis says, he would like universities to offer an engineering pedagogy track for aspiring teachers. Meanwhile, he remains passionate about his initial goals. Half of his time is spent traveling the country, much like a politician or an old-fashioned revivalist preacher, selling his beliefs that engineering must be taken seriously in public education. "He gets stormed at the end of his presentations," Bouchard says. "People say, 'Can you come and talk to my faculty, to my politicians, they need to hear this.' He comes back with 50 business cards and sets up travel to new places. It's not just a vision, it's happening in real time."

Alice Daniel is a freelance writer based in Fresno, Calif.

Science

3 March 2006 | \$10





PROFILE: IOANNIS MIAOULIS

A Passion for Teaching Leads to Engineering Change in Schools

Most U.S. students aren't exposed to engineering until college. Massachusetts is different—and Ioannis Miaoulis is a big reason why

Eighteen years ago, Ioannis Miaoulis took a wrong turn on his way to Tufts University and ended up in the parking lot of a middle school outside Boston. Instead of asking for directions to the Medford campus, where he was an assistant professor of mechanical engineering, Miaoulis walked into the principal's office and offered to demonstrate the principles of superconductivity, a hot field that he was exploring. One week later, Miaoulis was showing eighth grade students how a magnet could float in the air above a superconductor.

That classroom session launched the Greek-born researcher on a parallel career in science education that has made him a passionate advocate for technological literacy. Disturbed by a curriculum that contained "so much about flowers and rocks and nothing about planes and power plants," Miaoulis started a statewide campaign to introduce engineering concepts into schools. In 2001, Massachusetts education officials made their state the first to include engineering in its curricular standards and student assessments. "Miaoulis was the one who made that happen, no question about it," says Massachusetts education commissioner

David Driscoll. "He sold engineering to us in a way that demystified it and made a compelling case for teaching it to kids from an early age."

Today, Miaoulis, 44, has expanded that campaign into a national effort. In 2003, he left academic life to become president of the Museum of Science in Boston. It houses his National Center for Technological Literacy (NCTL), a nonprofit organization with \$32 million from businesses and the federal government that has developed an elementary school curriculum and an engineering course for high school students. Last fall, schools in a dozen states began trying out the elementary school curriculum, and high schools in seven states are piloting the advanced course. "My dream is to have the humanmade world be a part of the curriculum of every school in the country within the next 9 years," says Miaoulis. "I say nine because last year I said 10."

A prized speaker at education summits around the country, Miaoulis promotes the cause of precollege engineering education like nobody else. His monomaniacal focus can even be a little annoying to others in the field. "He thinks he discovered the idea of teaching

◀ The new world. Ioannis Miaoulis says students need to understand engineering as well as science to succeed.

engineering to kids," says Kendall Starkweather, executive director of the International Technology Education Association (ITEA) in Reston, Virginia. ITEA was founded in 1939, and in 2000, it issued national standards for technological literacy. But Starkweather doffs his hat at Miaoulis's achievements. "The bottom line is that he has succeeded in getting one state to adopt engineering standards and helped to focus national attention on the E and T in STEM."

A passion for teaching

Miaoulis's own acquaintance with engineering started at home: His father was a civil engineer. After moving to the United States as a teenager, Miaoulis got both his bachelor's and doctoral degrees in engineering from Tufts and eventually joined its faculty. But he was disturbed by the public's ignorance about what engineers do, as well as its higher regard for scientists. "People who drive trains and repair VCRs are considered engineers," he says. Even the old building that houses the National Academy of Engineering "has a janitor's closet that says 'Engineering' on it," he notes.

At Tufts, Miaoulis's passion for teaching made him immensely popular and raised engineering's profile on campus. For example, to teach heat transfer, he became a cooking instructor, providing students with laminated recipes alongside energy-rate equations. His tasty lessons reduced the traditionally high attrition rates for first-year engineering students to the point at which the department began to attract majors from the liberal arts.

But Miaoulis wasn't content to confine his teaching talents to a college campus. Working with local public schools in the late 1980s made him realize that "98% of the curriculum is focused on the natural world, even though 98% of the things that most people interact with in their daily lives (apart from their own bodies) are humanmade." It seemed crazy to him that students "spend days learning how a volcano works but no time learning how a car works." Then he delivers the punch line: "How often do they find themselves in a volcano?"

When Miaoulis was appointed to a panel revising the state's science and technology standards in 1998, he saw the opportunity to do something about his pet peeves, but he knew he needed allies. So he reached out to the state's association of technology education teachers, many of whom had been losing jobs as schools closed down printing and automotive shops to fund computer labs. "Going to science teachers did not seem like a good idea because teachers that are well-fed and secure—why would they change anything?" he says. "I thought, if I partner with tech-ed teachers and make the



Brushing up on technology. Second graders at Barbieri Elementary School in Framingham, Massachusetts, learn about the technology behind everyday items such as a toothbrush.

case that adding engineering could upgrade their whole profession and save their jobs, I'd have the backing of that entire community."

It didn't go that smoothly. Many tech-ed teachers without engineering degrees worried that they'd be left behind. Others thought that science teachers would be asked to carry the load because of the strong math and science foundation needed. Indeed, state officials did try to throw technology out of the standards, arguing that shop skills such as metalworking and woodworking did not belong in higher level academic standards. Miaoulis convinced them that tech ed would become as academically relevant as physics when blended with engineering. "He showed a lot of political savvy during the process," says Driscoll. "He made a connection with people—from the governor to state education officials—and he was relentless in a nice way."

Technical difficulties

Since his successful advocacy for precollege engineering in Massachusetts 5 years ago, Miaoulis has delivered talks in more than 25 states and lobbied hundreds of politicians and school administrators. But no state has yet followed Massachusetts's lead. Even within the state, most middle and high schools have been hard-pressed to implement the new standards. One hurdle is the lack of clear guidelines in the standards and the absence of curricular materials for the middle school grades, which NCTL is currently developing. But a tight budget and a finite school year also pose serious problems, says James Surowski, head of the science

department at Forest Park Middle School in Springfield, Massachusetts.

"In the 185 days available during our school year, an eighth grade science teacher already has to cover the Earth's history, change in ecosystems over time, the Earth and the solar system; ... the list goes on," says Surowski. "Now the same teacher—we can't hire a specialty engineering teacher—must make time for technology topics as well. The

"He sold engineering ... in a way that demystified it and made a compelling case for teaching it to kids."

—David Driscoll

pond just got a lot wider and a lot shallower." Laura Bottomley, who leads the American Society for Engineering Education's K-12 project, notes that "we have trouble getting schools to teach science, let alone engineering."

Some Massachusetts teachers worry that many high school students may not have a sufficient foundation in mathematics and physics to benefit from the engineering course. "We're currently designing a model deck for which students need to calculate live loads and dead loads, which requires algebra," says Richard Skrocki of Shepherd Hill Regional High School, who is implementing the high school engineering course developed by NCTL. "I can

see that some of my students who are weak in math are having difficulty. But I don't have the time to teach them algebra before proceeding with the class."

At the same time, other educators say that NCTL's engineering course for high schools is not rigorous enough. "When they teach students music, they don't give them cardboard models of musical instruments. Why should engineering be any different?" asks Richard Blais, vice president of Project Lead the Way (PLTW) in Clifton Park, New York, which offers a demanding middle school and a pre-college engineering program.

Miaoulis, who calls PLTW's course the "Cadillac" program, admits that the NCTL curriculum, including the use of cardboard models in the deck-building assignment, is more basic than what many engineers would like to see. But he thinks it gives them a good sense of engineering design and problem solving. "Once this thing catches on," he says, "we can create more specialized courses that involve calculus and advanced physics."

In the meantime, Miaoulis tries to help teachers fit engineering into their existing curricula. After taking a 2-week summer course offered jointly by Tufts, the Museum of Science, and Worcester Polytechnic Institute, Debbie Warms asked her seventh graders at Charlton Middle School to create assistive devices for students with disabilities. "They had to use math skills such as measurement, ratios, and proportions, and solve equations with a variable and geometry," says Warms, who found the exercise time-consuming but worthwhile.

That blending of disciplines is exactly what engineering can bring to precollege education, says Miaoulis: "It can bring to life not just the math and science but also the social studies, the English skills." As an example, he points to NCTL's pilot elementary school curriculum that combines history, geography, and culture into an engineering lesson. In one book, Yi Min learns about the use of materials engineering in

building and preserving the Great Wall in her native China. Another lesson follows Aisha, a young Boston girl, as she explores a local potato chip factory with her father and learns about industrial engineering.

Miaoulis believes that approach will boost undergraduate engineering enrollment and increase diversity by making the subject more relevant to students' lives. And he's unapologetic about the program's potential impact on other subjects now being taught. "Okay, you might have to cut other things from the curriculum a little bit," he says. "But then, so be it. Look at what you add."

—YUDHIJIT BHATTACHARJEE

CREDIT: Y. BHATTACHARJEE/SCIENCE

Beyond the Bunsen burner

SCIENCE AND technology create new knowledge, cool products, and merciful medical treatments, but newly released MCAS scores suggest that a lot of public school students are missing out on the excitement: 26 percent of high school students failed last spring's tests in biology, chemistry, physics or technology/engineering. And only 9 percent scored at the "advanced" level.

Students will have to work harder to pass, because the science MCAS becomes part of the graduation requirement in 2010. But the state also has a responsibility: to turn its schools into hotbeds of science education.

"Students should do science as scientists do," Ioannis Miaoulis, the president of the Museum of Science, said in an interview. He argues that the K-12 science curriculum should be infused with engineering, so that students can grapple with real-world problems that will inspire their interest in the underlying science and math.

For example, Miaoulis once taught a class at Tufts University called Gourmet Engineering, which explored the science of cooking. It was a hands-on way to teach a course about heat transfer. It's an approach the museum is using in its Engineering is Elementary project, an effort to increase children's engineering and technology literacy by exploring topics such as how potato chips are made. Next month, the museum is set to open a new engineering exhibit.

Massachusetts should join the party, stepping up its efforts to develop an innovative science education by investing more resources. "We're reckoning with what 21st-century schools should look like," said Paul Reville, chairman of the state Board of Education.

One challenge is outdated science labs. As the Globe's James Vaznis recently reported, thousands of students are working in aging labs and teachers are scrambling to get access to limited lab space. That's poor form. In the iPod era, labs should be modern and compelling, ideally one of the coolest places in schools. A bill filed in the State House by Senator Edward Augustus, a Worcester Democrat, could help by requiring the state's School Building Authority to set standards for building science labs and classrooms in newly constructed middle and high schools.

Improving science and technology education also requires having more passionate teachers at every level: in preschool and elementary classrooms when children are wide open to knowledge, and in middle and high school when they're trying to figure out who they might be in the world. And teachers need more time, either longer school days or a longer school year, to teach both the facts and the practice of science.

This state's economy is fueled by scientific innovation. So it's essential to invest in the state's budding scientists and engineers.



Arkansas Democrat-Gazette/RUSSELL POWELL

Ioannis Miaoulis, president and director of the Museum of Science in Boston, speaks Monday during a meeting on high school reform. More than 600 policy-makers, administrators and high school principals attended.

Emphasize work skills, educators told

Advocates for improving schools list challenges at LR conference

BY CYNTHIA HOWELL
ARKANSAS DEMOCRAT-GAZETTE

The academic skills required for high school graduates entering the work force are as tough as those demanded of students headed for college — and many high schools aren't meeting the needs of either group, national advocates for improving high schools said Monday at a Little Rock conference.

"It's no longer the case that

those who are going into college need a different set of skills than those who are going to work, not if 'going to work' means getting a good job that pays a decent wage and provides upward mobility," Matthew Gandal, executive vice president of the Washington, D.C.-based Achieve Inc., told a crowd of superintendents and high school principals at the Statehouse Convention Center.

Gandal urged the educators

to take the news to heart.

"That's a revelation that many parents and the public don't understand, but it's real," he said. "The employers are telling us this. You have to help get that message out because it will have a big impact on what you do with your high schools."

Achieve is an organization created by governors and business leaders to help states

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Educators

• Continued from Page 1B
improve the quality of public education. To that end, the organization is coordinating the newly formed 14-state American Diploma Project Network, which includes Arkansas.

Gandal was one of several presenters at the one-day conference, "Next Step: Arkansas Summit on High School Reform," hosted by the Arkansas Department of Education.

"We're here today to lay the groundwork for reforming high schools," said Ken James, director of the Education Department.

He described some of the challenges the state's schools face. Those include frequent turnover of teachers, principals and students in some schools, which he said was a formula for student failure. He also cited the achievement gap between black students and white students on standardized tests and college-going rates.

On the state's End-of-Course Algebra I test, for example, 63 percent of black students scored at a proficient or better level compared with 63 percent of white test-takers.

The results were similar for geometry and 11th-grade practice tests, James said.

He cited other data showing that of every 100 Arkansas eighth-graders, 74 will graduate from high school, 42 percent will go to college, 27 percent will return for their sophomore year and 15 will graduate with a bachelor's degree within six years of first enrolling.

"We have to take the talk and put it into action," James said about the calls for changes in schools.

Monday's conference followed a national summit of state governors, including Arkansas Gov. Mike Huckabee, and education leaders last month in Washington on the topic of

high school reform.

And President Bush has proposed a \$1.5 billion high school initiative to help ensure that high school graduates are prepared to go directly into the work force or college.

Willard R. Daggett of Rexford, N.Y., president of the International Center for Leadership in Education Inc., told the Arkansas educators Monday that it is business and industry pushing for high school reform — not the schools themselves.

To be successful in making the reforms, Daggett said school and community leaders will "have to create more pressure for change than there is resistance."

He cited his organization's own study that showed the required reading levels for entry-level positions in many of the nation's blue-collar jobs are higher than those required for jobs in intermediate and higher levels within the same occupations.

That's because of the manuals that entry-level employees must read and understand before they can operate new types of machinery.

Daggett described the sophisticated electronic devices that are already on the market or are about to be. Those include watches and jewelry able to project e-mail, Internet sites, calendar planners and even a keyboard onto a wall or desk that could replace handheld electronic planners.

Other devices include home kits that can analyze a person's DNA and determine a predisposition to thousands of genetic illnesses.

He said most adults are "immigrants to the world of technology" and in some ways student attendance in a school is comparable to visiting a museum. Educators must be able to teach students the thinking and analyzing skills that go beyond the basics, he said.

Not all the news was grim

for Arkansas high schools.

Gandal told the crowd that Arkansas has the highest high school graduation requirement for math in the nation, with specified courses in Algebra I and II, geometry and one course beyond geometry being required for the class of students now in the seventh grade.

That is the result of the new Smart Core requirements that were put into place by the state Board of Education last year.

Gandal praised the state's unusual requirement that students take the rigorous courses unless their parents sign waivers for them.

A former dean of Tufts University School of Engineering and now president of the Museum of Science in Boston told the 600 Arkansas high school teachers, principals and superintendents that the state's science standards are among the strongest in the nation and the best in the south.

Ioannis Miaoulis, a native of Greece, said that all too often science instruction focuses on the natural world and that an understanding of the human-made world — technology — is lacking.

"Sixth-graders may spend a month learning about volcanoes but never learn how a car works," said Miaoulis, who is known for his development of courses that use cooking, fishing and construction of musical instruments to teach engineering and mathematical concepts.

Miaoulis urged educators to use more practical applications in teaching science and engineering as a way to interest all students — including women and students of racial and ethnic minority groups — in the fields.

The nation as a matter of national defense can't allow engineering and product design to become the purview of China and India, he said.

Olivine Roberts, associate superintendent for curriculum and instruction for the Little Rock School District, said she agreed that curriculum needs to be reviewed to ensure that the most important skills are given top priority.

"We also need to restructure how we do things," said Roberts, an audience member. "When Dr. Daggett talked about the possibility of pushing more electives into the ninth grade and utilizing them to help students transition from middle school to high school, I thought that was powerful. I don't think we have thought of doing that to help the students make that bridge."

Annicie Steadman, a biology teacher at Little Rock's Central High, praised Miaoulis' ideas about teaching hands-on physics and engineering lessons in all grades, including the elementary grades.

"By the time they get out of the eighth grade you will have a population who can look at the lights in this room and talk about light fixtures and how they are put in and how much it costs. It makes science relevant to their everyday lives," she said.

Gandal told the group that elementary and middle school education has been the focus of national and state reforms for many years, but now high schools must make changes.

"Standards, curriculum, accountability and testing have been on the table for years, mostly in the elementary and middle school level," he said.

"The spotlight is on high schools now. Foundations are looking at it. The federal government is probably going to put the meat on the bones of its high school proposal. We firmly believe the states should lead the cause, states like Arkansas. That's where the momentum really is. The mission of the high school is now different and so should our policies be different."

Editorial

ENGINEERING A CURRICULUM

THE MUSEUM OF SCIENCE has gone beyond its traditional mission of science instruction and entertainment in Boston to engage young people throughout the United States in the value of engineering. It's an ambitious agenda, aided greatly by a \$20 million gift from Bernard Gordon, an entrepreneur and engineer who wants to get more young people interested in using science to solve real-world problems.

The education initiative is the brainchild of museum president Ioannis Miaoulis, previously the dean of engineering at Tufts University. Miaoulis is convinced that young people must be taught the basics of applied science as well as biology, chemistry, and physics. The question is whether the nation's fragmented education system will accept his approach.

Miaoulis has an ally in the Massachusetts Board of Education, which decided in 2000 that engineering questions should be included on the

fifth- and eighth-grade science Massachusetts Comprehensive Assessment System tests. The tests are just being rolled out, and it is too soon to say that students have mastered the material. But the state has become the first in the nation to put all its local districts on notice that engineering needs to be taught.

Through the National Center for Technological Literacy at the museum, Miaoulis is determined to devise the courses and train the teachers necessary to make engineering an essential and lively part of the national science curriculum.

The center has already drawn up programs for elementary and high school students and is working on a middle school version. One of the elementary school lessons features a potato chip factory. High school students learn how an athletic shoe is engineered. Science becomes connected to everyday experience through the medium of engineering.

School systems are pressed for

time and money to squeeze all required instruction into the short school year. As Gordon and Miaoulis realize, science is not being taught well now in many classrooms, and new approaches are needed to make it compelling.

The Gordon gift will allow the museum to create new exhibits, build a permanent headquarters for the center, and establish an endowment to guarantee its long-term success. Gordon also donated \$20 million to Northeastern University for its engineering programs. That's an important gift, but without solid K-12 instruction, college engineering programs will have trouble attracting qualified students, at least from this country.

As shown by its modern facilities and exciting exhibits at Science Park above the Charles, the Museum of Science has come far from its origins as a collection of artifacts. Miaoulis' engineering initiative is turning a Boston treasure into an asset for the nation.

Engineering for ALL

*Strategies for helping all
students succeed in the
design process*

By Pamela S. Lottero-Perdue, Sarah Lovellidge, and Erin Bowling

As calls for science, technology, engineering, and mathematics (STEM) education at the elementary level become more vociferous, elementary teachers may be wondering whether engineering is meant for all students. They may question whether engineering is appropriate for their inclusive classrooms, where children with special needs are included in regular instruction.

We—an assistant professor of science education, an enrichment teacher, and a third-grade teacher—assert that engineering can be taught in inclusive environments. It may be especially empowering for those who struggle with traditional subjects. Here we describe how the core

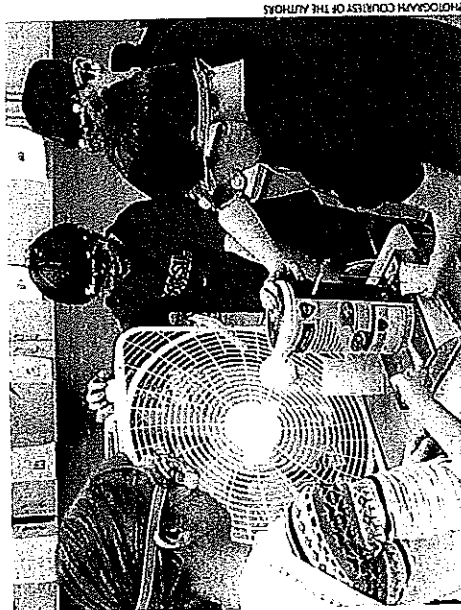
practice of engineering, the engineering design process, was taught in a third-grade inclusive classroom in which students used this process to design windmill blades. In this class, 7 of the 20 children received assistance from a reading specialist, and one child had an Individual Education Plan. However, the multiple strategies we feature can help all students succeed in engineering design.

Engineering Design Process

Engineers use the engineering design process to solve problems (e.g., how to transform wind into useable energy). The nomenclature used to describe the steps of the process varies across engineering education programs. However, the steps take a form similar to those in Figure 1 as articulated by Engineering is Elementary (EIE), a national program that has created elementary-level engineering units that link to national science education standards (see Internet Resource). Although Figure 1 suggests only one improved design, engineers improve their designs many times. Students can repeat the Improve step as time allows.

Windmill Blade Design

The EIE unit *Catching the Wind: Designing Windmills* was situated within a science unit in which students learned about position, force, motion, and energy. This introductory unit uses inquiry-based science instruction to help students understand these basic physics concepts prior to engagement in the engineering design process. For the culminating lesson in the unit, the students designed windmill blades. The blades are tested on a windmill apparatus placed in front of a fan. Ideally, the wind from



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the fan causes the blades to turn the windmill's axle, which winds a string on the other end of the axle, lifting a cup (like a bucket-type well). The cup is initially empty; pennies or washers can be added to create a greater lifting challenge. Teachers should operate the fan to ensure that

students do not put fingers in or get long hair too close to the fan. Students and teachers must wear safety goggles or safety glasses, have long hair tied back to prevent entanglement in the fan blades, and wear only closed-toe shoes or sneakers during windmill operation. OSHA regulations and best practice require fan blades to be protected with a guard having openings no larger than 1/4 in. (1.27 cm). The teacher should review safety precautions and proper equipment use technique with students prior to starting the activity.

Ask

Students were introduced to the concept of constructing a windmill when the teacher read aloud the EIE storybook *"Leaf Catches the Wind"* (see Internet Resources). In this story, two children, guided by the advice of a mechanical engineer, designed a windmill that turned a paddle to aerate a pond. The teachers noted that the students would design a similar windmill, yet theirs would lift a cup instead of turning a paddle.

To begin the Ask step, the teachers showed the students the windmill apparatus and asked how well-designed blades could make it work. Here and throughout the engineering design process, they encouraged students to use words like *spinning*, *force*, and *kinetic energy* to describe the windmill's operation and reinforce science learning.

The teachers reminded the students of a sailboat activity the students had completed. In this activity, children designed simple sails affixed to craft stick masts made from a range of simple materials including felt, paper, plastic bags, and coffee stirrers. The masts attached to sailboat hulls on a low-friction slide and were placed in front of a fan. The sailboat's motion was analyzed for its speed and consistency of motion, then children improved sails based on testing results. The engineering design process was at work here only implicitly; the careful work of moving through each step of the process was saved for the windmill design.

The teachers elicited what the students learned from the sail activity: that certain materials worked better than others, and that large, well-supported sails were effective at catching the wind. They also shared with the students that windmill blades could be designed using the same materials as were used for sail design.

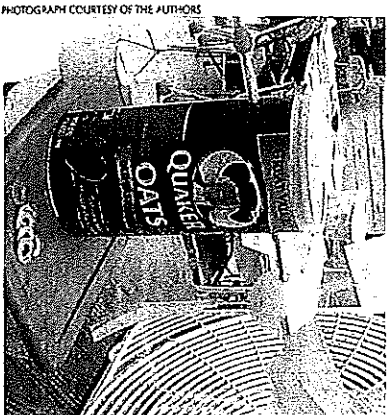
The classroom teacher led a whole-class discussion to complete a worksheet summarizing key aspects of this Ask step: the purpose of the windmill, testing procedures, and what was learned about effective sails. Worksheet questions projected on an interactive white board enabled her to guide struggling writers as she carefully recorded and projected essential Ask-step information for all to document. Students wrote, for example, that the purpose of the windmill was "to catch the wind and lift weight."

Imagine

Students worked in pairs during the Imagine and subsequent steps. During the Imagine step, students brain-

Figure 1
EIE engineering design process steps and descriptions.

Engineering Design Process Step (EIE)	Description of Step
Ask	Identify the problem. Determine design constraints (e.g., limitations on materials that can be used). Consider relevant prior knowledge (e.g., science concepts).
Imagine	Brainstorm design ideas. Draw and label those ideas.
Plan	Pick one idea. Draw and label the idea. Identify needed materials or conditions.
Create	Carry out the plan: create the design. Test the design.
Improve	Reflect on testing results. Plan for, create, and test a new (improved) design.



PHOTOGRAPH COURTESY OF THE AUTHORS

Up-close view of windmill with four blades.

sterned what different windmill blades might look like that could solve the problem. The focus of this step was on blade shape. An imagine step worksheet provided four blank boxes in which students drew up to four windmill blade ideas. No scoring rubric was used, but teachers circulated the room to ensure that each pair of students drew at least two ideas and that each idea was drawn with clarity. Students drew a range of blade shapes, including squares, triangles, and rectangles, all affixed to skinnny upright rectangular bases representing craft stick base supports.

Plan

During the Plan step, students selected one of their brainstormed ideas, sketched it, determined how many blades to include in their design, and listed needed materials. The teachers asked students about students' plans and why those plans might help solve the engineering problem. They inquired about students' choices in blade shape and material (Were these choices consistent with what was learned from the sails activity?). The number of blades students chose to put on the windmill (Why 3, 4, or 10?). and, blade angle, whether students chose to angle some or all of the blades (What made you decide to put this windmill blade at this angle?). The minimal writing demands of this task (the materials list) were primarily supported by the pairing strategy used, in addition to monitoring and assistance from the teachers. When pairing students, a somewhat stronger reader/writer was matched with one who needed a bit more help. This provided peer support for those with reading and writing difficulties. Children who had difficulty listing the materials they planned to use were

able to copy from their partner's list after agreeing on necessary materials.

Create

The students eagerly and swiftly created their blades. To prevent shoddy construction, at least eight minutes had to be spent building.

Two pairs of busy engineers seated at one table were Beth and Caitlin (girls) and Trevor and William (boys). One of these children has significant language challenges. Although we refer to these as the "girls" and "boys" we do not intend to generalize their experiences to all girls or boys.

Beth and Caitlin brought their first design to the apparatus. When the wind blew, nothing happened but a quiver of the four large card stock blades set on craft sticks, rattling in place but not spinning the windmill axle. The girls had learned from the sails activity that the blades needed to be large and stiff. However, the blades were not angled. Blade angle was not important in the sails activity, yet it was important for windmill blade design. Students were to discover this essential design feature themselves or with guidance from teachers.

William and Trevor's first design spun the axle and lifted the empty cup. Adding washers to the cup, however, brought the windmill to a halt. Most of their eight windmill blades made of cardstock were angled, yet some faced opposite one another, negating their potentially helpful angled positions. Unable to come to consensus about blade size and shape, the boys compromised: four of the blades were small and triangular (William's idea), and four were somewhat larger, elongated trapezoids (Trevor's idea).

Many of the students at work building at their desks would routinely pause to watch another pair's test. Once all students had tested their first designs, the teachers led a whole-class discussion so that students could share and reflect on their findings with one another.

Improve

The improve step began immediately after each pair tested their first design, as the teacher asked each pair to reflect on testing results and continued with more reflection during the class discussion. The students returned to put work, this time to focus on design improvement. The enrichment teacher circulated, posing questions about how students could improve their designs. She referenced the concept of "form fits function," from an earlier biology unit to suggest that students consider how the features of their designs (e.g., blade shape, size, and material) should be purposeful.

With Caitlin and Beth, who seemed stuck regarding how to proceed, the teacher shared images of real windmills and wind turbines, noting the angle of the blades. She demonstrated how to place one of the blades at an angle

by picking up a blade and angling it, and left the girls to modify the other blades.

The enrichment teacher met with the boys and inquired about their first design, yet the boys were satisfied with their blades and the compromise they had made. The teacher shared the windmill and wind turbine images with the boys, focusing on the blade-to-blade consistency of angle, and used her hands to show the boys how some of their blades opposed one another or were not angled.

After documenting the testing results and improvements they made, both groups were ready to test their improved design. The boys returned and were able to lift 30 washers in the cup, a marked improvement beyond their first design, which lifted only the empty cup. The girls, whose first design did not lift the cup at all, had looks of surprise and joy on their faces as their improved design lifted 50 washers. We suspect that the girls were not only excited by their design success, but felt a rare moment of achievement above others in the classroom.

Assessing the Design Process

During each step of the design process, the teachers formatively assessed students' progress by examining their participation, worksheets, and blade construction and testing. By the end of the design process, all student pairs were successful in lifting at least 20 washers, and many pairs lifted as many as 50.

Summative assessments included the success of students' improved designs and student achievement on a postunit Elicited-developed test. It asked questions such as, "Shara is making a windmill, but cannot make it spin. She made the blades bigger, but it still did not spin. Which of the following things could she do to improve her windmill?" (Check all that apply.) Students should correctly identify that Shara could add more blades, change the angle of the blades, or change the materials the blades are made of. Students should leave unchecked "Put holes in the blades to let air through."

Students performed significantly better on the postunit questions that assessed student understanding of wind energy, windmill operation, and engineering than for identical questions on the preunit test. The postunit average was 6.7 of 9 answers correct (standard deviation = 1.3); the preunit average was 4.8 (standard deviation = 1.6).

Helping All Students Succeed

Caitlin, Beth, Trevor, William, and their classmates all met varying degrees of success during the engineering design process. They enthusiastically participated in and documented the steps of the engineering design process. They created a first design using at least some aspects of prior knowledge from the sail activity. All of the pairs

were then able to improve their designs, with some having more well-reasoned improvements and ideas than others. Online, we have listed teaching strategies introduced in the vignette that encourage success for all students in engineering design, especially those who have special needs (see NSTA Connections).

Although we want well-reasoned designs, we also want students to try their own ideas. If students are attached to design ideas that fail to incorporate relevant concepts, allow them to test their designs. Testing results will help make the case to students that the most successful designs employ good reasoning.

We end with two warnings: (1) brace yourself for the excitement that students have as they engage in the engineering design process; and (2) be prepared for all students to succeed and for some who normally struggle to shine. ■

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Internet Resource

Engineering is Elementary (EIE)
www.mae.org/eie

NSTA Connection

Download a list of teaching strategies at www.nsta.org/SC1003.

Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Content Standards:

Grades K–4

Standard B: Physical Science

• Motions and forces

Standard E: Science and Technology

• Abilities of technological design

• Understanding about science and technology

National Research Council (NRC), 1996. *National science education standards*. Washington, DC: National Academies Press.

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Engineering challenge

Museum of Science president
Ioannis Miaoulis wants to make technology
as exciting as *Tyrannosaurus rex*

Ioannis Miaoulis swears he has nothing against dinosaurs or grasshoppers. That's a good thing, since he presides over Boston's Museum of Science, which attracts more than 1.6 million visitors each year, many of them interested in all manner of creatures, both living and extinct. There is still plenty at the museum to satisfy such tastes, but Miaoulis is looking to put the natural world in its place.

He says science museums have been out of balance, with so much attention given to the natural world that we lose sight of the man-made phenomena that dominate our everyday lives. He's out to inject more of that side into the museum's offerings: A Star Wars-themed exhibit two years ago explained robotics, and the recent "CSI" exhibit explored the technology behind crime-scene sleuthing.

That shift in the exhibit halls is hardly surprising, considering that Miaoulis arrived at the museum in 2003 after 10 years as dean of the engineering school at Tufts University. The bigger challenge he is taking on is to get engineering and technology studies into US schools, which he says have also focused too much of their science curriculum on subjects that are disconnected from the world immediately around us. "Folks spend a month teaching how volcanoes work and they don't teach at all in most schools how a car works," he says. "How often do the kids find themselves in a volcano?"

Miaoulis, who came to Massachusetts from Greece in 1980 to attend Tufts, is credited with pushing the state in 2001 to become the first in the country to incorporate engineering and technology education into its K-12 curriculum frameworks. Starting with the

class of 2010, Massachusetts students must pass one of four science MCAS exams, with technology and engineering one of the test options. The museum is playing a leading role nationally in science education through its National Center for Technological Literacy, launched in 2004 with \$32 million in grants to develop technology-related exhibits for science museums and to develop engineering curriculum materials for schools.

Miaoulis calls engineering "the connector" that ties math and science to real-world challenges around us, as he works to increase technological literacy, and, through it, to ensure a steady pipeline of future engineers. At stake, he says, is nothing less than the country's standing as a leader in technological innovation. I spoke with Miaoulis in his museum office overlooking the Charles River. What follows is an edited transcript of our discussion.

—MICHAEL JONAS

CW: You've sounded the alarm about the gaping hole in our science and technology education in this country. How bad is it?

MIAOULIS: Well, I started working in the whole K-12 outreach area in 1987. I came to the realization that we're focusing the entire science curriculum on the natural world, although we live in a world where 98 percent, or close to that, of the things we interact with on a daily basis are human-made.

There's a lot of discussion both at the federal level and the state level about huge resources that we have invested in the area of math and science without any results. Well, the point all these reports miss, I think, is

that the connector of math, science, and innovation is engineering. You use math and science, fundamental concepts, and also use your imagination and your creativity skills through engineering to create innovation. And that piece is missing from the curriculum.

CW: At Tufts you became alarmed that it wasn't enough to be working with people who'd come into the engineering pipeline, but that the problem was upstream from there, you might say, and that's how you turned to this focus to the K-12 system.

MIAOULIS: Our goal, in introducing engineering to [K-12] schools, was to focus on getting states to change their learning standards. And after quite a bit of effort, we managed to have Massachusetts change its learning standards. Massachusetts was the first state in the country to not only include engineering in its learning standards but also testing. I was still at Tufts, and I thought, now we're going to conquer the world. If one state does it, then everybody's going to do it. But we needed partners. So as I was frustrated trying to figure out how to get there, the museum called and asked if I was interested in becoming a candidate for the presidency. I quickly realized that this could be an amazing platform to take this initiative to the national level. We went from having one state considering engineering before I started at the museum to now working with 39 states throughout the country. Now we have hundreds of partners, universities, other science centers, and engineering collaboratives throughout the country.

CW: Right. Yet at least as of very recently, Massachusetts was still alone in having science testing as part of its K-12 statewide frameworks.

MIAOULIS: Well, No Childhood Left Behind may change that, because as science becomes one of the requirements, other states will start pouring resources into it. It's unfortunate, but it's a fact: Resources go to specific subjects where testing occurs.

CW: You also started the National Center for Technological Literacy, which has been further boosted by a \$20 million gift from the Gordon Foundation. So it's not enough just to spread the idea of engineering education. We really kind of are starting from square one in terms of curriculum, textbooks, and so forth.

MIAOULIS: The National Center focuses on three areas. We advocate for including engineering as a new discipline into the curricula. I travel and speak to key influential groups—to see the National Governors Association or to see the educational leadership of a particular state or at

the national level in meetings in DC. The second area is curriculum. We searched internationally, identified and purchased all the engineering curriculum we could find from K-12, and we have it here in our library. We hired a group of experts that analyzed the curriculum and correlated it with the engineering standards of Massachusetts and national technology standards. And our findings are on the Web, and it's free access for anyone to go and see. At the elementary school level, we've created a series of books featuring children from different parts of the world, describing a challenge or an opportunity and how an engineer solved the problem. The little girl from India talks about the problem in her town, which was quality of drinking water and how an environmental engineer built a filtration system. And children can then engage in activity to build an actual filtration system. We use engineering activities to support the math curriculum at the middle school level, and at the high school level we developed stories about real engineers along with content that satisfies 100 percent of the engineering standards. The third thing we do is professional development—anything from straight teacher workshops to train-the-trainer workshops, since we have partners throughout the country.

CW: For all the traction you've had in Massachusetts, the results of the recent MCAS science exam were regarded as pretty disappointing. More than a quarter of the students failed, and in urban districts it was often more than half. We have our work cut out for us, I guess.

MIAOULIS: I don't see it as a problem now. Most of the emphasis has been put into math and reading, and now that science is tested, we also realize that there is a problem with science. So I'm sure that because of that, there will be resources and excitement now toward science and technology. I'm hoping that these results will generate a mini-Sputnik for Massachusetts, something that will alert people to pay attention. But my message is to pay attention to math and science, but also to what [kind of] science and maybe change it a bit to be more relevant and connect what kids learn with innovation.

CW: In that vein, you seem to talk almost dismissively at times about the traditional focus of museums and schools on dinosaurs and volcanoes and so forth.

MIAOULIS: Well, I love grasshoppers and brontosaurus-es. I think it's wonderful for a museum to present the nat-

ural world, but I also don't think it's right to ignore the majority of the world around us, which is the human-made world. So when I speak, I usually focus on the new stuff, not the stuff that it's expected that the Museum of Science is going to have. We should have a strong natural-science presence. But if you want to move even to the center, you have to push a lot harder in one direction.

CW: Have you encountered resistance to that change in focus, either here at the museum from its supporters or in the science museum community nationally?

MIAOULIS: Of course, of course. Change is very hard. And believe it or not, the biggest opponents when I started this effort in the mid '90s were the science teachers. The biggest argument was, "We don't have time to teach what we teach now." I said, well, look at what you're teaching and how relevant is it to kids' lives. Folks spend a month teaching how volcanoes work, and they don't teach at all in most schools how a car works. How often do the kids find themselves in a volcano compared to a car?

CW: In terms of the museum's focus, you recently had the "Body Worlds" exhibit that was hugely popular, featuring

preserved cadavers people could see in close-up detail. Last year, you had the Star Wars-themed exhibit.

MIAOULIS: I loved the Star Wars exhibit, because it really showcased our new direction at the museum, taking a popular venue like Star Wars that would attract the audience, and then creating interactive engineering activities like robotics. So people would come and would engage in learning, sort of, without really figuring out they were learning.

CW: It's like you slipped spinach into cookies.

MIAOULIS: I think things here taste better than spinach, but it's a much more engaging way to educate than the dry way that people are used to.

CW: Is there a danger of going so far toward appealing to popular culture icons that you really lose the conveying of important information or learning?

MIAOULIS: There is danger if you don't pay attention. Our first priority is education. But educating in a fun way. We just have to make sure the fun doesn't overtake the learning, because then we're not a museum of science, we're an

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MASSACHUSETTS TECHNOLOGY COLLABORATIVE

From left to right:
18EW Local 103's wind turbine in Boston
Solar photovoltaics on house in Marshfield
Hydropower plant in Pepperell
Green middle school in Melrose
Solar photovoltaics at WGBH in Brighton
Residential wind turbine in Oak Bluffs
Background photo: 660-kilowatt wind turbine at Massachusetts Maritime Academy

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amusement park, and that we're not going to be.

CW: You have a missionary passion about your work. You're traveling extensively. What is at stake for the US if we don't get this right or if we don't see the urgency of this issue around engineering and technology education?

MIAOULIS: What has worried me over the last two years is that I have seen even more interest from foreign countries in this new engineering initiative than what I have seen from within the United States. In many cases it has been easier to work with countries like Malaysia than to work with Massachusetts school districts. If we don't create excitement in the area of technology, things are going to fall apart. Some things we can outsource, which we're already doing, but there are some things that you cannot outsource, like national defense. Other things you cannot outsource: basic services, your water supply, your electricity, you cannot outsource that. And other more subtle things, like innovation. The reason I came to this country is because it's a very innovative place, and a lot of new things come out of here. In many ways, the United States defines the innovation of tomorrow. Most things are [still] designed here. Some of them are built in India and then brought back here, but the design and the innovation has happened in the United States. But that's sliding, because there are a lot of brilliant people in India that can design. The other problem we have is that about 70 percent of engineers in the United States have a relative who's an engineer. So it's almost a prerequisite that you have a relative [who is an engineer] to become an engineer. That's something we're trying to change by exposing all kids to these topics.

CW: You often talk about the fact that not only in the developing world, but even in Europe, engineers are regarded differently.

MIAOULIS: Oh, yes. I came from Greece. In most countries in Europe, engineers are on the top of the respect list. Our educational system here came primarily from England, and if you look at the values in the traditional English educational system, typically the less practical the stuff you do, the more respected you are. You have the theoretical physicists on top and then experimental physics, so for some reason thinking and doing abstract things is valued more than doing things that run our lives, and that is a unique sort of Anglo-American value system that does not exist in other countries.

CW: So we sort of need a cultural revolution of a certain kind?

MIAOULIS: Yes. That's why I'm on the road all the time. **CW**

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