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Written Statement of
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submitted to the
Research and Science Education Subcommittee
Committee on Science and Technology
U.S House of Representatives
hearing regarding
Informal STEM Education

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On behalf of the Museum of Science, Boston and our National Center for Technological Literacy, I applaud Chairman Lipinski and the members of the Subcommittee for holding this hearing on the importance of informal science, technology, engineering and mathematics (STEM) education and the opportunity to contribute to it.

ENGINEERING CHANGE: Achieving STEM Literacy and Innovation

With an economy in crisis and a workforce at risk, educating the nation's future scientists and engineers and advancing technological literacy are more important than ever. And, while there are no easy "fixes," informal education centers can help ensure that future Americans are prepared to make the informed decisions life in a complex technological world requires and to create the products and services that will enable our economy to thrive.

Informal Environments Play a Vital Role in Public and K-12 STEM Education.

According to the January 2009 National Research Council (NRC) report, *Learning Science in Informal Environments: Places, People, and Pursuits*, "tens of millions of Americans, young and old, choose to learn about science in informal ways - by visiting museums and aquariums, attending after-school programs, pursuing personal hobbies, and watching TV documentaries, for example." The report also notes that informal learning experiences can significantly improve outcomes for individuals from groups historically underrepresented in science.

Science centers and museums in particular can spark life-long interest in and understanding of science, engineering, mathematics, and technology. Non-threatening, friendly environments where adults and children can explore without fear of being wrong, museums have resources that many schools do not and offer informal, often interactive, activities that complement the school curriculum. By helping the public investigate the natural world and why and how the human-made world works, science museums help equip young people to live and work in the 21st century, while also increasing the public's ability to make educated decisions. Many of the complex issues that shape our lives require an understanding of basic science, technology, engineering, and math.

The **Museum of Science, Boston** is one of the world's largest science centers an New England's most attended cultural institution. We work to bring science, technology, engineering, and mathematics alive for about 1.5 million visitors a year through our interactive exhibits and programs, serving 100,000 more in traveling and overnight programs. Our landmark, long-range exhibits plan "Science Is an Activity" encourages visitors to practice scientific thinking skills. "Science Is an Activity" has been awarded many National Science Foundation grants and influenced exhibit development at other science centers. The Museum of Science also partners with school districts to bring the excitement of the Museum to the classroom, while providing support and resources for teachers through field trip workshops, pre- and post-visit activities, teacher professional development, outreach, and linking resources to state and national learning standards.

For example, the Museum's **Eye Opener Program** has served 80,000 children from disadvantaged city neighborhoods in the last 40 years. Supported by the Germeshausen Family Foundation and others, 2,500 to 3,000 second graders a year from 45 to 60 Boston public schools explore science and engineering for free and share their experiences with dedicated Museum volunteers. An Eye Opener visit is not just a field trip, but an all-in-one learning experience that begins the week before with a visit by Museum staff. When the children pour out of the buses, they are primed to marvel at a live alligator, climb on a seesaw to learn balance, and more. Meanwhile, as the youngsters tour the Museum, their teachers learn how to use the Museum's resources in their classrooms. The Eye Opener program is also a career and academic learning opportunity for urban high school youth. Duci Goncalves, 28, reported that when she was an Eye Opener teen volunteer, the Museum "opened my eyes and expanded my world. Now, I feel I can do anything." A 2002 graduate of Boston University with a Northeastern University law degree, she works as an attorney with the Youth Advocacy Project in Roxbury.

Each year, the Museum hosts 20,000 youngsters in grades 1-6 and their adult chaperones in a unique **overnight field trip** for a very different kind of learning experience. Since 1985, years before the popular movie, "Night at the Museum," the Museum of Science has hosted about 435,000 overnighters who can sleep beneath a life-sized model of *Tyrannosaurus Rex,* after engaging in hands-on activities focusing on science, technology, engineering and math.

Museums can also be **a valuable community resource**. In addition to on-site visitors, the Museum of Science serves others through outreach programs, K-12 engineering curricula, partnerships, traveling exhibits, and Web-based media. Since 1995, the Museum has welcomed underrepresented cultural, ethnic, and disabled communities via partnerships with over 3,500 organizations in Greater Boston and surrounding areas. In the last 10 years, over 207,000 underrepresented visitors have enjoyed free and/or discounted admission to the Museum and/or participated in Museum or neighborhood-based community events.

When, with the support of the Hearst Endowment, the Museum of Science **traveling program** was able to bring free presentations featuring live animals to 400 public school fifth graders in Holyoke, Massachusetts to spark their interest in biology, Dr. Helen Gibson, Holyoke's K-8 science academic coordinator, said, "A lot of our children are from homes where poverty is an issue. Having high-quality, hands-on programs from the Museum's inspiring educators, is wonderful."

Each year, in over 100 learning environments across the globe, modeled on the Museum's flagship **Computer Clubhouse,** 25,000 underserved youths worldwide are changing their lives through the creative use of technology and support of adult mentors via the Intel Computer Clubhouse Network. Its "Girls Day" program builds confidence and life skills of girls, using technology to create projects related to their interests.

Connecting Math and Science to Innovation via Technology and Engineering in Formal and Informal Education Settings.

We greatly appreciate that K-12 Science, Technology, Engineering and Mathematics (STEM) education in the United States has received significant attention, in response to international competition, national security, and the need for a well-informed citizenry, however, we are concerned that K-12 technology and engineering education has been largely overlooked. We hope for different results, while following an age-old model of instruction.

Much of our science curricula was established in the nineteenth century, when our society was largely agrarian, and focused on the natural world. There were no cell phones, automobiles, video games, nuclear power plants or space stations. Obviously, our world has dramatically changed but most curricula have not, leaving a huge gap in learning. Teachers and students learn little of the human-made world (i.e. technologies) or of the process in which technologies are created – engineering. While most people spend 95 percent of their time interacting with the technologies of the engineered world, few know that these products, systems and services are created via the engineering design process. Despite the exponential growth and influence of technology in our lives, much of our core curricula remain largely unchanged and only address the human-made world in elective courses or vocational programs. Only in rare instances is engineering discussed or taught.

We need to add technology and engineering as standard content in U.S. public schools and modernize our teaching to reflect our technological world – our widely diverse and technologically rich world. We are not simply referring to computers in the classroom. We advocate and educate for a broader understanding and appreciation of the wide array of technologies, that we often take for granted, like clean water and air technologies, simple and complex transportation technologies, energy technologies, production and distribution technologies, waste disposal technologies, and other engineered solutions that respond to our human needs and sustain our planet.

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

Engaging students in engineering skills -- identifying a problem, designing a solution, testing, and improving the design -- can offer a platform for applied and integrated learning in math, science, English language arts, and history and social studies. Allowing for failure and hands-on activities, engineering can also open doors for different kinds of learners.

Introducing engineering in K-12 learning opens career opportunities for children of all backgrounds. More than 70% of U.S.-born engineers are influenced by a relative to become an engineer. Children from ethnic groups underrepresented in technology and engineering most often do not have the relatives or counselors to guide them to pursue these fields. As minority groups become majority groups, we may see a parallel decrease in U.S.-born engineers. To maintain our country's vitality and security and diversify our workforce, we must expand teacher and student understanding of technology and engineering.

We need to make the "technology" and "engineering" in STEM education as important as the "science" and "math" in all policy-making, funding, K-12 standards and curricula, teacher professional development and certification, and student programs and assessments.

Understanding the importance of scientific and technological literacy and the need for trained scientists and engineers, the Museum of Science launched **the National Center for Technological Literacy® (NCTL®)** in 2004 to enhance knowledge of engineering and technology for people of all ages and to inspire the next generation of engineers and scientists. Through the NCTL, the Museum is working to integrate engineering as a new discipline in schools nationwide via standards revisions, assessment items, research and standards-based K-12 curricula development, pre-service and in-service teacher professional development, and new technology and engineering museum exhibits and programs. The Museum strives to introduce engineering and technology to schools and at least one science center or informal education organization in every state by 2015. The Museum of Science is the only science museum in the country with a comprehensive strategy and infrastructure to foster technological literacy in both science museums and schools nationwide.

An early initiative of the NCTL was to examine and enhance K-12 engineering curricula. The Museum's online *Technology and Engineering Curriculum Review* includes instructional materials in a searchable database (www.mos.org/TEC). The Museum offers educators and students nationwide 2,600 science, technology, math, and engineering curriculum resources and links the Museum's exhibits and programs to state and national standards.

The NCTL is now helping states modify their educational standards and assessments to include engineering, developing standards- and research- based K-12 engineering curricula, and offering educators support and professional development. Involving students in engineering, before stereotyping about math and science discourages them, the our curricula projects are geared to both genders and people of all colors, backgrounds, and cultures. Our **Engineering is Elementary (EiE)** curriculum, for example, integrates engineering and technology with science, language arts, social studies, and mathematics via storybooks and hands-on design activities for 1st - 5th graders. Each unit includes an illustrated storybook with a child from a different country and culture who uses the engineering design process to solve a community-based problem. The curriculum has reached over 13,300 teachers and 935,800 students in 50 states and Washington, DC.

This program incorporates research, evaluation, and assessment into its design. On more than 75 percent of questions, students performed significantly better on the post-assessment than on the pre-assessment. In most cases, EiE students performed significantly better than the control. This was true for both genders and all racial/ethnic groups. Students demonstrated, among other things: a better understanding that engineering involves design and teamwork; a better understanding of the engineering design process; and, an increased likelihood of understanding science content related to the unit. Teachers reported gains in their knowledge and understanding of the range of engineering disciplines, what engineers do, and the pervasiveness of engineering.

Engineering is Elementary also shows promising preliminary results in narrowing the achievement gap in a national controlled study of thousands of students who participated in an EiE unit and related science instruction, and who participated as the control group in 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.

The Museum of Science's **informal education** efforts involve prototyping museum exhibits and programs that will inspire people to become technologically literate by exploring: 1) what technology is; 2) how it is created and used; and 3) how to make informed decisions about its development, use, and impact. Among the Museum's educational approaches are: 1) a "showcase" presenting new technologies and the latest research, 2) a "creativity workshop" for hands-on problem-solving with technology and invention, and 3) a "forum" focusing on developing critical thinking skills about science and technology issues. The goal is to help the public understand the innovation process—the skills of designing, building, and using technology—and the impact of science and technology. Since 2003, for example, Museum of Science educators have engaged 76,000 young visitors (47% boys) and (53% girls) in Design Challenges involving the engineering design cycle and intended to appeal to girls and boys.

Well-Managed Partnerships Create Opportunities.

Science centers, particularly those with a focus on technology and innovation, are well positioned to form **partnerships with the private sector.** It's critical to manage them well. Perhaps most important is setting expectations up front and ensuring that the plan of action will meet both organizations' goals. These partnerships can provide science centers with financial, intellectual, and marketing support. Financial support is the traditional model; firms view this support as part of their marketing, community relations or long-term workforce development, and/or philanthropy. Intellectual support ranges from employee participation in museum programs as presenters, advisors, and conveners of other potential partners to lending or donating artifacts, images, and video.

In addressing STEM advances, the Museum of Science often features the work and knowledge of the world-class science and technology companies, laboratories, hospitals, and universities that surround it. In addition in 1984, the Museum of Science created the **Science Museum Exhibit Collaborative** to develop and share exhibits with other museums across the country. In one case, the Museum collaborated with Lucasfilm Ltd. to create *Star Wars: Where Science Meets Imagination*, a national touring exhibit which has promoted technological literacy since 2005.

For the Museum of Science, intellectual partnerships are critical to supporting a program that reflects current research and advances. Firms offer marketing support, too, as advisors, through co-promotion and communication with employees about the Museum's events. Partnerships can revolve around specific programs or the Museum as a whole. Firms value partnerships. Associating with a science center provide benefits for their employees from free Museum admission and a sense of pride to opportunities for volunteerism, and helping development of well-informed consumers or voters and a science-and-technology-literate workforce. The Museum of Science has developed corporate partnering guidelines to address important issues like content integrity, ethics, and conflict of interest.

The ***Beyond the X-Ray*** **exhibit** involved extensive intellectual collaboration between Philips Medical Systems and the Museum, featuring their name and images and engaging their people in Museum activities, including compelling presentations of live 3-D cardiac ultrasound. In this challenging economy, sponsorship from companies also helps reach communities unable to afford a visit as with the Museum's partnering in 2009 with the MathWorks to bring programs on physics, chemistry, astronomy, and animal sciences into the Natick, Massachusetts, public schools.

The Cambridge, Massachusetts, biotechnology company Genzyme has donated hundreds of Museum passes enabling non-profits and schools to visit. A 2006 $2 million gift to the Museum to create the **Genzyme Biotechnology Education Initiative** supports programs to educate the public about the rapid discoveries in biotechnology and how these advances affect their lives. The programs will include interactive exhibits and educational forums, teacher professional development, presentations for school groups, lectures, Web-based resources, and K-12 science and technology curricula. Genzyme also supports the Museum's model teacher sabbatical program enabling educators to step out of their classrooms and become students at the Museum for five days.

For **partnerships between informal science educators and formal education** institutions, common mission, aligned approaches, funding, and synergistic strengths are key. Successful partnerships have a shared sense of accountability, preferably with written agreements, to deliver on projects and programs. Examples include:

- The Museum's **Building Mathematics** curriculum development projects*,* created with Tufts University, provides innovative practices for integrating engineering with math to help middle school students develop algebraic thinking.

- To address the national shortage of technology educators, **Closing the Technology & Engineering Teaching Gap,** a new K-12 initiative, is integrating NCTL materials into the fully accredited online technology education programs of Valley City State University (VCSU), North Dakota. The goal is to improve the technological literacy of K-12 teachers and prepare qualified teachers. The NCTL will make its curriculum materials and training available to VCSU via this innovative online teacher certification program.

- The Museum is also working with three Massachusetts community colleges to help educate future elementary teachers via its three-year **Advancing Technological Literacy and Skills** project (ATLAS). It involves the community colleges in developing their understanding of technology and engineering content and teaching tools. Faculty engage in engineering design challenges, connect technology and engineering concepts with science, mathematics, literacy, and other subjects, learn about technical career options, and modify courses to include technology and engineering. The project will also include outreach to four-year colleges and high schools working with the community colleges to ensure continuity and create a cadre of faculty to introduce this model to colleagues across the state.

- The Museum launched its first school textbook publishing partnership in 2007 with Key Curriculum Press. The standards-based **Engineering the Future® (EtF) curriculum** engages high school students in hands-on design and building challenges reflecting real engineering problems and encourages them to explore what engineering and technology are and how they influence our society. Preliminary studies show that students increase their understanding in all four *Engineering the Future* units. The textbook is narrated by practicing engineers – female and male – from various ethnic and cultural backgrounds.

Research on Informal Learning is Invaluable

Since 2004, the Museum of Science, Boston has conducted over 50 research, evaluation and literature review studies on informal science education, addressing how the Museum engages the public in STEM learning. The Museum has focused on these four areas:

1) Museum-led teacher professional development: The Museum is exploring ways to enhance the capacity of teachers to engage their students in STEM learning. Early evaluation findings suggest that, in addition to increased knowledge, teachers participating in the programs report feeling “renewed enthusiasm” and “rejuvenation” for teaching and learning about science. This suggests that the ability for informal science learning to enable learners to “experience excitement, interest, and motivation to learn about phenomena in the natural and physical world” may extend not only to children but also to the adults who play a critical role in educating their children. Future research could explore the longitudinal impacts of such programs for teacher interest and motivation for teaching and learning about science, as well as the impact on increased teacher retention.

2) Universal design for museum learning: Recent Museum of Science studies have found that people with physical, sensory, and learning disabilities can engage in and learn from museum experiences that include multisensory interactions and multimodal interpretations. Some studies also found that people with disabilities report feeling positively about themselves as learners when they can fully participate in and learn from the experience on their own, and report intense negative feelings when a design presents a barrier to learning. Further research could examine the relationship between independent learning and people with disabilities' identities as science learners.

3) Adult forums: The Museum of Science has studied the implementation of over 50 events across the country that engage adults in discussing the relationship between science, technology, and society. The Museum has found that adults: attend Forum discussions based on their interest in the topic; highly value the opportunity to engage in these discussions; learn about science and technology content and about the relationship between science, technology and society through these programs. These studies also demonstrate that program participants continue learning about the topic afterwards. Examination of the potential causal relationship between program participation and continued learning is a potential area for further research.

4) Engineering design challenges: Early studies by the Museum demonstrated that most children complete most steps in the engineering design process when engaged in existing activities, but that children need more help during certain phases of the design cycle than others. Recent research efforts have focused on how exhibit designs and adult involvement can increase children's engagement in the engineering design process by providing supports and scaffolds that structure the child's engagement and increase learning through multiple iterations.

Challenges of metrics: The Museum uses many tools cited in the recent NRC report: self-reported learning through surveys and interviews, conversational analysis of videotape data, and observations. The Museum triangulates findings across instruments to reduce reliance on any one instrument. When possible, the Museum uses existing validated instruments to collect data. The availability of validated instruments is limited, however, especially in the above described areas.

Museums' self-directed, open-ended learning experiences which vary from participant-to-participant are hard to measure, using standardized tests that measure specific constructs, even for our self-contained programs, such as teacher professional development and adult forums. In these programs, adults direct their own learning process, a practice participants report as one of the most valued aspects of these programs. This makes it difficult, however, to study these programs as controlled "treatments." A formalized test would also detract from the self-directed nature of the programs. This is why the Museum relies on self-reported learning to measure learning in adult programs, triangulated with additional instruments such as journals or videotaped conversations.

Another challenge of conducting research and evaluation studies in museums is developing instruments that capture the learning of its diverse visitors, especially in research on universal design. The tools need to be flexible and allow for differences in how individuals receive and convey information. It is important to make sure that regardless of the delivery and collection method, similar constructs or ideas can be elicited from the users.

Major Challenges and Opportunities in Informal Science Learning

Exhibit development: For nearly all science-technology centers, the principal challenges are financial. Drawing support from corporate and individual donors, governmental agencies, and visitors who pay admission, science centers are in jeopardy when the economy is down. With the rising costs of utilities and basic functions, science centers turn to cutting educational programs and deferring maintenance of their facilities in order to stay open. They also turn to program activities that may have a record or expectation of drawing large numbers of visitors, even if those activities do not offer the high level of educational impact to which the NRC report aspires. Science museums can create exhibits that draw large numbers of visitors and address important learning goals, but not without the financial resources. The Museum of Science was fortunate to win an award from the National Science Foundation (NSF) for *Star Wars: Where Science Meets Imagination*, an exhibit that drew over a million and a half visitors in its first eight U.S. venues, with learning experiences focused on engineering design. Future opportunities exist and funding to support imaginative educational exhibit development would be beneficial.

Relevance: Science museums have been so successful at engaging family audiences in science learning experiences that they are under-developed in meeting other community needs, in particular those of adults faced with decisions about how to use science and technology in their lives. That's one reason the Museum launched its National Center for Technological Literacy.

The 5th World Congress of Science Centers recently challenged science museums to pull people together "to create a better future for all through global engagement with issues of local, national, and global relevance." The Museum of Science has also been fortunate to have an NSF grant to establish the **Nanoscale Informal Science Education Network (www.NISENet.org).** The Network is building partnerships between university research centers and science museums to raise public awareness, understanding, and engagement with nanoscale science, engineering, and technology. This is an area of significant current research with future impact upon jobs and STEM careers, as well as possible societal benefits and risks. Over 100 science museums are working with university researchers to address the needs of youth and adults. Funding to support similar network-wide approaches to other topics would further raise the capacity of the public to engage with the larger enterprises of science and engineering that relate directly to their lives. Funding for activities that support public engagement and foster dialogue between experts and lay people also represent an opportunity to bridge important socio-scientific issues.

Two final challenges: First the challenge of inclusion -- broadening the reach of informal science education to under-represented audiences, ethnic and racial minorities, people with disabilities, and those in rural communities. Existing programs could be strengthened and disseminated more broadly. The second challenge is professional development. Informal science education is a complex field with only a few opportunities for directly relevant formal education and so in-service professional development is essential.

Recommendations

Key federal agencies such as the Department of Education, National Science Foundation, and NASA can make the "technology" and "engineering" in STEM education as important as the "science" and "math" in all policy-making, funding, K-12 standards and curricula, teacher professional development and certification, and student programs and assessments. NASA is uniquely positioned to champion the technology and engineering components of STEM, inspiring children to pursue careers in these areas. NASA can focus more of its grant activity on the technology and engineering curriculum, teacher professional development, and support the development of informal science education programs, such as museum exhibits and television programs. NASA can again become the main driver for STEM education as it was after Sputnik.

As you pursue education and innovation policies and legislation, please also consider the following:

- Remember science museums are excellent providers of teacher professional development and make sure they can participate in such programs;
- Expand and rename the Math/Science Partnerships to STEM Partnerships to include technology and engineering educators in teacher professional development opportunities;
- Support after-school programs that include technology and engineering activities as well as math and science activities.
- Encourage states to adopt technology and engineering standards and assessments;
- Encourage states to include technology and engineering in the definition of “rigorous curricula” for high school graduation; and
- Expand the No Child Left Behind (NCLB) definition and requirement for “technology literacy” to go beyond the use of computers to include the engineering design process.

Thank you for your efforts to highlight the role of informal science education in STEM learning. For more information on our museum programs and services, visit www.mos.org and the work of the NCTL, visit www.nctl.org. If we can provide any additional information, please let me know.