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ENGINEERING IN K–12 EDUCATION

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

OCTOBER 22, 2009

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Dr. Thomas W. Peterson, Assistant Director, Engineering Directorate, National Science Foundation (NSF) 77

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ENGINEERING IN K–12 EDUCATION

THURSDAY, OCTOBER 22, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:07 a.m., in Room 2325 of the Rayburn House Office Building, Hon. Daniel Lipinski [Chairman of the Subcommittee] presiding.

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BART GORDON, TENNESSEE
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COMMITTEE ON SCIENCE AND TECHNOLOGY
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Hearing on

Engineering in K-12 Education

Thursday, October 22, 2009
10:00 a.m. – 12:00 p.m.
2325 Rayburn House Office Building

Witness List

Dr. Linda Katehi
Chair, Committee on K-12 Engineering Education,
National Academy of Engineering, and
Chancellor, University of California, Davis

Dr. Thomas Peterson
Assistant Director for Engineering,,
National Science Foundation (NSF)

Dr. Ioannis Miaoulis
President and Director, Museum of Science, Boston, and
Founding Director, National Center for Technological Literacy

Dr. Darryll Pines
Dean and Nariman Farvardin Professor of Engineering,
A. James Clark School of Engineering,
University of Maryland, College Park

Mr. Rick Sandlin
Principal, Martha and Josh Morriss Mathematics and Engineering
Elementary School, Texarkana, Texas

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U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
HEARING CHARTER

Engineering in K–12 Education

THURSDAY, OCTOBER 22, 2009
10:00 A.M.—12:00 P.M.
2325 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

The purpose of this hearing is to examine the potential benefits of, challenges to, and current models for incorporating engineering education at the K–12 level.

2. Witnesses

- **Dr. Linda Katehi,** Chair, National Academy of Engineering Committee on K–12 Engineering Education, and Chancellor, University of California, Davis
- **Dr. Thomas Peterson,** Assistant Director for Engineering, National Science Foundation (NSF)
- **Dr. Ioannis Miaoulis,** President and Director, Museum of Science, Boston and Founder, National Center for Technological Literacy
- **Dr. Darryll Pines,** Dean and Nariman Farvardin Professor of Engineering, A. James Clark School of Engineering, University of Maryland, College Park
- **Mr. Rick Sandlin,** Principal, Martha and Josh Morriss Mathematics and Engineering Elementary School, Texarkana, Texas

3. Overarching Questions

- How can engineering concepts be incorporated at the K–12 level? What are the potential benefits of pre-college engineering education? Can engineering be added to the classroom without sacrificing core competencies in math and science? What are reasonable learning outcomes for engineering education at the elementary school level? What about middle and high school?
- What are the current models and initiatives for teaching engineering at the K–12 level? What kind of curricula have been used and how were such curricula developed? What has been done in terms of curricula that combine K–12 engineering with science and math in an integrated approach? To what extent have these efforts increased student learning and/or interest in STEM, and what metrics were used to carry out those assessments of learning and interest? What are the biggest challenges and barriers to incorporating engineering education in the elementary or secondary school classroom?
- What is the current state of research on engineering education at K–12? What are the biggest unanswered research questions? What assessment tools exist for evaluating the effectiveness of engineering education in primary and secondary school, and what are the bathers to improving assessment?

4. Background

Over the past decade, a variety of studies have documented the decline of American students' interest and achievement in science, technology, engineering, and math (STEM) fields, as well as the growing gap between American students' achievement compared to their international counterparts in these fields. A consensus now exists that improving STEM education throughout the nation is a necessary condition for preserving the United States' capacity for innovation and for ensuring the nation's economic strength and competitiveness. The 2005 National Academies report, "Rising Above the Gathering Storm," cited a vast improvement of science and math education as the highest priority policy recommendation for our nation to maintain its competitiveness in the 21s' century global economy.

In recent years, a variety of educators and other STEM education stakeholders have advocated for pre-college engineering education, arguing that our current STEM education system is out-dated given the skills needed by today's workforce.

Engineering education has been introduced to a small but growing number of K–12 classrooms in the United States. The National Academy of Engineering study committee on K–12 engineering education estimates that six million elementary and secondary students have been exposed to engineering-related coursework. However, the implementation of such engineering education varies greatly in classrooms across the country, ranging from ad hoc infusion of engineering activities and ideas into existing science or math classes to stand-alone courses on engineering.

While K–12 engineering education is a relatively new phenomenon, there is much to suggest it has the potential to have profound implications for engineering fields as well as STEM education as a whole. While there is a critical need for more research and data on the impacts of K–12 engineering education efforts, preliminary research findings suggest that K–12 engineering education has the potential to not only increase the awareness of the work of engineers, boost youth interest in pursuing careers in engineering, and increase the technological literacy of students, but may also improve student learning and achievement in science and math.

Since it is such a new field for pre-college students, unlike science, math, and to a certain extent, technology education, many questions remain unanswered regarding how engineering education at the K–12 level is defined, designed, and implemented. At present, there are no established learning standards for K–12 engineering education, nor is there much in the way of professional development for teachers. Furthermore, most K–12 engineering education has been implemented in an ad hoc fashion and there is very little coordination between the various programs and curriculum developers, making it more difficult to compare programs and evaluate impacts.

National Academies Report on Engineering in K–12 Education

In order to begin to address some of these unanswered questions, in 2006, the National Academy of Engineering (NAE) and the National Academies' Center for Education . established the Committee on K–12 Engineering Education to undertake a study regarding the creation and implementation of K–12 engineering curricula and instructional practices, focusing on the connections among science, technology, and mathematics education. In September 2009, the study committee released a report entitled, "Engineering in K–12 Education: Understanding the Status and Improving the Prospects," summarizing the key findings of the study and providing guidance to key stakeholders regarding future research and practice. The committee looked at the current scope and nature of K–12 engineering education and examined available curricula as well as professional development programs for teachers. Many of the recommendations stressed the need for continued investment in research in this area. Another key conclusion of the report was that engineering education could potentially serve as the catalyst for a less "siloed" approach to STEM education. Many have argued that our current STEM education system does not leverage the natural connections between STEM subjects. The NAE Committee suggests that engineering could be used as a tool to develop a more interconnected STEM education system in our Nation's K–12 schools.

Diversity

The lack of diversity in engineering fields is a well documented problem in the United States. In July of this year, the Subcommittee held a hearing to examine the status of participation and achievement of female students in STEM fields. Witnesses testified on the continued lack of participation of girls and young women in certain STEM fields, most notably in the engineering fields. The Subcommittee also plans to hold a series of hearings on the participation of historically under-represented minorities in STEM. Research findings suggest that women and other under-represented groups face unique challenges at multiple stages of the STEM pipeline, beginning at an early age. By helping to make STEM learning more tangible and relevant to students, pre-college engineering education has the potential to attract a more diverse group of students to STEM fields.

5. K–12 Engineering Education and Research at NSF

STEM education research and activities are funded by a number of federal agencies, with NSF being the primary source of support for STEM education research. Historically, NSF's mission has included supporting and strengthening the nation's STEM research and education activities at all levels. NSF funds research on K–12

engineering education as well as a variety of K–12 engineering education activities ranging from teacher training to curriculum development. Many of the Foundation's STEM education and research activities are housed in the Directorate for Education and Human Resources (EHR), but some K–12 engineering activities are funded out of NSF's Engineering Directorate through the Engineering Education and Centers (EEC) Division, which funds work that encourages the integration of engineering research and education with the goal of improving the quality and diversity of engineering graduates entering the workforce.

In his testimony, Dr. Peterson will provide more detailed information regarding the K–12 engineering research and activities funded by NSF. As an example, the GK–12 program, which provides funding for graduate students to bring their research practice and findings to K–12 classrooms, funds a variety of projects that place graduate engineering students into high schools in their communities to do hands-on engineering activities. In addition, the Research and Evaluation on Education in Science and Engineering (REESE) program has funded research on evaluation of pre-college engineering curricula. The Museum of Science, Boston, represented at the hearing by Dr. Miaoulis, also received support from NSF for the development of their "Engineering is Elementary" Curriculum.

6. Questions for Witnesses

Linda Katehi

1. Please summarize the findings and recommendations of the recent National Academy of Engineering report, "Engineering in K–12 Education: Understanding and Status and Improving the Prospects."
2. What is the current state of research on engineering education at the K–12 level? What do we know about the influence of early exposure to engineering concepts on student interest and achievement in STEM fields in the elementary, middle, and high school years? What are the most important unanswered research questions?
3. What metrics and methodologies exist for-evaluation and assessment of K–12 engineering education? What are the bathers to developing better metrics? Is the current level of support for research in these areas adequate?

Thomas Peterson

1. How is engineering education incorporated into NSF's K–12 STEM education programs, including the Math and Science Partnerships Program and K–12 education programs within the Engineering Directorate?
2. What is the current state of research on engineering education at the K–12 level? What do we know about the influence of early exposure to engineering concepts on student interest and achievement in STEM fields in the elementary, middle, and high school years? What are the most important unanswered research questions?
3. What is the current level of support and scope of NSF-funded research on K–12 engineering education? How much of NSF's research support in this area is funded out of the Engineering Directorate? How much research support is funded through Education and Human Resources Directorate programs? How do you communicate the findings supported by your division to your colleagues in the Education and Human Resources Directorate and vice versa?
4. What metrics and methodologies exist for evaluation and assessment of K–12 engineering education? What are the barriers to developing better metrics? What is or should be NSF's role in developing those metrics?

Ioannis Miaoulis

1. Please describe the mission and work of the Museum of Science, Boston's National Center for Technological Literacy (NCTL.) How did NCTL develop its 1(42 engineering curricula? What have you learned about combining engineering concepts with science and math in an integrated approach to K–12 STEM education? To what extent increased student learning and/or interest in STEM, and what metrics were used to carry out those assessments of learning and interest?
2. Where has NCTL received its financial support? What types of federal resources were most valuable in supporting the development of NCTL's engi-

neering education programming? Has the NCTL partnered with stakeholders in the private sector and/or academia for intellectual and financial support? If so, what is the nature of such partnerships?

3. What do you see as the biggest challenges and barriers to incorporating engineering education in the elementary or secondary school classroom?
4. What is the appropriate role of informal learning environments, such as museums, in educating students and teachers about engineering design?

Darryll Pines

1. As a dean of an engineering school, what do you consider to be the necessary skills that make for a successful undergraduate engineering student? Which of those skills should students ideally possess upon enrolling in the university? Which of those skills are better taught and learned at the undergraduate level?
2. What do you consider to be the potential benefits of pre-college engineering education, and at what grade level would you suggest beginning to introduce engineering concepts? What do you see as potential challenges or disadvantages of pre-college engineering education?
3. Please describe the University of Maryland's (UMD) K–12 engineering programs and initiatives. Do these programs involve formal partnerships with local K–12 schools, and if so, what is the nature of such partnerships? How do you evaluate the effectiveness of these programs and partnerships? What kind of engineering related professional development programs does the University provide for K–12 teachers? Does UMD incorporate engineering into any of its degree or certification programs for pre-service STEM teachers?

Rick Sandlin

1. Please describe the establishment of the Martha and Josh Morriss Mathematics and Engineering Elementary School. What was the impetus for its development? What role did partnerships with local businesses and institutes of higher education play in the development of the school?
2. What do you consider to be the benefits of pre-college engineering education? Can engineering be added to the classroom without sacrificing core competencies in math and science? What are reasonable learning outcomes for engineering education at the elementary school level? What do you consider to be the biggest challenges and barriers to incorporating engineering education in the elementary school classroom?
3. What kind of curricula does the school use? What percentage of your teachers have engineering degrees? What kind of teacher training and professional development opportunities do you provide for your teachers?
4. Once a student has completed the elementary grades at your school, do they have the opportunity to go on to a STEM-focused middle school? Are there programs in place to ensure these students maintain an interest in STEM subjects as they transition to middle school and high school?

Chairman LIPINSKI. The hearing will now come to order. I am glad everyone could find the room here. I feel a little bit different being in this committee room rather than the other one, so a few things I am just getting used to here. This microphone sounds very loud to me.

Good morning, and welcome to the Research and Science Education Subcommittee hearing on *Engineering in K–12 Education.*

Today we will explore the concept of pre-college engineering education. Even though I was trained as an engineer, this is something that is fairly new to me, simply because it was not formally around when I was in school.

We on the Committee are dedicated to improving STEM education in this country, and are always exploring new ideas that have the potential to have a positive impact on student learning and achievement in STEM fields. This year alone, we have held three hearings on K–12 STEM education, but those have focused primarily on science and math, and we have yet to examine the small but growing movement in K–12 engineering education.

Today we will hear from witnesses who are involved in engineering education in a variety of capacities. I look forward to hearing the witnesses explain the current models and initiatives for teaching engineering in the K–12 setting, to what extent these efforts have been successful in teaching engineering concepts, and perhaps most importantly, how they might be used to improve student learning in all STEM fields.

We are fortunate to have a new report on this subject from the National Academy of Engineering and the National Research Council. I hope discussing this report will help us understand what questions remain unanswered and what research might need to be conducted.

Finally, I am interested in learning more today about how pre-college engineering education might broaden the STEM pipeline by helping to make STEM learning tangible and exciting to students from all backgrounds.

I want to thank all of our witnesses for taking the time to appear before the Subcommittee this morning and I look forward to your testimony.

The Chair now recognizes Dr. Ehlers for an opening statement.

[The prepared statement of Chairman Lipinski follows:]

PREPARED STATEMENT OF CHAIRMAN DANIEL LIPINSKI

Good morning and welcome to this Research and Science Education Subcommittee hearing on *Engineering in K–12 Education.*

Today we will explore the concept of pre-college engineering education. Even though I was trained as an engineer, this is something that's fairly new to me, simply because it was not formally around when I was in school.

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I want to thank all of the witnesses for taking the time to appear before the Subcommittee this morning and I look forward to your testimony.

Mr. EHLERS. Thank you, Mr. Chairman, and actually I like this cozy room. We may have to pull in a few extra chairs or you will have to take people on your lap or something like that. At any rate, it will be a fun session here.

Today's hearing will look at what we know and what we need to know about fostering K–12 engineering education, and I have become known as the great pusher of STEM education here. Engineering is definitely a part of STEM education. In fact, if you count the letters, it is one-fourth of the package. But it faces unique challenges in the classroom, and I am very pleased that the witnesses are here today that are going to help us understand what that unique place is and what the unique challenges are that are faced.

I happen to be a great believer in using engineering in the elementary schools, and if I had my druthers, the Federal Government would give a free set of Tinker Toys and Lincoln Logs to every child born in this country, male or female, and get them started off right, right from the start.

Engineering is nothing but making things that work, making things out of materials that are at hand and that you make into useful devices that work, and I can't think of a more valuable skill for students to learn in school, regardless of whether or not they go into engineering. But if they don't explore math, science and engineering in elementary school, they almost certainly are not going to take the Advanced Placement courses in high school. If they don't take the Advanced Placement courses in high school, they get to the university and they find well, if they want to become an engineer, they are going to have to spent at least one extra year there to make up time, and so what student wants to do that, especially when faced in their freshman year, and so suddenly we have lost an engineer just because the elementary schools have not instilled that excitement of discovery, the excitement of putting things together and making it work when the students were younger.

I suspect that many innovative teachers have been including engineering in their classrooms for many years and it is our job collectively in this committee to tap that knowledge that is out there, and you are going to be important channels today in helping us begin that education. It is pretty rare you have the opportunity to educate Members of Congress. Most Members by nature assume they know everything already. And so here is a golden opportunity for you to educate us. I hope that we can really get something started here. We have so many forward-thinking ideas on this committee, but if you don't start with a good idea and you don't push it, you are not going to get anywhere, and that is our effort here today. Thank you for participating and thank you for your interest, and I yield back.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Today's hearing will look at what we know and what we need to know about bolstering K–12 engineering education. Though engineering is a part of the "STEM" acronym, it faces unique challenges not shared by math and science. Our witnesses today will help us explore how we can more effectively integrate engineering into our elementary and secondary schools.

I suspect that many innovative teachers have been including engineering in their classrooms for years without explicitly calling it such; however, there is a benefit to students knowing that it is indeed engineering they are learning and how it may be applied in the workforce. Furthermore, it is impossible to research the engineering in the classroom without a common nomenclature. It is critical that we understand the current types of engineering being taught in order to have a strong research base supporting future policy actions to strengthen engineering education.

To advance K–12 engineering education, it will also be necessary to improve communication and collaboration between the various STEM disciplines. Knowing that we all share the goal of our students receiving a high-quality education, I look forward to hearing from our witnesses today about how engineering can be a part of that goal.

Chairman LIPINSKI. Thank you, Dr. Ehlers. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good afternoon, Mr. Chairman. I am pleased that the Subcommittee is holding today's hearing on K–12 education in the area of engineering. I would like to welcome our witness from Texarkana. Mr. Sandlin, we appreciate you taking time away from your duties at the Martha and Josh Morriss Mathematics and Engineering Elementary School to testify today.

My colleagues may know that middle school is a critical period when students are forming their opinions about math and science. It is also a time in which we begin to see an achievement gap between White and African American students, in terms of math test score performance. In fact, the disparities are greatest in fifth grade and in seventh grade, for the math standardized test scores. Today's hearing will cover witness views on teaching models that have the greatest impact for engineering education.

We'll also cover some of the challenges that exist to incorporating engineering education in the elementary or secondary school classroom. Programs like the Noyce Teacher Scholarship have made great strides in putting highly qualified teachers in the classrooms. What we need are more people like them, who are passionate about the subject matter, to ignite the imaginations of their students.

I also hope that this hearing will include a discussion of the lack of diversity in the engineering workforce, and how we can address that from the K–12 education standpoint. We know that minority students begin to under-achieve at a young age. What we don't understand is the complex challenges that they face and what specific interventions would make the greatest difference for them.

Townview is a multi-school complex that is located in Dallas. The schools are public schools, and they are among the very best in the Nation. The schools are diverse, and they are competitive. Townview has received tremendous support from Texas Instruments and other members of the local community. Students at Townview excel. I would like to see this model studied further and replicated around the Nation. I want to invite Members of this subcommittee to come to Dallas and visit Townview. It really is a special place and a model of educational excellence.

The National Academy of Engineering has released a report entitled, *"Engineering in K–12 Education: Understanding and Status and Improving the Prospects."* The report should provide guidance to Congress on how to best leverage our public resources for the betterment of education for all. Clearly, the National Science Foundation has a role to play in this area. Other federal agencies should become more involved in educational enrichment activities.

Again, I want to welcome today's witnesses to the hearing. This subject, K–12 engineering education, is one of great interest to me, and I stand ready to partner with you to guide federal policies toward a better-educated engineering workforce.

Thank you, Mr. Chairman. I yield back the remainder of my time.

Chairman LIPINSKI. At this time I would like to introduce our witnesses. First, we have Dr. Linda Katehi, who is the Chair of the National Academy of Engineering Committee on K–12 Engineering Education and a Chancellor of the University of California, Davis. Dr. Thomas Peterson is the Assistant Director for Engineering at the National Science Foundation. Dr. Ioannis Miaoulis is the President and Director of the Museum of Science, Boston, and the Founding Director of the National Center for Technological Literacy. Dr. Darryll Pines is Dean and Professor of Engineering at the A. James Clark School of Engineering at the University of Maryland, College Park. I will now yield to Ranking Member Hall to introduce our fifth and final witness.

Mr. HALL. I thank you, Mr. Chairman, and I thank you for calling this meeting here today, and Professor Ehlers, thank you for your good advice. I have always admired the Chairman, his history of success and leadership that he gives to this committee. I always admired Professor Ehlers but I never really liked him. He is the kind of guy that ruined the curve for ordinary students like me.

But I would like to thank all the witnesses here today, and my basic job is to introduce my favorite witness and some of my folks, Mr. Chairman, if I might, that are in the audience, but I respect all of you for the dedication to strengthening K–12 STEM education and specifically K–12 engineering education. Our nation has always, as you know, been the leader in cutting-edge innovation and our young children and grandchildren are the key to our success. How we inspire them and how we keep them inspired as they continue their education are very critical questions.

And I might say on behalf of the Chairman here that don't have dismay at the lack of Members that are here because we all have several Committees and there are Committee meetings everywhere and we are trying to wind up and get away from here, maybe tonight or first thing in the morning. But everything you testify to will be put into writing by our court reporter there and it goes into the books and every Member of Congress will read it. So you are not just testifying to a good Chairman and a couple of Members and their groups.

Sometimes it is hard to grasp how a seven- or eight-year-old can understand engineering, but when you put it in terms of toys with which they play and see them light up with excitement, and I was excited to learn that Silly Putty was invited by a chemical engineer trying to find a rubber substitute. A mechanical engineer invented the Slinky when he saw a spring fall off of a table, and a basic water gun was transformed into the very popular Super Soaker Max D–6000 Giant Water Blaster, they say, by a NASA mechanical engineer. You know, during World War II, I flew for the Navy and I landed probably 50 times right there in Pearl Harbor and I never really realized anything historical had taken place there, didn't even get a picture of the Arizona that was still floating partially and it is down into the mud now. And Mr. Chairman, to bring it more home, one of my sons cut my garden hose and had it wrapped around his arm and was ringing it around like that, and I whipped him with the rest of the garden hose. Three years later they came out with the hula hoop. I just don't ever see anything that is suc-

cessful. I see successful people here that are testifying for us today and we are very grateful to them.

I applaud the Subcommittee for taking up this issue, and my job is to introduce him. He has influenced the lives of Texarkana children since 1974, first as a teacher, then as an assistant principal and now as the principal of the Martha and Josh Morriss Mathematics and Engineering Elementary School, and what great and giving people are the Morrisses. He is a Senior Administrator for the Texarkana Independent School District. He along with a lot of others including Texas Independent School District Superintendent James Henry Russell are here, City Manager Larry Sullivan, a former Superintendent, and his wife Roseanne Stripling, Provost of Texas A&M, Texarkana, and the Morriss family were instrumental in the construction and development of Morriss Elementary in 2006. Now, Bart Gordon was with me there when we honored them and recognized that some time ago and it is good to see my friend, James Henry, in the audience as well as well as other members of the Texarkana Independent School District staff, Autumn Thomas Davis, the Superintendent, and Ronnie Thompson, Assistant Superintendent for Instructional Services.

As I say, Mr. Chairman, Chairman Gordon and I were privileged to visit this very phenomenal campus last year and see firsthand one of only a very few public model schools currently in the Nation focused specifically on elementary engineering and mathematics, and I was pleased to see that the National Academy study "Engineering in K–12 Education" also recognizes the Morriss School as a model. Hopefully it can be replicated in other towns suitable for a similar experience.

Mr. Sandlin, welcome to Washington and thank you for being here and for your willingness to share your Morriss Elementary experiences with us. I look forward to learning more about it and believe that my colleagues also find your testimony along with the testimony of those other very knowledgeable and respected witnesses to be very beneficial.

Mr. Chairman, I thank you for allowing me to recognize my favorite group of people.

Chairman LIPINSKI. Thank you, Mr. Hall.

Mr. HALL. I yield back my time if I have got any left.

Mr. EHLERS. Thank you, Mr. Chairman. Mr. Hall, you don't have to worry about me destroying the curve. I did get a B once in advanced electrodynamics.

Mr. HALL. I never did get a B. One time my dad whipped me. They said that I made four F's and a D and he whipped me for spending too much time on one subject.

Chairman LIPINSKI. Thank you, Mr. Hall.

I just—at the beginning you were talking about—you know, you said those nice things about me and then you were criticizing Dr. Ehlers here, but I noted that you didn't use the slur of professor with me as you did with Dr. Ehlers, so I thank you for that. It is always good to have you and always get a few good stories, so thank you always for your contributions.

As our witnesses should know, you each will have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When you all have completed your

spoken testimony, we will begin with questions. Each Member will have five minutes to question the panel.

We will start the testimony here with Dr. Katehi.

STATEMENT OF DR. LINDA P.B. KATEHI, CHAIR, COMMITTEE ON K–12 ENGINEERING EDUCATION, NATIONAL ACADEMY OF ENGINEERING, NATIONAL RESEARCH COUNCIL/CENTER FOR EDUCATION, THE NATIONAL ACADEMIES; CHANCELLOR, UNIVERSITY OF CALIFORNIA, DAVIS

Dr. KATEHI. Good morning, Mr. Chairman and Members of the Subcommittee. My name is Linda Katehi. I am Chancellor at the University of California, Davis, and I served as the Chair of the Committee on K–12 Engineering Education of the National Academy of Engineering and the National Research Council Center for Education. I am sure you are familiar with the history and role of the National Academy so I will not say anymore on that front.

My written testimony goes into some detail about the Committee's recently released report which is titled *"Engineering in K–12 Education: Understanding the Status and Improving the Prospects."*

In my brief remarks today, I am going to focus on our key findings and recommendations. I would like to start by noting that our study was motivated by several factors. One was a desire to get a handle on what is happening nationally regarding efforts to introduce engineering into K–12 classrooms. For example, how many kids and teachers have taken part in these initiatives, what impact various programs had on student learning, what is the relationship between engineering and the other STEM subjects. Another motivator was the concern about the uneven quality of our K–12 STEM education system. The system provides the feedstock for the country's STEM workforce which in turn fuels the U.S. innovation engine and U.S. economy. We wanted to better understand the potential of K–12 engineering education to support a broader national interest.

At this point I want to very briefly define engineering so that the Subcommittee has some sense of what I mean when I use the term. Whereas science can be thought of as a process of discovering what is, engineering is a process used to create something new, something useful, typically a technological product, process or a service. In our report, we call engineering design under constraint. These constraints include the laws of nature. Engineers cannot design anything that violates those laws but they also include other things such as research availability, environmental impact, manufacturability, time deadlines, government regulations, political realities and ethical considerations. The engineering designing process relies heavily on science and mathematics, and engineers work collaboratively with scientists, technicians and many others, often in dispersed and global teams.

The most intriguing finding from our study in my view is the idea that K–12 engineering education might become a catalyst for more integrated and effective STEM education in the United States. In the real world of research and technology development, science, technology, engineering and mathematics are not isolated from one another. Our committee wondered then why the subjects should continue to be isolated or siloed when taught at schools. To

begin moving down the path toward integration, the Committee recommends that the National Science Foundation support research to characterize or define STEM literacy including how much literacy might develop over the course of a student's K–12 school experience.

A major element of our study involved reviewing a representative sample of K–12 engineering education curricula. Most of these curricula recognize that scientific inquiry and engineering design are closely related activities that can be mutually reinforcing, but we found that the connection is not systematically emphasized to improve learning in both domains. Similarly, mathematical analysis and modeling are essential to engineering design but very few curricula or professional development initiatives we reviewed used mathematics in ways that support modeling and analysis. To address these shortcomings, the Committee recommends that the National Science Foundation or the U.S. Department of Education fund research to determine how science inquiry and mathematical reasoning can be better connected to engineering design in K–12 curricula and teacher professional development.

Our study also evaluated a variety of claims that have been made for the benefit of teaching engineering to K–12 students. Although only limited reliable data are available to support these claims, we found that most evidence for benefit relates to improved student learning and achievement in mathematics and science. For engineering education to become a more mainstream component of K–12 education, the Committee believes there will have to be much more and much higher quality outcome-based data. To this end, we recommendation that foundations and federal agencies with an interest in K–12 engineering education support long-term research to confirm and refine the findings of earlier studies of the impacts of engineering education.

At this point I would like to note that the Committee was unanimous that whatever benefit K–12 engineering education provides, they should be made available to all students—what we term the mainline, not just to those relatively few students who wish to pursue a career in engineering or another technical field, what we normally call the pipeline. Our study determined that teacher professional development opportunities for K–12 engineering are seriously lacking. The roughly 18,000 teachers we estimate who have received some training to teach engineering have almost all participated in service initiatives associated with existing curricula. We uncovered no pre-service initiatives that are likely to contribute significantly to the supply of qualified engineering teachers in the near future. Given this situation, the Committee recommends that the American Society of Engineering Education begin a national dialogue on preparing K–12 engineering teachers to address the very different needs and circumstances facing elementary and secondary teachers and the pros and cons of establishing a formal credentialing process.

The Committee concluded that lack of gender and ethnic diversity is an issue for K–12 engineering education just as it is an issue for the engineering workforce. To expand access and participation, the Committee recommends that K–12 engineering curricula should be developed with special attention to features that appeal

to girls and students from under-represented groups and programs that promote K–12 engineering education should be strategic in their outreach to these populations.

Many questions remain about the best way to deliver engineering education in the K–12 classroom. In the Committee's view, there are at least three options: ad hoc infusion, standalone courses and interconnected STEM education. These approaches would fall along a continuum in terms of ease of implementation as described in greater detail in our report. We believe that implementation of K–12 engineering education must be flexible because no single approach is likely to be acceptable or feasible in every district or school. Ideally, we believe that all K–12 students in the United States should have the option of experiencing some form of formal engineering design. To help reach that goal, the Committee recommends that philanthropic foundations or federal agencies with an interest in STEM education and school reform fund research to identify models of implementation for K–12 engineering education.

Our project did not attempt to calculate the Nation's investment in K–12 engineering education. It is clear, however, that the greatest spending over time has been on curriculum development. A much, much smaller amount has been devoted to research on comprehension and learning, on assessment and evaluation and on professional development. K–12 engineering education could benefit from addressing the research questions suggested by many of our recommendations.

I want to return briefly to the ideas of integrated STEM education and STEM literacy. The Committee believes that STEM-literate students would be better prepared for life in the 21st century and better able to make career decisions or pursue post-secondary education. They will also become better citizens and our country will greatly benefit from them. Integrated STEM education could include teaching and learning in all four subjects by reducing excessive expectations for K–12 STEM teaching and learning. This does not mean that teaching should be dumbed down, but rather the teaching and learning in fewer key STEM areas could be deepened and then more time should be spent on the development of a set of STEM skills that includes engineering design and scientific inquiry.

I would like to thank the Subcommittee for the invitation to speak here today and welcome your questions.

[The prepared statement of Dr. Katehi follows:]

PREPARED STATEMENT OF LINDA P.B. KATEHI

Good morning, Mr. Chairman, and Members of the Subcommittee. My name is Linda Katehi. I am Chancellor at the University of California, Davis, and served as the Chair of the Committee on K–12 Engineering Education of the National Academy of Engineering (NAE) and National Research Council (NRC) Center for Education. The NAE and NRC, along with the National Academy of Sciences (NAS) and Institute of Medicine (IOM), are part of the National Academies. The National Academies provide science, technology, and health policy advice under a congressional charter signed by President Abraham Lincoln that was originally granted to the NAS in 1863. Under this charter, the NRC was established in 1916, the NAE in 1964, and the IOM in 1970. My testimony today focuses on the report of the study committee I chaired. The report, *Engineering in K–12 Education: Understanding the Status and Improving the Prospects,* was released a little over a month ago. The bulk of funding for the study came from Mr. Stephen D. Bechtel, Jr., a

member of the NAE. Additional support was provided by the National Science Foundation and PTC Inc.

Introduction

Although K–12 engineering education has received little attention from most Americans, including educators and policy makers, it has slowly been making its way into U.S. K–12 classrooms. Today, several dozen different engineering programs and curricula are offered in school districts around the country, and our research suggests about 18,000 teachers have attended professional development sessions to teach engineering-related course work. In the past 15 years, our committee estimates, some six million K–12 students have experienced formal engineering education.

The presence of engineering in K–12 classrooms is an important phenomenon, not because of the number of students impacted, which is still small relative to other school subjects, but because of the implications of engineering education for the future of science, technology, engineering, and mathematics (STEM) education more broadly. In fact, our committee came to the conclusion that engineering education could be a catalyst for more integrated, and effective, STEM education in the United States. I will talk more about this at the end of my remarks.

In recent years, as you know, educators and policy-makers have come to a consensus that the teaching of STEM subjects in U.S. schools must be improved. The focus on STEM topics is closely related to concerns about U.S. competitiveness in the global economy and about the development of a workforce with the knowledge and skills to address technical and technological issues.

However, in contrast to science, mathematics, and even technology education, all of which have established learning standards and a long history in the K–12 curriculum, the teaching of engineering in elementary and secondary schools is still very much a work in progress. Not only have no learning standards been developed, little is available in the way of guidance for teacher professional development, and no national or State-level assessments of student accomplishment have been developed. In addition, no single organization or central clearinghouse collects information on K–12 engineering education.

Thus a number of basic questions remain unanswered. How is engineering taught in grades K–12? What types of instructional materials and curricula have been used? How does engineering education "interact" with other STEM subjects? In particular, how has K–12 engineering instruction incorporated science, technology, and mathematics concepts, and how has it used these subjects as a context for exploring engineering concepts? Conversely, how has engineering been used as a context for exploring science, technology, and mathematics concepts? And what impact have various initiatives had?

In 2006, the NAE and NRC established the Committee on K–12 Engineering Education to begin to address these and related questions. The goal of our effort was to provide carefully reasoned guidance to key stakeholders regarding the creation and implementation of K–12 engineering curricula and instructional practices, focusing especially on the connections in science, technology, engineering, and mathematics education.

Principles for K–12 Engineering Education

In part because there are no standards for K–12 engineering and also because the specifics of how engineering is taught vary from school district to school district, the Committee felt it important to lay out several general principles that could guide all pre-college engineering education efforts. The first principle is that K–12 engineering education should emphasize engineering design, the approach engineers use to identify and solve problems. The second principle is that K–12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills. And the third principle is that K–12 engineering education should promote engineering habits of mind, including systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations. These principles are described more fully in our report.

Review of Curricula

A major element of our study involved identifying and reviewing a representative sample of K–12 engineering education curricula. Our analysis included 31 such curricula and examined 15 in great detail. We found that engineering design is predominant in most K–12 curricular and professional development programs. This is encouraging. However, we also found that the treatment of key ideas in engineering,

many closely related to engineering design, is much more uneven and, in some cases, suggests a lack of understanding on the part of curriculum developers.

In part, these shortcomings may be the result of the absence of a clear description of which engineering knowledge, skills, and habits of mind are most important, how they relate to and build on one another, and how and when (i.e., at what age) they should be introduced to students. In fact, it seems that no one has attempted to specify age-appropriate learning progressions in a rigorous or systematic way; this lack of specificity or consensus on learning outcomes and progressions goes a long way toward explaining the variability and unevenness in the curricula.

Although there are a number of natural connections between engineering and the three other STEM subjects, we found that existing curricula in K–12 engineering education do not fully explore them. For example, scientific investigation and engineering design are closely related activities that can be mutually reinforcing. Most curricula include some instances in which this connection is exploited (e.g., using scientific inquiry to generate data that can inform engineering design decisions or using engineering design to provide contextualized opportunities for science learning), but the connection is not systematically emphasized to improve learning in both domains.

Similarly, mathematical analysis and modeling are essential to engineering design, but very few curricula or professional development initiatives reviewed by the Committee used mathematics in ways that support modeling and analysis. The Committee believes that K–12 engineering can contribute to improvements in students' performance and understanding of certain mathematical concepts and skills.

Based on its review of curricula, *the Committee recommended that the National Science Foundation and/or U.S. Department of Education fund research to determine how science inquiry and mathematical reasoning can be better connected to engineering design in K–12 curricula and teacher professional development.* Our report details a number of specific areas the research should cover.

Impacts of K–12 Engineering Education

A variety of claims have been made for the benefits of teaching engineering to K–12 students, ranging from improved performance in related subjects, such as science and mathematics, and increased technological literacy to improvements in school attendance and retention, a better understanding of what engineers do, and an increase in the number of students who pursue careers in engineering. Although only limited reliable data are available to support these claims, we found the most intriguing possible benefit of K–12 engineering education relates to improved student learning and achievement in mathematics and science. The Committee believes that for engineering education to become a mainstream component of K–12 education there will have to be much more, and much higher quality outcomes-based data. To this end, *the Committee recommended that foundations and federal agencies with an interest in K–12 engineering education support long-term research to confirm and refine the findings of earlier studies of the impacts of engineering education. The Committee additionally recommended that funders of new efforts to develop and implement curricula for K–12 engineering education include a research component that will provide a basis for analyzing how design ideas and practices develop in students over time and determining the classroom conditions necessary to support this development. After a solid analytic foundation has been established, a rigorous evaluation should be undertaken to determine what works and why.*

Professional Development Programs

Compared with professional development opportunities for teaching other STEM subjects, the opportunities for engineering are few and far between. Our study found that nearly all in-service initiatives are associated with a few existing curricula, and many do not have one or more of the characteristics (e.g., activities that last for at least one week, ongoing in-classroom or online support following formal training, and opportunities for continuing education) that have been proven to promote teacher learning.

The Committee found no pre-service initiatives that are likely to contribute significantly to the supply of qualified engineering teachers in the near future. Indeed, the "qualifications" for engineering educators at the K–12 level have not even been described. Graduates from a handful of teacher preparation programs have strong backgrounds in STEM subjects, including engineering, but few if any of them teach engineering classes in K–12 schools.

Given this situation, *the Committee recommended that the American Society of Engineering Education, through its Division of K–12 and Pre-College Education, begin a national dialogue on preparing K–12 engineering teachers to address the very dif-*

ferent needs and circumstances of elementary and secondary teachers and the pros and cons of establishing a formal credentialing process. Participants in the dialogue should include leaders in K–12 teacher education in mathematics, science, and technology; schools of education and engineering; State departments of education; teacher licensing and certification groups; and STEM program accreditors.

Diversity

The lack of gender and ethnic diversity in post-secondary engineering education and the engineering workforce in the United States is well documented. Based on evaluation data, analysis of curriculum materials, anecdotal reports, and personal observation, the Committee concluded that lack of diversity is probably an issue for K–12 engineering education as well. This problem is manifested in two ways. First, the number of girls and under-represented minorities who participate in K–12 engineering education initiatives is well below their numbers in the general population. Second, with a few exceptions, curricular materials do not portray engineering in ways that seem likely to excite the interest of students from a variety of ethnic and cultural backgrounds.

For K–12 engineering education to yield the many benefits its supporters claim, access and participation will have to be expanded considerably. To this end, *the Committee recommended that K–12 engineering curricula should be developed with special attention to features that appeal to students from under-represented groups, and programs that promote K–12 engineering education should be strategic in their outreach to these populations.* In doing so, the Committee suggested, curriculum developers and outreach organizations should take advantage of recent market research that suggests effective ways of communicating about engineering to the public, such as the 2008 NAE publication *Changing the Conversation: Messages for Improving Public Understanding of Engineering.*

Policy and Program Issues

Many questions remain to be answered about the best way to deliver engineering education in the K–12 classroom and its potential on a variety of parameters of interest, such as science and mathematics learning, technological literacy, and student interest in engineering as a career. Despite these uncertainties, engineering is already being taught in K–12 schools scattered around the country, and the trend appears to be upward. Given this situation, it is important that we consider the best way to provide guidance and support to encourage this trend.

In the Committee's view, there are at least three options for including engineering education in U.S. K–12 schools—ad hoc infusion, stand-alone courses, and interconnected STEM education. These approaches, which fall along a continuum in terms of ease of implementation, are described in greater detail in the report. Each has strengths and weaknesses and is not mutually exclusive. Indeed, the Committee believes that implementation of K–12 engineering education must be flexible, because no single approach is likely to be acceptable or feasible in every district or school.

Broader inclusion of engineering studies in the K–12 classroom also will be influenced by State education standards, which often determine the content of State assessments and, to a lesser extent, curriculum used in the classroom. It is worth noting that the *No Child Left Behind Act of 2001* (NCLB; P.L. 107–110) puts considerable pressure on schools and teachers to prepare K–12 students to take annual assessments in mathematics, reading/language arts, and science, and these assessments are based on State learning standards. Thus NCLB currently provides little impetus for teaching engineering.

The Committee believes that plans for implementing engineering education in a school curriculum at any level must take into account places and populations (e.g., small rural schools, urban schools with high proportions of students of low socioeconomic status, etc.) with a limited capacity to access engineering-education resources. Such plans also will benefit by approaches that emphasize coherence, that is, the alignment of standards, curricula, professional development, and student assessments, and that include support from school leadership.

Finally, the Committee believes that, ideally, all K–12 students in the United States should have the option of experiencing some form of formal engineering studies. To help us reach that goal, *the Committee recommended that philanthropic foundations or federal agencies with an interest in STEM education and school reform fund research to identify models of implementation for K–12 engineering education that embody the principles of coherence and can guide decision-making that will work for widely variable American school systems. The research should explicitly address school populations that do not currently have access to engineering studies and*

take into account the different needs and circumstances of elementary and secondary school populations.

Integrated STEM Education

After considerable discussion and thought, the Committee came to the conclusion that the most compelling argument for K–12 engineering education can be made if it is not thought of as a topic unto itself, but rather as part of integrated STEM education. After all, in the real world engineering is not performed in isolation—it inevitably involves science, technology, and mathematics. The question is why these subjects should be isolated, or "silo-ed," in schools.

Although the Committee did not target K–12 STEM education initiatives specifically, we believe that the great majority of efforts to promote STEM education in the United States to date focus on either science or mathematics (generally not both) and rarely include engineering or technology (beyond the use of computers). By contrast, the Committee's vision of integrated STEM education in U.S. K–12 schools sees all students graduating from high school with a level of "STEM literacy" sufficient to (1) ensure their success in employment, post-secondary education, or both, and (2) prepare them to be competent, capable citizens in a technology-dependent, democratic society. Engineering education, because of its natural connections to science, mathematics, and technology, might serve as a catalyst for achieving this vision.

To begin to tackle this critical issue, *the Committee recommended that the National Science Foundation should support research to characterize, or define, "STEM literacy," including how such literacy might develop over the course of a student's K–12 school experience. Researchers should consider not only core knowledge and skills in science, technology, engineering, and mathematics, but also the "big ideas" that link the four subject areas.*

Pursuing a goal of STEM literacy in K–12 will require a paradigm shift by teachers, administrators, textbook publishers, and policy-makers, as well as by scientists, technologists, engineers, and mathematicians involved in K–12 education. Standards of learning, instructional materials, teacher professional development, and student assessments will have to be re-examined and, possibly, updated, revised, and coordinated. Professional societies will have to rethink their outreach activities to K–12 schools in light of STEM literacy. Colleges and universities will have to cope with student expectations that may run counter to traditional departmental stovepipe conceptions of courses, disciplines, and degrees.

Why do we suggest such a comprehensive change? First, the Committee believes that STEM-literate students would be better prepared for life in the 21st century and better able to make career decisions or pursue post-secondary education. Second, integrated STEM education could improve teaching and learning in all four subjects by reducing excessive expectations for K–12 STEM teaching and learning. This does not mean that teaching should be "dumbed down," but rather that teaching and learning in fewer key STEM areas should be deepened and that more time should be spent on the development of a set of STEM skills that includes engineering design and scientific inquiry.

The Important Role of Research

A major component of our study was the collection and synthesis of research evidence related to 1) how children learn engineering concepts and skills and 2) what impact K–12 engineering education has had on a variety of parameters of interest. In the former case, we learned that certain experiences can support sophisticated understanding and skill development, even in young children, but several conditions seem important: students need sufficient classroom time; there must be opportunities for iterative, purposeful revisions of designs, ideas, models; and learning is most successful when ideas are sequenced from less to more complex. Overall, however, there are still significant gaps in our understanding of how K–12 students learn and might best be taught engineering.

In the latter case, as noted previously, the most intriguing possible benefit of K–12 engineering education relates to improved student learning, achievement, and interest in mathematics and science. Interestingly, some of the evidence suggests that learning gains may be greatest for minorities and low-SES students. Limited data support other possible benefits, including that engineering experiences can increase awareness of engineering and engineers, improve understanding of engineering design, and increase interest in engineering-related careers. But none of these benefits have been shown to occur universally, which reinforces the need for more and higher quality evaluation and assessment research. As my testimony demonstrates, many of the Committee's recommendations address this need.

One major obstacle to determining whether and how K–12 engineering education is having an impact is that, in many cases, curriculum developers do not build in adequate time or resources for this kind of research. Assessments require advanced planning and viable pre-tests. Longitudinal research demands even greater planning and financial support. Another weakness of much of the extent literature on impacts is a tendency to study self-selected populations. Thus the findings about effectiveness cannot be generalized to students who choose not to participate. And a great many impact studies neglect to collect information on subgroups, such as girls or under-represented minorities. This kind of disaggregation is only possible, of course, if the research includes a sufficiently large study population.

We also attempted to uncover what was known from a research and practice standpoint about the professional development of K–12 engineering teachers. There is a considerable literature on teacher professional development in other domains, including science education, and we believe that many of these findings can be applied to engineering education. However, there is almost no documented pre-service teacher professional development in K–12 engineering, and only a small number of qualitative studies have been done that examine in-service training initiatives.

Our project did not attempt to calculate the amount of investment in research related to K–12 engineering. It is clear, however, that the greatest investment over time has been on curriculum development. A much, much smaller amount has been devoted to research on cognition and learning, on assessment and evaluation, and on professional development. K–12 engineering education could benefit from a major infusion of research dollars, as suggested by many of our recommendations.

Conclusion

In the course of our efforts to understand and assess the potential of engineering education for K–12 students, the Committee underwent an epiphany of sorts. To put it simply, for engineering education to become more than an afterthought in elementary and secondary schools in this country, STEM education as a whole must be reconsidered. The teaching of STEM subjects must move away from its current siloed structure, which may limit student interest and performance, toward a more integrated whole. The Committee did not plan to come to this conclusion but reached this point after much thought and deliberation.

We feel confident that our instincts are correct, but other organizations and individuals will have to translate our findings and recommendations into action. Meaningful improvements in the learning and teaching of engineering and movement toward interconnected STEM education will not come easily or quickly. Progress will be measured in decades, rather than months or years. The changes will require a sustained commitment of financial resources, the support of policy-makers and other leaders, and the efforts of many individuals both in and outside of K–12 schools. Despite these challenges, the Committee is hopeful that the changes will be made. The potential for enriching and improving K–12 STEM education is real, and engineering education can be the catalyst.

I thank the Subcommittee for the invitation to testify today and welcome your questions.

BIOGRAPHY FOR LINDA P.B. KATEHI

Linda Katehi became the sixth Chancellor of the University of California, Davis, on August 17, 2009. As Chief Executive Officer, she oversees all aspects of the University's teaching, research and public service mission.

Chancellor Katehi also holds UC–Davis faculty appointments in electrical and computer engineering and in women and gender studies. A member of the National Academy of Engineering, she chairs the Presidents Committee for the National Medal of Science and is Chair of the Secretary of Commerces Committee for the National Medal of Technology and Innovation. She is a fellow and board member of the American Association for the Advancement of Science and a member of many other national boards and committees.

Previously, Chancellor Katehi served as provost and Vice Chancellor for academic affairs at the University of Illinois at Urbana–Champaign; the John A. Edwardson Dean of Engineering and Professor of Electrical and Computer Engineering at Purdue University; and Associate Dean for Academic Affairs and Graduate Education in the College of Engineering and Professor of Electrical Engineering and Computer Science at the University of Michigan.

Since her early years as a faculty member, Chancellor Katehi has focused on expanding research opportunities for undergraduates and improving the education and professional experience of graduate students, with an emphasis on under-rep-

resented groups. She has mentored more than 70 post-doctoral fellows, doctoral and Master's students in electrical and computer engineering. Twenty-one of the 42 doctoral students who graduated under her supervision have become faculty members in research universities in the United States and abroad.

Her work in electronic circuit design has led to numerous national and international awards both as a technical leader and educator, 16 U.S. patents, and an additional six U.S. patent applications. She is the author or co-author of 10 book chapters and about 600 refereed publications in journals and symposia proceedings.

She earned her Bachelor's degree in electrical engineering from the National Technical University of Athens, Greece, in 1977, and her Master's and doctoral degrees in electrical engineering from UCLA in 1981. and 1984, respectively.

The University of California, Davis, is one of 10 UC campuses and one of a select group of 62 North American universities admitted to membership in the prestigious Association of American Universities.

For 100 years, UC–Davis has engaged in teaching, research and public service that matter to California and transform the world. Located close to the State capital, UC–Davis has 31,000 students, an annual research budget that exceeds $600 million, a comprehensive health system and 13 specialized research centers. The university offers interdisciplinary graduate study and more than 1.00 undergraduate majors in four colleges—Agricultural and Environmental Sciences, Biological Sciences, Engineering, and Letters and Science—and advanced degrees from six professional schools—Education, Law, Management, Medicine, Veterinary Medicine and the Betty Irene Moore School of Nursing.

Chairman LIPINSKI. Thank you, Dr. Katehi.

Dr. Peterson.

STATEMENT OF DR. THOMAS W. PETERSON, ASSISTANT DIRECTOR, ENGINEERING DIRECTORATE, NATIONAL SCIENCE FOUNDATION (NSF)

Dr. PETERSON. Chairman Lipinski, Ranking Member Ehlers and distinguished Members of the Subcommittee on Research and Science Education, I want to thank you for inviting me to participate in this hearing on engineering and K–12 education. I am Thomas Peterson, the Assistant Director for Engineering at the National Science Foundation.

Every student who takes either the SAT or the ACT college entrance exam is asked to indicate the discipline of study that they intend to pursue after graduation from high school. The fraction of total test takers who intend to pursue engineering declined from 7.7 percent in 1994 to 4.6 percent in 2006. As a former engineering dean, I along with my colleagues, Dr. Katehi, Dr. Miaoulis and Dr. Pines, all either current or former engineering deans themselves, have firsthand experience with the challenges of finding a diverse and qualified pipeline of domestic students interested in pursuing the study of engineering. The introduction to basic engineering concepts in pre-college curricula, even in the elementary and middle schools, can be an important factor in addressing these challenges. Engineering education in the K–12 curriculum holds promise to encourage student learning in fundamental science and mathematics, to raise the level of understanding and awareness of engineering and what engineers do, to stimulate interest in a rapidly changing demographic population to pursue careers in engineering and to increase the basic technological literacy for all of our citizens. In other words, far from being an additional burden for schools, engineering education in the K–12 environment is an enabler for motivating students to learn other aspects of the curriculum as well.

The key to inclusion of engineering in the K–12 curriculum is the emphasis on the elementary principles of engineering design. It il-

lustrates the importance and application of the basic science and mathematics principles. It stimulates creativity within students. It encourages them to work in partnership with other students because design is fundamentally a team-based activity. It helps to develop communication skills as students work together and describe their work to each other, and it even promotes a platform for the consideration of important social, environmental and ethical issues.

At the National Science Foundation, the Engineering and the Education and Human Resources Directorates have partnered on numerous K–12 activities. For example, we have teamed to support a GK–12 fellowship program at the University of Colorado in Boulder and these fellows work with Skyline High School in Longmont to bring highly interactive, hands-on engineering projects into the classroom. Another partnership supports Design Squad, a PBS reality competition series with an accompanying outreach campaign and web site designed to inspire a new generation of engineers. The series is making a special effort to reach out to girls and minorities, groups that are critically under-represented in engineering, as we all know. The Engineering is Elementary Project developed by the National Center for Technological Literacy with NSF support holds promise to reach very deeply into elementary schools throughout the Nation. And it is also noteworthy and reassuring that support for engineering in K–12 education extends beyond government agencies like the NSF. In 1992, FIRST Robotics, an extracurricular program, was launched in New Hampshire under the visionary leadership of Dean Kamen. While he received support from NSF in the early stages of that competition, FIRST Robotics is now supported by industry partners in over 2,000 high schools in the United States, and a significant number of alumni are now studying in engineering colleges.

In summary, the NSF is not about providing long-term and sustained funding for programs. We provide the support for new ideas, new curriculum, new approaches to engineering education and educational pedagogy. We provide the support for targeted programs in schools and institutions with new and creative ideas. The challenge is twofold. First, we must find the support to continue programs developed under NSF sponsorship once NSF support is no longer provided, and second, we must find the means to financially support the dissemination of these best ideas developed through NSF support to a much broader range of institutions and schools.

Mr. Chairman, this concludes my remarks and I would be happy to answer any questions following the testimony.

[The prepared statement of Dr. Peterson follows:]

PREPARED STATEMENT OF THOMAS W. PETERSON

Chairman Lipinski, Ranking Member Ehlers, and distinguished Members of the Subcommittee on Research and Science Education, thank you for inviting me to participate in this hearing on *"Engineering in K–12 Education."* I am Dr. Thomas Peterson, Assistant Director for Engineering at the National Science Foundation.

Today I will address the challenges we face in attracting and retaining talented students in engineering education as well as your questions focusing on: (1) How engineering education is incorporated into NSF's K–12 STEM education programs; (2) What the current state of research on engineering education is at the K–12 level; (3) What the current level of support and scope of NSF-funded research on K–12 engineering education is; and, (4) What metrics and methodologies exist for evaluation and assessment of K–12 engineering education.

The Challenge We Face

Every student who takes either the SAT[1] or ACT college entrance examination is asked to indicate the discipline of study that they intend to pursue after graduation from high school. An analysis of this data reveals that the fraction of total test takers (both SAT and ACT) who intend to pursue engineering declined from 7.7 percent in 1994 to 4.6 percent in 2006. In absolute numbers, Almost 150,000 test takers expressed a preference for engineering in 1994 compared to fewer than 120,000 in 2006. In 1983 about 1.9 percent of all four-year baccalaureate degrees received by women were in engineering. Twenty years later, 1.7 percent of female baccalaureate recipients were engineers.

As a former Engineering Dean I, along with my colleagues Dr. Katehi and Dr. Miaoulis, also both former Engineering Deans, have first-hand experience in dealing with the challenges of finding a diverse and qualified pipeline of domestic students interested in pursuing the study of engineering. There are many extenuating factors that contribute to this situation, but I personally believe that the absence of introducing basic engineering concepts in pre-college curricula, even down to the elementary and middle school levels, is a dominant factor in this situation. Not only will the profession of engineering benefit, but so will society as a whole, if a much larger fraction of our general populace understands the basic elements of the highly technological society in which we all live.

I believe that the presence of engineering education in the K–12 curriculum holds promise to encourage student learning in the fundamental science and mathematics subjects, to raise the level of understanding and awareness of engineering and what engineers do, to stimulate interest in a rapidly changing demographic population to pursue careers in engineering, and to increase the basic technological literacy for all of our citizens. In other words, far from being an additional burden that must be shouldered by the already challenged curriculum, engineering education in the K–12 environment should be viewed as an enabler for motivating students to learn other aspects in the curriculum as well.

Engineering Education at the K–12 level—Influence of Early Exposure

Engineering in the K–12 curriculum provides instruction in numerous basic areas, but the key to inclusion of engineering concepts is the emphasis on engineering design. Previously, the standard engineering curriculum at a university culminated in a year-long course in the concepts and practice of engineering design. Undergraduate engineering students would see little, if any of the basic elements of engineering design until they reached that course in the senior year. Engineering design, after all, is that element, more than any other that separates and distinguishes engineering from the basic sciences. More recently, however, Engineering, both the profession and the academic discipline, has come to realize that this approach of postponing the introduction of design principles until the last possible moment in one's educational career is counterproductive and frustrating for many students. After all, in this previous approach students never really truly understood the basis for engineering, the joy of discovery and creative endeavor, until they had almost completed their studies. As a consequence, a large fraction of students who would otherwise become productive practicing engineers left the field in favor of other pursuits.

The modern engineering curriculum, while still maintaining a capstone design experience, now begins the engineering curriculum with an introduction to the basic concepts of design. Why? Because this structure allows us to demonstrate to students very early on what engineering is all about.

For exactly this same reason, the inclusion of engineering design principles within the K–12 education system could not only increase the level of understanding of what engineering is, but it can also provide a motivation to students for learning basic concepts in science and mathematics, which will always be the foundational building blocks of engineering. Obviously, engineering design in its complete implementation by a professional engineer is an elaborate and complex process. Nonetheless, there are many elements of the design process that can easily be illustrated even at elementary school levels. Design is an iterative process, it is illustrative of the concept that more than one solution to a problem may exist, and that the major challenge is to find the best, or optimum solution. Finally, it illustrates the importance and application of basic science and mathematics principles.

Engineering design also stimulates creativity within students. It encourages them to work in partnership with other students because design is fundamentally a team-

[1] Source: Derived from data provided by the College Board. Copyright © 1993–2008 The College Board. *www.collegeboard.com*

based activity. It helps to develop communication skills as students work together and describe their work to each other, and even provides a platform for the consideration of important social, environmental and ethical issues.

Support and Scope of NSF-funded research on K–12 Engineering Education

The National Science Foundation plays an important role in encouraging the development and dissemination of materials for engineering education in the K–12 environment. In addition to support provided by the Education and Human Resources (EHR) directorate, the Engineering directorate, through our division of Engineering Education and Centers (or EEC), has supported numerous engineering education programs, the primary purpose of many being to introduce engineering education into the K–12 curriculum. For example, the Innovations in Engineering Education, Curriculum, and Infrastructure (IEECI) program supports research which addresses three basic issues related to engineering education: (1) how students learn, (2) how to attract a more talented and diverse student body, and (3), how to evaluate and assess successful teaching, advising, and mentoring. One of the project areas we directly solicited ideas for was "Strategic Supply-Chain Partnerships for Engineering," where we strongly encouraged the establishment of "leadership partners" between Engineering Deans and K–12 school district Superintendents and Principals. Such partnerships could improve guidance and cooperation on developing pre-engineering curricula, career opportunities for students, K–12 faculty development, and, importantly, provide a stronger image of engineering in local communities.

Just this past summer, EEC supported an Engineering Education Summit here in Washington, where we brought together the thought leaders from those key universities (such as Purdue, Virginia Tech, Clemson and Utah State) focusing directly on engineering education. While much of their focus was on improving the engineering curriculum in universities, these engineering education programs are leading the profession in establishing partnerships with Colleges of Education to include engineering content in elementary, middle and high school teacher preparation. Just as Education colleges turn to colleges of Science for content preparation in chemistry, physics and biology, we want them to turn to colleges of engineering for content preparation in engineering.

Engineering Education and NSF STEM Education programs

The Engineering and EHR directorates have partnered on numerous K–12 activities. For example, we have teamed to support a GK–12 Fellowship program at the University of Colorado, Boulder. These Fellows are working with Skyline High School (SHS) in Longmont to bring highly interactive, hands-on projects into the classroom. The projects are targeted at moderately at-risk students and allow them to receive high school credit. SHS has a large Hispanic student population and is a school where 49 percent of the students qualify for free and reduced lunches. SHS also has the largest English Language Learners program in the District.

As a direct result of the funding, the initial new STEM course offerings introduced include "WIRED" (a technology-based course designed for all 9th grade students), Exploration in STEM, Engineering Design I, Introduction to Computer Programming, AP Computer Science, and AP Chemistry. The enrollment demographics in these courses are encouraging. 40 percent of students accepted into the academies are minority and 33 percent are female.

Another EHR/ENG partnership supports *Design Squad,* a PBS reality competition series-with an accompanying outreach campaign and web site designed to inspire a new generation of engineers. Over 10 weeks, six high school and college-aged kids learn to think smart, build fast, and contend with a wild array of engineering challenges-all for real-life clients. Targeted to nine- to twelve-year-olds and fun for people of all ages, this fast-paced TV series is the fuel behind a national, multimedia initiative designed to attract kids to engineering.

The series is making a special effort to reach out to girls and minorities, groups that are critically under-represented—comprising just 11 percent and 21 percent of engineers, respectively. By casting teens from a range of racial, ethnic, and socioeconomic backgrounds (50 percent of the Season I and II cast are female and 56 percent minority), Design Squad provides positive, diverse role models for younger viewers. These casting decisions have a measurable impact. 16 percent of the Design Squad audience is comprised of Black or African American households and 27 percent is comprised of Hispanic households.

Since its premiere in 2007, *Design Squad* has conducted 71 trainings for 3,479 engineers and educators, and engaged 89,453 kids and families with hands-on engineering activities through 263 events and workshops across the country. 64 engineering and education organizations have become formal partners, and 2,700 pro-

grams have used *Design Squad*'s educational materials, which include six educators' guides (containing step-by-step directions and leaders notes for 30 activities) targeted to after-school providers, engineers, and teachers. Recent data estimates that approximately 500,000 viewers watch *Design Squad* each week. A selected list of current K–12 Engineering projects supported by EHR is found in the Appendix.

Finally, it is noteworthy, and reassuring, that interest and support in expanding opportunities in engineering among K–12 students extends beyond government-related programs. In 1992, FIRST Robotics, an extra-curricular program, was launched in New Hampshire under the visionary leadership of Dean Kamen. Dean received support from NSF in the early stages of his national robotics competition. FIRST Robotics is now supported in over 2000 high schools in the U.S. and a significant number of FIRST alumni are now studying in engineering colleges. Another program, Project Lead the Way, started in New York State in the early 1990s, is a curricular program with engineering-based courses now embedded in about 3,000 schools and boasts student participation of upwards of 300,000 students. Programs like this (and several others) will hopefully motivate boys and girls of all ethnicities to become the innovative engineers of the future.

Evaluation and Assessment

Assessment for success in such programs is absolutely critical. Much of our assessment analysis to date has been anecdotal, and true successful assessment metrics can only be defined over a fairly long time horizon. For example, how many students who experience the excitement of discovery and creativity through simple engineering projects in the third and fourth grades end up pursuing academic studies and professional careers in engineering? Obviously longitudinal analyses over decades are required to quantitatively answer that question. But we must begin collecting that information now.

The Engineering and Education and Human Resources directorates held a joint retreat this past summer, for the purpose of delineating the many opportunities for continued and future collaborations on engineering education issues of particular interest to both of us. One topic of discussion was precisely this question of developing better metrics for assessment and evaluation. Suggested metrics and measures for evaluating our investments in K–12 engineering education included:

- Number of K–12 development intensive projects that employ appropriate methods to evaluate efficacy and that apply them rigorously
- Number of teachers and students who engage in the capacity building efforts, including increasing awareness, interests, and skills in K–12 engineering education.

Summary

The National Science Foundation continues to play a role in this important task of educating future engineers and society decision-makers. Moreover, an equally important responsibility is to provide the intellectual rationale and framework for developing educational tools that will give all our citizens the basic engineering and technological skills to live in this complex society. But we must also engage local school districts and the Department of Education in this endeavor. The Boston Museum of Science, which received support from NSF for technological literacy, directs the National Center for Technological Literacy and is, I believe, one good example of an approach to take in this regard.

The NSF is not about providing long-term and sustained funding for programs. We provide the support for new ideas, new curricula, new approaches to engineering education and educational pedagogy. We provide that support for targeted programs in schools and institutions with new and creative ideas. The real challenge is twofold. First, we must find the support to continue programs developed under NSF Sponsorship once NSF support is no longer available. Second, and equally important, is to find the means to financially support the dissemination of the best ideas developed through NSF support to a much broader range of institutions and schools. For this, we must rely on individual school districts throughout our country. I believe that the Skyline High School in Longmont, Colorado, mentioned above, is one example that shows promise in this regard.

Mr. Chairman, this concludes my remarks and I would be happy to answer any questions at this time.

APPENDIX

Active Engineering Education projects in the Education and Human Resources Directorate National Science Foundation

- **UTeachEngineering: Training Secondary Teachers to Deliver Design-Based Engineering Instruction** (MSP, 0831811, University of Texas at Austin)

The University of Texas at Austin's Cockrell School of Engineering is partnering with the successful UTeach Natural Sciences program and the Austin Independent School District to develop and deliver UTeachEngineering, an innovative, design- and challenge-based curriculum for preparing secondary teachers of engineering. To meet the growing need for engineering teachers in Texas, and to serve as a model in engineering education across the Nation, UTeachEngineering has the following four professional development pathways to teacher preparedness, two for in-service teachers and two for pre-service teachers: UTeach Master of Arts in Science and Engineering Education (MASEE); Engineering Summer Institutes for Teachers (ESIT); Engineering Certification Track for Physics Majors; and Teacher Preparation Track for Engineering Majors. UTeachEngineering anticipates reaching 650 teachers (80 pre-service and 570 in-service) over the first five years. In the future, it is expected that UTeachEngineering will be sustained as a vital program at the University of Texas at Austin. UTeachEngineering is firmly rooted in current research in the field of engineering education and affords a much-needed opportunity to study the teaching and learning of engineering. While the focused goal of UTeachEngineering is to train a cadre of secondary teachers, the project's vision is that all students are "engineering enabled," acquiring the design and interaction skills that would enable them to be successful in an engineering career should they choose one, while enhancing their lives and participation as global citizens even if they do not become engineers.

- **Partnership for Student Success in Science** (MSP, 0315041, Palo Alto Unified School District)

The Partnership consisting of nine Silicon Valley school districts and San Jose State University's (SJSU) Colleges of Engineering and Education is taking a regional approach to improving science education by building institutional capacity, instructional quality, and student achievement in a major urban region and providing pre-service preparation, new teacher induction, on-going in-service and leadership development for over 1,300 pre-service students and in-service teachers. Elementary and middle school students experience exemplary inquiry and laboratory-based lessons linked appropriately to math, literacy, and technology resulting in higher achievement. Engineering faculty devote time as consultants in middle schools. While they contribute scholarship and content background they also learn by viewing the variety of teaching strategies that serve diverse student needs. Undergraduate engineering education is improved through close collaboration between engineers and teachers.

- **GK–12—Engineering in Practice for a Sustainable Future** (GK–12, 0538655, University of Oklahoma–Norman Campus)

This project builds upon two awards: The Authentic Teaching Alliance (ATA); and the Adventure Engineering (AE). The outcomes from the first two grants include: (1) a dual degree program in engineering education; (2) greater than 50 percent of the undergraduate Fellows were accepted into STEM graduate programs; (3) four competitive grants were awarded to the ATA teachers and Fellows; (4) over 100 teaching and learning modules were developed of which 30 are available through the Internet on the ATA web site; and (5) improvements in the Fellows communications and teaching skills. The current work focuses on the integration of the 100 units referenced to include more utilization of the engineering processes; conducting summer engineering academies (SEA) that would serve to disseminate the material and be professional development opportunities for the teachers; and preparing Future Faculty through a proposed dual STEM education degree between the Colleges of Engineering and Education.

- **NJ Alliance for Engineering Education** (GK–12, 0742462, Stevens Institute of Technology)

The objective of the New Jersey Alliance for Engineering Education (NJAEE) is to create a partnership that promotes the integration of problem-solving, innovation and inventiveness within mainstream high school STEM curricula, while fostering the cross-fertilization of innovative teaching methods across K–12 and university level education. A cohort of graduate engineering students (Fellows) is collaborating with engineering professors, education professionals, and high school STEM teachers to design, develop, and implement innovative and motivating educational modules based on the Fellows' research areas. The modules will be aligned with the NJ science curriculum requirements and will incorporate themes of engineering design, innovation and inventiveness within the STEM curriculum. Stevens Institute of Technology (SIT) faculty, education professionals and Lawrence Hall of Science staff will collaborate in the creation of a new course "Communicating Engineering," which all Fellows will experience. While completing their engineering studies, Fellows will also complete a nine-credit graduate certificate in education from SIT. NJAEE will enhance STEM learning for approximately 11,700 high school students, will provide considerable professional development opportunities to 130 participating K–12 teachers, and will immerse the next generation of engineering professors in innovative teaching methodologies.

- **Transforming Elementary Science Learning through LEGO™ Engineering Design** (REESE, 0633952, Tufts University)

This project involves development, implementation, and evaluation of innovative engineering-based science curriculum for grades 3–5. A major activity is to measure what and how students learn from engineering design challenges tailored to standards-based science concepts. Another aim is to establish best practices for designing engineering curricula that are more effective at promoting students' fundamental understanding of and interest in science content. The third objective is to determine whether engineering contexts improve elementary teachers' practice of science instruction. The research team seeks to advance theory, design, and practice in the emerging field of elementary school engineering education, which they believe can motivate and deepen the learning of science. To accomplish the project goals, researchers are collaborating closely with participating Boston-area teachers to develop a series of curriculum modules that pose engineering design challenges whose solutions require understanding of specific science content. The learning objectives of these modules will be aligned with the National Science Education Standards (NSES) for grades K–4 and the Massachusetts Science and Technology/Engineering Curriculum Frameworks for grades 3–5. The instruction and assessments will be designed according to three sets of requirements: (1) the concerns and experience of the collaborating classroom teachers, (2) the Project 2061 criteria for science curriculum set forth by the American Association for the Advancement of Science, and (3) the analytical, creative, and practical domains of Sternberg's Triarchic Theory of Intelligence. The curriculum will use the LEGO™ MINDSTORMS toolset for prototype construction and ROBOLAB™ software for algorithm development. These instructional materials have been proven to be engaging and authentic tools for children's engineering. The data from teacher and student studies will be analyzed to answer the following three driving research questions: (1) Does engineering-based science instruction improve 3rd–5th grade students' analytical, creative, practical abilities related to science content, as well as their memory of science content? (2) How are the attitude, engagement, and self-efficacy of both teachers and students affected by the use of engineering design problems to teach science? (3) Does the efficacy of engineering based science instruction depend on demographic characteristics of the students? The primary intellectual merit of the proposed activity includes (1) the contribution of needed systematic research on the efficacy of elementary-level engineering education for science instruction, and (2) the development of new and potentially more effective methods for engineering-based science instruction.

- **Exploring Content Standards for Engineering Education in K–12** (Discovery Research K–12, 0733584, National Academy of Sciences) and

  National Symposium on K–12 Engineering Education (Discovery Research K–12, 0935879. National Academy of Sciences)

The National Academy of Sciences is assessing the potential value and feasibility of developing and implementing K–12 content standards for engineering education. The specific objectives of this exploratory project, to be carried out by the National Academy of Engineering (NAE), are (1) to review existing efforts to define what K–12 students should know, (2) to identify elements of existing standards documents

for K–12 science, mathematics, and technology that could link to engineering, (3) to consider how the various possible purposes for K–12 engineering education might affect the content and implementation of standards, and (4) to suggest what changes to educational policies, programs, and practices at the national and State levels might be needed to develop and implement K–12 engineering standards. To accomplish these objectives, the project will conduct literature reviews, two commissioned background papers, three meetings of the project committee, and a two-day workshop to solicit expert views on the subject. The principal product of the project will be a peer-reviewed workshop summary report, which will be distributed to key stakeholders and presented in various professional meetings. This report is expected to set the stage for discussions and future actions related to the establishment of engineering standards.

The National Academy of Engineering and the National Research Council will hold a workshop to disseminate the findings of a privately-funded, two-year study of the status and nature of efforts to teach engineering to U.S. K–12 students. The symposium and other dissemination activities inform key stakeholders about the role and potential of engineering as an element of K–12 STEM education and also inform the programmatic activities of organizations and individuals concerned about engineering education. The report provides a brief history of engineering, reviews the evidence for the benefits of K–12 engineering education, discusses a large number of curriculum projects and associated teacher professional development efforts, summarizes the cognitive science literature related to how students learn engineering concepts and practices, and concludes with the Committee's findings and recommendations. The report is of special interest to individuals and groups interested in improving the quality of K–12 STEM education in the U.S.: engineering educators, policy-makers, employers, and those concerned with development of the technical workforce, as well as those working to boost technological literacy of the general public. For educational researchers and for cognitive scientists, the report exposes a rich set of questions related to how and under what conditions students come to understand engineering and design thinking.

- **Family Engineering for Parents and Elementary-Aged Children** (ISE, 0741709, Michigan Technological University)

Michigan Technological University is collaborating with David Heil and Associates to implement the Family Engineering Program, working in conjunction with student chapters of engineering societies such as the American Society for Engineering Education (ASEE), the Society of Hispanic Professionals (SHP) and a host of youth and community organizations. The Family Engineering Program is designed to increase technological literacy by introducing children ages 5–12 and their parents/caregivers to the field of engineering using the principles of design. The project will reach socio-economically diverse audiences in the upper peninsula of Michigan including Native American, Hispanic, Asian, and African American families. The secondary audience includes university STEM majors, informal science educators, and STEM professionals that are trained to deliver the program to families. A well-researched five step engineering design process utilized in the school-based Engineering is Elementary curriculum will be incorporated into mini design challenges and activities based in a variety of fields such as agricultural, chemical, environmental, and biomedical engineering. Deliverables include the Family Engineering event model, Family Engineering Activity Guide, Family Engineering Nights, project web site, and facilitator training workshops. It is anticipated that 300 facilitators and 7,000–10,000 parents and children will be directly impacted by this effort, while facilitator training may result in more than 27,000 program participants.

- **A Comprehensive Pathway for K–Gray Engineering Education** (NSDL, 0532684, Colorado School of Mines)

The K–Gray Engineering Education Pathway is the engineering "wing" of the National Science Digital Library (NSDL). It provides a comprehensive engineering portal for high-quality teaching and learning resources in engineering, computer science, information technology and engineering technology. Project goals are to: 1) merge NEEDS and TeachEngineering into a unified K–Gray engineering educational digital library, 2) significantly grow high quality resources in the NSDL Engineering Pathway in a sustainable way, 3) align the unified curricular materials with appropriate undergraduate and K–12 educational standards, 4) grow the participation of content providers and users, 5) enhance quality control and review protocols for Engineering Pathway content, and 6) create a nonprofit strategy and partnership for the sustainability of the Engineering Pathway. This project also expands the Pathway's gender equity and ethnic diversity components by cataloging and reviewing curricular resources created by female-centric and minority-serving organi-

zations. The K–Gray Engineering Education Pathway is having far-reaching impact by engaging K–12 communities and institutions of higher education, engineering professional societies, engineering research centers, NSF K–12 programs, and ABET.

- **Engineering Equity Extension Service** (GSE, 0533520, National Academy of Sciences)

The Center for the Advancement of Scholarship on Engineering Education of the National Academy of Engineering will, over a five-year period, implement an Engineering Equity Extension Service (EEES) as a comprehensive research-based consultative and peer mentoring infrastructure in support of enhanced gender equity in engineering education in the U.S. Based on key leverage points identified from the literature, EEES will focus its efforts on bringing expertise in gender studies and the research base on science and engineering education to a) academic preparation for engineering study for students at the middle school (grade 6) through collegiate sophomore levels, b) the out-of-class social environment, c) the in-class social environment, c) curricular content, d) curricular scope and sequence design, e) curriculum delivery and instructional style. A key part of our strategy is reaching those teachers and faculty who do not have an a priori interest in gender equity activities by suffusing attention to gender equity into other core areas of concern. The study team is developing a handbook on proposing and managing engineering education projects and conducting workshops on this topic at national and regional engineering meetings. The handbook will fuse attention to gender equity, engineering education, and project management into a seamless whole.

- **Examining Engineering Perceptions, Aspirations and Identity among Young Girls** (GSE, 0734091, Purdue University)

The primary goal of this research project is to examine girls' (grades 1–5) conceptions of self and engineering and how these conceptions are shaped by their engagement and learning in various engineering activities. More specifically, the study seeks to learn how girls approach, experience, and interact with engineering activities and how their learning informs who girls think they are (what community of practice they participate in) and who they want to be (what communities of practice they aspire to). The context of this research study is Purdue University's Institute for P–12 Engineering Research and Learning (INSPIRE), a new initiative focused on creating an engineering literate society through P–12 engineering education research and scholarship. The specific research questions that guide the study include: 1) What are elementary school children's perceptions of engineering and career aspirations? How do girls' perceptions and aspirations compare to boys' perceptions and aspirations? 2) What do elementary school girls report as who they think they are and who they want to be? How do girls' self-images compare to boys' self-images? 3) What new engineering content knowledge do children construct and are there gender-related differences in the new knowledge children construct? and 4) What is the relationship between girls' perceptions, career aspirations, identity development, and learning in engineering? Using a mixed-methods approach (Engineering Identity Development Scale [EIDS], Pre/Post Engineering Knowledge Tests, semi-structured interviews, and document review), the three year study measures individual differences in relational, school, and occupational identity; engineering perceptions and aspirations; and engineering content knowledge construction through problem solving and modeling. The research team works with elementary school teachers and students from school sites in Detroit, MI and Lafayette, IN.

- **Girls Understand, Imagine, and Dream Engineering** (GSE, 0735000, Girl Scouts of the USA)

Girl Scouts of the USA (GSUSA) is developing three separate culturally-relevant parent/girl engineering career toolkits entitled "GUIDE—Girls Understand, Imagine and Dream Engineering," for dissemination to African American, Native American and Hispanic parents and their daughters ages 13–17. The goal of this informal education resource is to inform and engage parents from the three racial/ethnic groups about engineering in a culturally-relevant manner, so that they may take an active role in encouraging their daughters to consider engineering careers. The GUIDE Toolkit will consist of: (1) the GUIDE Handbook, a customized, culturally-appropriate engineering career resource for use with both parents and girls; and (2) GUIDE Workshops to introduce the GUIDE Handbook to parents and girls from the target racial groups at Girl Scout councils and the larger community.

BIOGRAPHY FOR THOMAS W. PETERSON

Thomas W. Peterson is Assistant Director of the National Science Foundation, for the Engineering Directorate. Prior to joining NSF, he was Dean of the College of Engineering at the University of Arizona. He received his B.S. degree from Tufts University, M.S. from the University of Arizona, and Ph.D. from the California Institute of Technology, all in Chemical Engineering. He has served on the faculty of the University of Arizona since 1977, as head of the Chemical and Environmental Engineering Department from 1990–1998, and as Dean from 1998 until January 2009.

During his service as Dean, Dr. Peterson was a member of the Executive Board for the Engineering Deans' Council of ASEE, and was Vice-Chair of EDC from 2007–2008. He has served on the Board of Directors of the Council for Chemical Research, and on the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET). He was one of the founding members of the Global Engineering Deans' Council, and at Arizona made global education experiences a high priority for his engineering students. He is a Fellow of the American Institute of Chemical Engineers and a recipient of the Kenneth T. Whitby Award from the American Association for Aerosol Research.

The Engineering Directorate at NSF provides critical support for the Nation's engineering research and education activities, and is a driving force behind the education and development of the Nation's engineering workforce. With a budget of approximately $640 million, the directorate supports fundamental and transformative research, the creation of cutting edge facilities and tools, broad interdisciplinary collaborations, and through its Centers and Small Business Innovation Research programs, enhances the competitiveness of U.S. companies.

Chairman LIPINSKI. Thank you, Dr. Peterson.

Dr. Miaoulis.

STATEMENT OF DR. IOANNIS MIAOULIS, PRESIDENT AND DIRECTOR, MUSEUM OF SCIENCE, BOSTON; FOUNDING DIRECTOR, NATIONAL CENTER FOR TECHNOLOGICAL LITERACY

Dr. MIAOULIS. Mr. Chairman, Ranking Member Ehlers and Members of the Committee, I would also like to thank you for calling this hearing and inviting me to share my experiences. K–12 engineering has been my passion since 1993. I was then the Dean of the School of Engineering at Tufts University, and now my passion continues as President and Director of the Museum of Science in Boston.

We claim that science is a discipline that teaches children about the world around them, but I would like you to take a look at this room and tell me how many things you see around you are natural things and how many are human made, and I would argue that about 98 percent of the world around us is human made. If you look at the science curriculum in schools, it is primarily focused on the natural world, so it captures pretty much two percent of the world of children, and we leave out 98 percent. So understanding 98 percent of the world around us, I would argue, is basic literacy, and is not an extra. So technological literacy is basic literacy. But there are a few other reasons why engineering should be part of the formal curriculum.

Engineering offers a wonderful vehicle for problem solving and project-based learning, pulling all the other disciplines together and bringing them to life. It brings, in particular, math and science to life and makes them relevant, and we all know that relevance in science is what attracts or retains girls in science. If you look at the science fields that women gravitate to, they are the ones that truly benefit the world, like medicine, veterinary medicine, life sciences, environmental engineering. Also, by introducing engineer-

ing into schools, we will ensure that we have a technologically literate and diverse workforce. Seven out of 10 U.S. engineers have had a relative that is an engineer, so it is parents that mentor the kids to become engineers. And popular television does not help either, because for all of the wonderful popular shows that glorify wonderful professions such as law and medicine, there are no real engineers in popular TV to encourage kids to go into engineering. Actually, the only engineer in prime time TV is Homer Simpson from the Simpsons, the cartoon, which is unfortunate. By introducing engineering as a main discipline, kids of all ethnic groups would know what it is and they can choose to pursue it or not.

At the National Center for Technological Literacy, which is housed within the Museum of Science, we do three things to promote engineering literacy nationwide, and, please, if I could have the slide so that we are all looking at it as I am speaking. I would appreciate it.

[See slide in written statement.]

So we do three things. First, we create curriculum. We have, I would argue, probably the broadest and most diverse curriculum development effort for children in engineering in the world. We have an elementary curriculum that is being used by over a million children, including the children at Mr. Sandlin's school, actually, in Texas. They are using our curriculum. And we have also middle school and high school engineering curricula. This is all standard-based, research-based engineering curricula that integrates mathematics and science. We also have an extensive number of pre-service and in-service workshops for teachers. Our model is to develop partnerships nationwide. We have dozens of partners at university science centers, corporations that do professional development of teachers in the region. We also work with universities to assist in developing curriculum for future teachers, and we also have an extensive advocacy effort both at the State level—we work with many State legislative bodies and departments of education—as well as federal entities, such as the National Governors Association, to introduce engineering standards, assessments and programs.

There are a few challenges, of course, with this initiative. There is apprehension and fear. Engineering for many people is a scary word. Some believe it is not for young children. I don't agree with that. You can do engineering at different levels like you can do physics at different levels. There is a lack of resources. Although there is a lot of talk and enthusiasm about STEM, all the money goes to the SM of STEM, the science and the math, and the T and E are left out. So there is still a lack of resources.

There is concern over lack of time to teach engineering. Well, our children spend about a month during middle school learning how a volcano works, and spend no time learning how a car works. How much time do you have to spend on a volcano compared to a car in your life, and why should we spend a month learning about volcanoes and no time learning about cars? And don't get me wrong; I think volcanoes are a wonderful way to teach plate tectonics, which is very important for children to learn, but I would argue that we could make some space to teach engineering as well.

Here are three recommendations. First, that we increase funding on professional development of teachers to enable them to include

engineering in their teaching and to enable informal science organizations such as science museums and science centers to provide such support. The second recommendation is to provide resources for development of more curriculum and materials. And the third is to support legislation that would provide states planning grants to figure out how they would introduce engineering in their formal standards and assessments; implementation grants after they have the plan down of how they are going to do it, to actually support funding teacher professional development and curriculum materials; and also support evaluation studies so that we can build research that will help us understand how we should introduce engineering better for children. Thank you very much.

[The prepared statement of Dr. Miaoulis follows:]

PREPARED STATEMENT OF IOANNIS MIAOULIS

On behalf of the Museum of Science, Boston and our National Center for Technological Literacy (NCTL), I applaud Chairman Lipinski and the Members of the Subcommittee for holding this hearing on the occurrence and effect of K–12 engineering education. This has been my passion and focus for the past 20 years.

The Museum of Science, Boston is one of the world's largest science centers and 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 186,000 students and 100,000 more in traveling and overnight programs. The goal of the NCTL is to introduce engineering into K–12 classrooms nationwide.

Why K–12 Engineering?

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

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

Lately, K–12 math and science education has received a lot of attention, while K–12 technology and engineering education has been largely overlooked. The problem is that the school science curricula still focus more on the natural, not the human-made or technological, world, and have taught little or no engineering. The beauty of engineering is that it is the connector that uses science and math to create the technological innovations that facilitate daily experience.

Our curricula frameworks were established in the nineteenth century society, when the society was largely agrarian—no phones, automobiles, or computers. Obviously, our world has changed but most curricula have not, leaving a huge gap in students' learning. While most people spend 95 percent of their time interacting with technologies of the human-made world, few know these products are made through engineering. We need to add technology and engineering as standard subjects in U.S. schools.

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

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

Second, engineering brings math and science to life, demonstrating that they are relevant subjects thereby motivating students to pursue them. Relevance is particularly significant for girls and other under-represented groups. Engineering pulls together many other disciplines, including math, science, language arts, history, and art, engaging children of differing abilities in problem-based learning, where teamwork is important.

Third, to create a diverse, technologically literate workforce, we need to support engineering in K–12 schools. Most engineers will tell you they were inspired by an engineer in their family. Unfortunately, the engineering profession is not diverse—we are mostly white men. Therefore, many children are not exposed to such role models nor have access to enhancement experiences which will lead them to pursue engineering careers. To break this cycle, expand opportunities, and diversify the profession, we must offer engineering education in K–12 classrooms to make those careers more desirable and accessible to all children from all backgrounds.

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

However, according to, *Technically Speaking: Why All Americans Need to Know More About Technology* (National Academy of Engineering/National Research Council, 2002, page 1), "Although the United States is increasingly defined by and dependent on technology . . . its citizens are not equipped to make well-considered decisions or think critically about technology." The report also said, "Neither the educational system . . . nor the policy-making apparatus has recognized the importance of technological literacy." Far beyond a facility with computers, "technological literacy" involves understanding what technology is, how it is created, and how it influences our lives. To paraphrase from *Technically Speaking* (page 4), a technologically literate person should:

- recognize technology in its many forms;
- understand basic engineering concepts and terms such as systems, constraints, and trade-offs;
- have a range of hands-on skills in using a variety of technologies;
- know that people shape technology and technology shapes behavior;
- know there are risks and benefits in using or not using technology to solve problems; and,
- be able to use math concepts to make informed decisions about technological risks and benefits.

An important goal of engineering education is to introduce students to engineering as a profession which takes skill, creativity, and knowledge of science and mathematics, but which novices can begin to practice in an intellectually honest way, just as they can practice scientific inquiry at an amateur level in an intellectually honest way. We want students to feel that engineering design can be fun, can help people, and is worth learning to do better. In addition, we want them to be exposed to the enormous range of technologies in use today, as well the enormous inheritance they receive of accumulated design know-how. Engineering is ongoing, and can be used to solve human problems. These are goals worthy of students' time and effort.

Understanding the importance of technological literacy and the need for trained engineers, the Museum of Science launched the National Center for Technological Literacy in 2004 to enhance knowledge of engineering and technology for people of all ages and to inspire the next generation of engineers and scientists. A detailed description of our work follows the Challenges and Recommendations sections.

Challenges

While the NCTL has made tremendous progress in advancing K–12 engineering education in Massachusetts and in an increasing number of states, we have encountered a number of challenges that can be overcome.

Because K–12 engineering education is not terribly widespread, the one challenge lies in the sense of apprehension and misunderstanding by teachers and administrators. Engineering may frighten some teachers, especially those uncomfortable with science. However, once they have received our training, which ranges from a day and a half to three weeks, most are excited and willing to implement.

Through our professional development training, we explain that the engineering design process is similar to scientific inquiry that explores the natural world, except that engineering explores the human-made world (see comparison chart in appendices). This provides a frame of reference and comfort level. We do not expect our teachers to teach something as complex as tribology and finite element analysis. We do want them to expose students to open-ended problem-solving using limited resources or designing under constraint.

Lack of appropriate resources is another challenge. Schools and teachers need access to effective instructional materials and hands-on kits so students can actually apply their skills.

Some argue there is no time to add a new topic to an already packed school year. They express concern that adding another subject or topic will simply extend the content rather than allow deeper exploration. Our engineering curricula allow students to multi-task—applying science, math, language arts, and technology in engineering design challenges thereby covering multiple subjects at once. As one elementary teacher says, "it's an add-in, not an add-on."

Another concern we hear is that there are no separate engineering education standards for curricula development, teacher preparation, student achievement, etc. Some advocate for the creation and implementation of new separate K–12 engineering standards and assessments. Some advocate the revision of existing standards including math, science and technology standards to incorporate and integrate engineering education. The National Academies of Engineering is currently studying these options and that report is due to be published next year. We support the integration of engineering in all grades, particularly in science and math, and separate courses for both middle and high school students.

It is important to note, on the assessment front, that the National Assessment of Educational Progress—Science 2009 will include a number of items that will assess student technological design skills. Further, the National Assessment Governing Board is currently developing a Technological Literacy study that will likely assess design and systems thinking, as well as information and computer technology literacy, and technology and society.

Another challenge is the lack of recognition by some policy makers and education leaders that K–12 engineering education is taking place in classrooms across the Nation and that positive results are occurring. This is further complicated by the fact that there are no existing federal programs to specifically support K–12 engineering education in core academic classrooms. Many agencies espouse support for STEM programs; however, most focus on science and math to the exclusion of technology and engineering. While the National Science Foundation, which has awarded several grants to the Museum and the NCTL, and other science and engineering agencies support STEM education, there are no specific programs designed to help all states pursue K–12 engineering education nor has there been any large scale research programs to measure the efficacy of the various curricular programs.

Recommendations

To respond to these challenges, we encourage the Chairman, the Committee and the Congress to consider legislation that will further implementation and research of K–12 engineering education. We suggest a three part grant program that would allow states to plan and to implement K–12 engineering education more broadly in their schools and to participate in a large scale evaluation. We suspect this research will confirm the promising preliminary results uncovered by the National Academy of Engineering K–12 Engineering Education study group and provide tremendous guidance to future development and implementation of K–12 engineering education, student learning and STEM, career aspirations.

Furthermore, as Congress considers revising the *Elementary and Secondary Education Act,* we suggest the following:

- Allow informal STEM education centers and other non-profit educational organizations to receive funds for teacher professional development;
- Expand and rename the Math/Science Partnerships to STEM Partnerships to include technology and engineering educators in teacher professional development opportunities;
- Encourage states to adopt technology and engineering standards and assessments;
- Encourage states to include technology and engineering in the definition of "rigorous curricula" for high school graduation;
- Expand the definition and requirement for "technology literacy" to go beyond the use of computers to include the engineering design process;
- Include engineering/technology teachers alongside math/science teachers in all incentive programs to recruit, train, mentor, retain, and further educate teachers; and
- Support after-school programs that include technology and engineering activities.

National Center for Technological Literacy: Mission and Function

The NCTL is integrating engineering as a new discipline in schools via: 1) standards-based, teacher-tested K–12 curricula development; 2) pre-service and in-service

teacher professional development and leadership training programs; and, 3) advocating for aligned standards, assessments, and policies promoting K–12 engineering education. The Museum of Science is the only science museum in the country with a comprehensive strategy and infrastructure to foster engineering education and technological literacy in both K–12 schools and science museums nationwide.

I. Curricula Development

Our curricula follow in large measure the three core principles for K–12 engineering education recommended in the recent report by the National Academy of Engineering (NAE) and the National Research Council (NRC), *Engineering in K–12 Education: Understanding the Status and Improving the Prospects.* Our materials: 1) emphasize the engineering design process; 2) incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills; and, 3) promote engineering habits of mind including systems thinking, creativity, collaboration, communication and attention to ethical considerations.

The curricula we create are not intended to replicate college level sources. We intend to impart habits of mind that include an engineering design process, optimization, efficiency and economy. It allows students to apply their math and science skills to solve community-based problems. It opens their minds to a variety of technology and engineering careers they may have never heard of before. It demonstrates that all students are capable of engineering.

An early project of the NCTL was to examine existing K–12 engineering curricula. Our online *Technology and Engineering Curriculum Review* includes instructional materials in a searchable database. The most promising have been peer reviewed and mapped to national standards. During this review process, we discovered that very little was available to address the elementary grades. *www.mos.org/TEC*

Our philosophy is that children construct a much deeper understanding of the world around them, including science, technology, and engineering, when they interact with meaningful, challenging activities. The NCTL curricula development team performs a detailed curriculum development process that is based heavily on, *Understanding by Design* (Wiggins & McTighe, 1998).

For example, each of our elementary units entails more than 3,000 hours of development over the course of two years. In addition to this development time, units are pilot tested across Massachusetts and field tested across the United States. A typical unit development cycle begins with background research and ends with a unit release two years later.

A major focus of our work is to expand interest in engineering across all demographics. Our curricular resources emphasize diversity, including both genders, and people of races, ethnic backgrounds, physical abilities, and cultures. We also work to integrate with other topics including science, mathematics and language arts.

The *Engineering is Elementary* series is closely aligned with popular elementary science topics and is steeped in language arts. The middle school series, *Building Math,* integrates algebra with engineering design challenges and is typically taught by math teachers and also used in technology education classes. The new middle grades series, *Engineering Today,* is aligned with science subjects. *Engineering the Future* is a full year course that is taught by either technology/engineering educators or physics teachers.

A. Engineering is Elementary®

The Engineering is Elementary (EiE) project integrates engineering and technology with science, language arts, social studies, and mathematics via storybooks and hands-on design activities. Each unit begins with an illustrated storybook, in which a child from a different country uses the engineering design process to solve a community-based problem, and includes four lessons. Elementary school teachers nationwide can use these curricular materials to teach technology and engineering concepts to children in grades 1–5. The development of this series is funded in large measure by a National Science Foundation Instructional Materials Development grant as well several corporate sponsors.

The NAE report, *Engineering in K–12 Education,* cites EiE as one of the curricula offering the "most comprehensive" resources to support implementation. Materials "are clearly written to enrich and complement existing instruction . . . the emphasis on literacy is especially noteworthy." 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 . . . the idea that engineers combine creativity with their knowledge of math and science to solve problems is introduced and reinforced."

As of May 14, 2009, EiE had reached 15,660 teachers (750 in MA) and 1,021,725 students in 50 states and Washington, DC. Of those states, 34 have a significant presence with larger orders and professional development participants. Sales have also reached over one million dollars over the five years of sales. The receipts are reinvested into the enhancement and implementation of the curricula. These units can be obtained at *www.mos.org.eie*.

B. Building Math®

Building Math, created with Tufts University, provides innovative practices for integrating engineering with math to help middle school students develop algebraic thinking. *Building Math* consists of three middle school instructional units that uniquely integrate inquiry-based mathematics investigations and engineering design challenges. The engineering design challenges provide meaningful and engaging contexts to learn and use mathematics, and to develop students' teamwork, communication, and manual skills. The mathematics investigations yield useful results to help students make informed design decisions.

Building Math was pilot tested in Massachusetts and has sold almost 1,900 units and is estimated to reach almost 95,000 students. Six states have ordered more than 100 units and the curriculum is placed in 42 states at some level.

According to *Engineering in K–12 Education,* the units are "very deliberative in their use of contextual learning to make the study of math more interesting, practical, and engaging." The math activities have a "direct bearing on the solution to the problem." The materials are also "very consistent" in using the engineering design process to "orchestrate learning." The "richest" portion of the design process involves doing research and testing the final design and the "richest" analysis in the materials involves interpreting data and discovering "quantitative patterns and relationships."

Awarded the 2008 Distinguished Curriculum Award by the Association of Educational Publishers, the *Building Math* series for grades 6–8 are available from Walch Publishing *www.walch.com*.

C. Engineering Today: New Middle School Series

The NCTL is developing a new series of middle-school supplemental units that meet engineering and science standards by integrating the two subjects. Introduced by *WGBH Design Squad* reality TV shows, the hands-on units engage students in engineering design challenges that are informed by the relevant science topics. Students work in teams to tackle the challenges and learn about engineers and scientists who work on similar projects in the U.S. Department of Defense laboratories. It will focus on 10 areas including communications, energy, aerospace, bioengineering, construction, and transportation. Pilot testing will begin in Fall 2010.

D. Engineering the Future(r): Science, Technology, and the Design Process:

This standards-based, full year course engages high school students in hands-on design and building challenges reflecting real engineering problems. The textbook, narrated by practicing engineers from various ethnic and cultural backgrounds, encourages students to explore what engineering and technology are and how they influence our society. According *Engineering in K–12 Education,* one of the most prominent features of this curriculum is the "emphasis placed on people and story telling." All the laboratory 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."

Engineering the Future is currently taught in over 25 states. Over the past three years, on site and online professional development has been delivered to more than 500 teachers. Preliminary studies show that students increase their understanding of engineering in all four *Engineering the Future* units. The *Engineering the Future* textbook and related materials are available from Key Curriculum Press *www.keypress.com.etf*.

E. Efficacy

Our curricula development process incorporates research, evaluation, and assessment into all aspects of its design and testing. During the development, pilot and field testing, students complete pre-and post-assessments that measure pupils' understandings of engineering, technology, and science or math concepts. Most of our post-implementation research has focused on EiE and to a lesser extent, *Building Math*.

National, controlled studies indicate that children who engage with engineering and science through EiE learn engineering, technology, and related science concepts significantly better than students who study just the science (without engineering). This was true for both sexes and all racial/ethnic groups. They were also more positive about the prospect of being an engineer after participating in EiE.

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

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

In summary, EiE students:

- are much more likely to correctly answer science content questions relating to the unit after completing an EiE unit;
- are much more likely to correctly identify the work of the field of engineers related to the unit on the post-assessment after completing an EiE unit;
- are much more likely to correctly identify relevant aspects and types of technologies featured in the unit after completing an EiE unit;
- demonstrate a much clearer understanding of relevant criteria for a design, as well as how to judge a design against those criteria, after completing the *Designing Plant Packages* or the *Evaluating a Landscape* unit;
- are significantly more likely to choose a more scientific method for answering a hypothetical question after completing the *Designing Plant Packages* unit;
- show that they understand what a model is after completing the *Evaluating a Landscape* unit;
- demonstrate a clearer understanding of materials, their properties, and their uses in different engineering design scenarios after completing the EiE unit *Designing Maglev Systems*; and
- show evidence of increased data analysis skills after completing the *Designing Maglev Systems* unit.

EiE 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. All EiE research can be found here: *www.mos.org/eie/research_assessment.php#formalfindings*

At the Science and Technology Committee field hearing in Texarkana, then Assistant Director of the NSF, Education & Human Resources Directorate, Dr. Cora Marrett noted, "Studies show that children using the Engineering is Elementary materials gain in their understanding of engineering and science topics, compared to children not using the materials. In addition, children in the experimental group come to know what engineers do and what technology entails . . .. Initial research suggests that this approach has been successful in helping young children envision themselves as engineers."

With the *Building Math* units, students engage in algebraic reasoning by modeling physical phenomena, analyzing change in both linear and non-linear relationships, extrapolate and interpolate data based on trends, describe the shapes of graphs within meaningful contexts, represent data in tables and graphs, and generalize patterns.

Our research shows that when engaged in *Building Math* design challenges, middle school students at different grade levels use algebraic reasoning when analyzing changing rates of an exponential function, interpret slope in a meaningful context, and use a mathematical model to make reasonable predictions. They then use this understanding to inform their engineering designs to meet the criteria and constraints of the challenge. (ASEE, 2008)

Integrating algebra and engineering can be done effectively by having math be essential to informed engineering decisions. A contextual approach for the units provides engagement in the activity, especially when students can learn together in small groups. Through the *Building Math* activities, students can find meeting the engineering design challenges satisfying without being overly competitive. The findings from this analysis indicate that it is possible to make non-linear, exponential functions accessible to students of different grade levels using different approaches.

II. Professional Development

While science centers and museums are known to spark life-long interest in and understanding of science, engineering, mathematics, and technology, few appreciate the extent to which these informal science education organizations impact the formal education setting. Science centers and museums have resources that many schools do not and offer interactive, professional development activities that support school curriculum.

The Museum of Science and the NCTL routinely work with school districts to bring the excitement of the science, technology and engineering 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.

We understand that professional development necessitates partnership. We work closely with local or State agencies to provide professional development for teachers about engineering and technology. We employ a train-the-trainer model, working jointly with teacher educators to help them better understand core engineering and technology concepts, how to most effectively communicate these to other teachers, and how to structure and run workshops about engineering and technology.

We also work with other educational institutions to offer professional development opportunities. Two such partnerships are noted below:

- The NCTL is working with three Massachusetts community colleges to help educate pre-service elementary teachers with a three-year NSF Advanced Technology Education grant. The Advancing Technological Literacy and Skills (ATLAS) Project builds their understanding of technology and engineering content and teaching tools in community college course work. 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 includes 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 technology and engineering pedagogy to colleagues across the state. More details can be found here: *www.mos.org/eie/atlas/index.php*
- 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 is making its curriculum materials and training available to VCSU via this innovative online teacher certification program.

The NCTL's train-the-trainer approach to professional development helps teacher educators understand engineering and technology concepts, communicate them to other teachers, and run workshops. The NCTL has worked with teacher educators from over 25 states and Washington, DC, through institutes and online courses to familiarize them with engineering and lead professional development workshops in their region. A list of our educational partners appears in the Appendices.

We also conduct education leadership training for school and district administrators. The Gateway to Engineering and Technology Education project builds a community of school and district leaders in sharing best practices, experiencing hands-on engineering activities, and helping each other solve problems in order to implement technology and engineering standards. An Institute of Museum and Library Services grant allowed us to support 50 school district leadership teams over the first three years. Participant district leadership teams collaborated during summer institutes, call-back days and online forums with other Gateway teams.

In Massachusetts, the Gateway program has reached nearly 300 teachers and administrators and 319,028 students (34.1 percent of MA public school enrollment). This Gateway model is being used in a partnership with Maine Math and Maine Mathematics and Science Alliance and Transformation 2013 in Austin and San Antonio, TX.

The Museum and the NCTL 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. 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.

III. Advocacy

Another function of the NCTL is advocacy. We work to develop policy and programs to support the advancement of K–12 technology and engineering education. We work at all levels of government to inform policy makers of the benefits of engineering education and how they can help promote and sustain it. We also work with like-minded organizations to further K–12 technology and engineering education across the Nation.

We have been involved in the following advocacy efforts: 1) incorporating questions on technological design alongside those on scientific inquiry in the National Assessment of Educational Progress (NAEP) Science Framework for 2009; 2) the National Governors Association STEM agenda which calls for the adoption of technology and engineering standards and assessments, among other things; 3) the *America COMPETES Act,* which creates opportunities for technology teachers and engineering instruction at several federal agencies; and 4) the Higher Education Act expands the definition of "technology literacy" to include the engineering design process.

In 2001, I had the privilege of working with the State of Massachusetts to develop the first statewide K–12 curriculum framework and assessments for technology and engineering in the Nation. While forty states address technology education in their standards (often found I career and technical education standards), several states are also moving to include engineering in their core academic State standards. The NCTL has been in contact with people interested in K–12 education in all 50 states and Washington, DC, in various ways. We have worked specifically with New Hampshire, Minnesota, North Carolina, Ohio, Florida, Oregon, and Washington in revising State standards to include engineering in some form.

Conclusion

Thank you for the opportunity to present our efforts to promote, develop and implement K–12 engineering education across the Nation. The National Center for Technological Literacy stands ready to assist in re-engineering today's schools, inside and out. Please visit our web site, *www.nctl.org*. If we can provide any additional information, please let me know.

Appendices

1. Inquiry and Design

Scientific Inquiry	Engineering Design
Formulate a question.	Define a problem.
Research how others have answered it.	Research how others have solved it.
Brainstorm hypotheses and choose one.	Brainstorm solutions and select one.
Conduct an experiment.	Create and test a prototype.
Modify hypothesis based on results.	Redesign solution based on tests.
Draw conclusion, write paper.	Finalize design, make drawings.
Submit paper for peer review.	Present optimal solution to client.
Ask new question	Define new problem.

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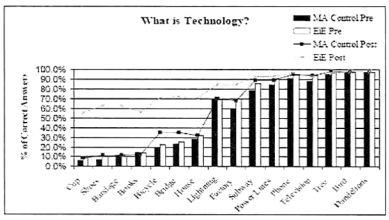
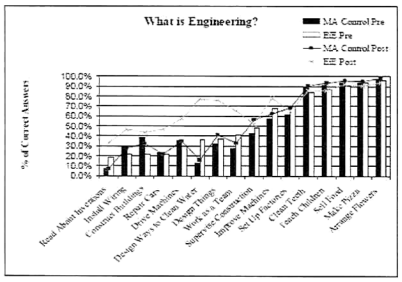
2. Engineering is Elementary Results



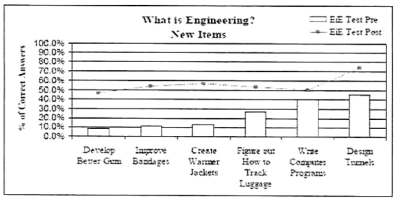
What is Technology?

Students were asked to identify 12 of 16 items that were forms of technology. Of the 9 items that were more difficult to classify - cup, shoes, bandage, bicycle, house, lightening, & factory - EiE students improved significantly.



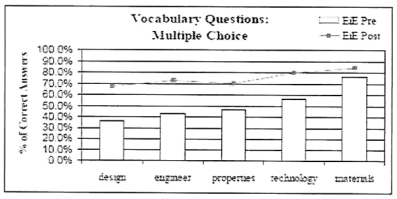
What is Engineering?

Students were asked to identify things that engineers might do on the job. EiE students showed significant improvement on 10 of the 16 items. The others were too easy. Where comparison to a control sample is available, EiE students have, for the most part, performed significantly better than the control students.



Myth Busters

More EiE students think that engineers might read about inventions, work and design as a team, and fewer think engineers drive machines, repair cars, install wiring or construct buildings.



Getting it Right!

EiE students were significantly more likely to choose the correct vocabulary word on the post-assessment than on the pre-assessment. Control students did not receive these questions so there is no comparison available.

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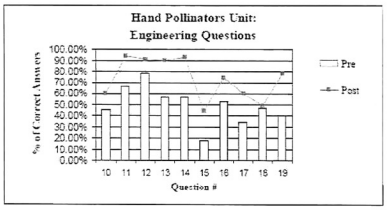
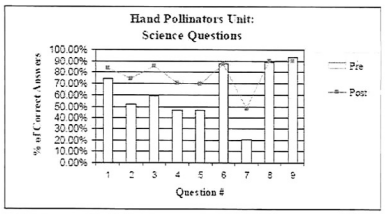


Elementary Students Learn Engineering!

Engineering is Elementary students consistently showed improvement—frequently dramatic improvement—on post-assessments designed to assess student understanding of science and engineering concepts.



Science Achievement Enhanced

Students were asked a series of questions about the roles of insects, plants, and parts of plants in the pollination process and whether sunlight, insects, people, and water are needed by plants to survive. On the more difficult science questions, EiE students improved significantly. Questions 6, 8 & 9 were too easy and not useful.

3. States that have purchased NCTL Curricula

Engineering is Elementary is in all 50 states and DC.

Building Math is in: AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, IL, IN, KY, LA, MA, MD, MI, MN, MO, MS, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, TN, TX, VA, VT, WA, WI.

Engineering the Future is in: AL, CA, CT, FL, GA, MA, MD, MI, NC, ND, NH, NJ, NY, OH, PA, RI, SC, TX, VA, VT.

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4. **National Center for Technological Literacy Funders**

Total: $57.4 million as of August 24, 2009 for formal and informal education efforts.

Federal Funding
Institute of Museum and Library Services
National Aeronautics & Space Administration
National Institute of Standards and Technology
National Science Foundation
U.S. Small Business Administration

State Partners
Massachusetts Board of Higher Education
Massachusetts Department of Elementary and Secondary Education
Massachusetts Technology Collaborative

Foundations
Boston Foundation
The Cargill Foundation
GE Foundation
Gordon Foundation
The Highland Street Foundation
Harvard Pilgrim Health Care Foundation
The Charles Hayden Foundation
S.D. Bechtel, Jr. Foundation
Stephen Bechtel Fund
Massachusetts Biotechnology Education Foundation

Corporations
AeroVironment, Inc.
Cisco Systems, Inc.
E.I. du Pont de Nemours & Co.
GreenFuel Technologies Corporation
Hewlett-Packard Company
Intel Corporation
Liberty Mutual
Lockheed Martin Corporation
Mercury Computer Systems, Inc.
Millipore Corporation
Novartis Institutes for BioMedical Research, Inc.
Philips Medical Systems
Teradyne, Inc.

Individuals
Sarah and Jeffrey Beir
Mr. and Mrs. Richard Burnes, Jr.
Mr. and Mrs. Paul Egerman
Paul Howley
Dr. and Mrs. Donald Kaplan
Segundo and Laura Mateo
Mr. and Mrs. Raymond C. McAfoose
Carolyn W. Miller
Dr. Leo Liu and Dr. Pendred Noyce
Mr. and Mrs. Ira Stepanian
Mr. and Mrs. Henri A. Termeer
Alice and A. Zaff
Mr. Michael J. Zak and Mrs. Roxanne Zak

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5. Formal Educational Partnerships

Building Engineering and Science Talent/NDEP
Maine Mathematics and Science Alliance
Minnesota Department of Education
New Hampshire Department of Education
Stevens Institute of Technology, NJ
Transformation 2013: Education Service Center (ESC) Region 13 – Austin, TX and ESC Region 20 - San Antonio,TX
Valley State City University, ND
Villanova University College of Engineering, PA

Educational Collaborations

Aldine Independent School District, TX
Charles Dana Center, Austin, TX
ESC Region 1 – Edinburg, TX
ESC Region 3 – Victoria, TX
ESC Region 4 – Houston, TX
ESC Region 9 - Wichita Falls, TX
ESC Region 11 - Fort Worth, TX
ESC Region 12 – Waco, TX
ESC Region 16 – Amarillo, TX
ESC Region 18 – Midland, TX
Falcon School District #49, CCO
Georgia Department of Education
Hofstra University, NY
Long Beach Unified School District, CA
Massachusetts Department of Elementary and Secondary Education
Minorities in Mathematics, Science, and Engineering, OH
Mobile Area Education Foundation, AL
Montgomery County ESC – Dayton, OH
North Carolina State University
National Governors Association, Center for Best Practices
North Central Texas College
Ohio Department of Education
Oregon Museum of Science and Industry
Oregon State University
PA Department of Education
Purdue University, IN
Putnam County Education Service Center, OH
Sally Ride Academy, WI
Science and Math on the Move Center, OH
Science Museum of Minnesota
Stark County Education Service Center, OH
Texarkana ISD, TX
Towson University, MD
Tufts University, MA
University of Louisville, KY
University of Maryland Baltimore County
University of Alabama, Huntsville
University of Cincinnati, OH
University of Texas - Austin
Vermont Department of Education
Wichita Falls ISD, TX
Worcester Polytechnic Institute, MA

Biography for Ioannis Miaoulis

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.

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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 together interested parties in government, industry, and education 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 179 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 15,600 teachers and one 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 over 25 states. A *Building Math* middle school course, created with Tufts University, has reached teachers and almost 95,000 students in 42 states (plus Washington, DC).

Under Miaoulis' 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 technological literacy. Examples include the 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 Fel-

lowship. 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 is also on Mass. Governor Deval Patrick's Commonwealth Readiness Project Leadership Council, charged with creating a plan to improve statewide public education. Miaoulis is a member of the Boards of Trustees of Wellesley College and Tufts University and in 2007 was appointed to the NASA Advisory Council by NASA Administrator Michael Griffith.

Chairman LIPINSKI. Thank you.

Dr. Pines.

STATEMENT OF DR. DARRYLL J. PINES, NARIMAN FARVARDIN PROFESSOR AND DEAN, A. JAMES CLARK SCHOOL OF ENGINEERING, UNIVERSITY OF MARYLAND, COLLEGE PARK

Dr. PINES. Good morning, Chairman Lipinski and Ranking Member Ehlers and other distinguished Members of the Subcommittee and all who are concerned about STEM education, especially in the K–12 area. My name is Darryll Pines and I am the Nariman Farvadin Professor and Dean of A. James Clark School of Engineering. I want to thank you for inviting me.

The Clark School attracts a large number of outstanding young people from the highly regarded Maryland school system and also the Maryland private school system as well as from excellent schools across the country and around the world, in fact. We have created an array of programs to interest these younger students in engineering and develop insights concerning the inclusion of engineering concepts and approaches to their pre-college education. One simple but important insight is the following fact: In K–12 engineering education, proper pacing and mentorship are crucial. By engaging students at the proper level at the proper time with the proper mentors, schools can ensure that students are neither intimidated by the difficulties of engineering nor deluded that engineering means dreaming up ideas about creating, analyzing, testing and refining a solution using math and science. With proper pacing and mentors, we can inspire students with engineering potential for a positive impact in the world while beginning to train them in the skills they would need to make that impact. To achieve these goals, the Clark School and other university programs must do a better job of educating high school and middle school teachers about the field of engineering, academic requirements for engineering students as well, and the proper level of engineering concepts to include in their lesson plans.

To answer the first question that was posed by the Committee, a successful undergraduate engineering student should graduate with the following attributes: number one, high awareness of the areas in which engineering can impact our quality of life; number two, time spent in direct work in one or more of the areas through related research, internships or voluntary service programs; number three, the entrepreneur skills and confidence to organize and launch an initiative in one of those areas number four, the ability to solve open-ended problems by applying engineering methods, mathematics and the sciences; number five, the ability to focus on a problem and imagine one or more ways to solve it; number six, a strong work ethic and the ability to learn autonomously; number seven, skills in communicating with professionals and laypeople;

and number eight, the ability to work alone or in teams or to lead when necessary. To ensure that undergraduates possess these skills and attributes on graduating from college and to increase the number who do graduate, we must first ensure that high school students come to us possessing all of these skills in some part and to some degree and the last five to a high degree. A useful example of the boundary between high school and college is a project that is commonly implemented in high school science or engineering courses—that is, the making of a truss bridge. In high school, students will build a truss bridge based on how they think it should look, how they think they can make it stronger, relying really on their experience and their intuition. This is appropriate for high school for middle school. However, in a mechanics class in college, students will learn the concepts of stress and strain, axle loading, material properties and other concepts that allow them to design the truss, then build it rather than simply putting something together to see how it stands up to a load. This is expected and appropriate for students that are in college.

In response to Question 2, pre-college engineering education can inspire students with the potential of engineering to improve our world and prepare them for the challenges of the university engineering program. First, schools must identify students who are proficient in mathematics and science. Without proficiency, students cannot succeed in the field of engineering. Next, schools must show students how they apply that proficiency through engineering in fields such as energy, cybersecurity, health care, transportation, homeland security, space flight, communications and so on. This provides the spark of excitement so that students begin to know what engineering really matters and what matters in engineering. It also allows them to be creative, an important and highly satisfying aspect of engineering. Middle school is indeed the right time to weave in some of these very basic applications of engineering, but too early to do more rigorous engineering-type classes. The four years of high school are the right time for this type of training. Making an engineering elective available in each of the four years would be appropriate for high school.

In response to Question 3, the Clark School delivers K–12 programs during the academic year and the summer. Our Center for Minorities in Science and Engineering offers two academic-year programs, and I will just highlight them right now. The ESTEEM program brings the students together with a faculty mentor in a yearlong research project through a research practicum for high school students. Our Maryland Mathematics, Engineering and Science Achievement program, also referred to as MESA, engages students in Saturday academies, summer programs and in-service and after-school enrichment programs. Our additional lead academies are offered through our Women in Engineering program. They introduce female students to one of our academic programs such as aerospace engineering or bioengineering or electrical and computer engineering using demonstrations and hands-on projects.

Evaluating the program effectiveness is very challenging for all of our K–12 STEM programs. We do have in fact case-by-case evidence that students who participate in these particular programs become more positive about engineering and actually enroll in our

school. Regarding partnerships, we have identified the top 25 Maryland high schools that send us the greatest number of engineering students and propose a stronger partnership with those schools, an opportunity for students to engage in engineering activities, training for teachers and availability of merit scholarships. We have also produced summer programs for high school STEM teachers. They witness presentations. They do hands-on projects, tour our facilities and speak with our faculty, all to enhance their understanding of engineering and encourage them to take their new knowledge back to their students.

Our next step is to partner with our College of Education to ensure that teachers can be certified in engineering education, and parallel, we are meeting with the Maryland State Department of Education STEM coordinator to explore ways to establish closer cooperation between our two organizations.

So in concluding, I would like to thank the Committee for the opportunity to report on Clark School's programs in support of K–12 education, and I will be happy to answer any additional questions. Thank you very much.

[The prepared statement of Dr. Pines follows:]

PREPARED STATEMENT OF DARRYLL J. PINES

Good morning to Chairman Lipinski, Ranking Member Ehlers, and other Members of the Subcommittee; to fellow witnesses; and to all who share an interest in and concern for the future of engineering. Thank you for inviting me to testify on the specific subject of *"Engineering in K–12 Education."* My name is Darryll Pines and I am the Nariman Farvardin Professor and Dean of the A. James Clark School of Engineering at the University of Maryland, College Park.

The Clark School is fortunate to attract a large number of outstanding young people from the highly regarded Maryland school system and Maryland private schools, as well as from excellent schools across the country and around the world. We have developed a strong sense of the skills and attributes students need to complete our rigorous curriculum and developed programs that are proving effective in retaining and graduating more of those students. We have also developed an array of programs to interest younger students in the field of engineering and a few insights concerning the inclusion of engineering concepts and approaches in pre-college education. Chief among these is the following very simple, but sometimes forgotten, idea:

In K–12 engineering education, the proper pacing is critical. By engaging students at the proper level at the proper time, schools can ensure that students are neither intimidated by the difficulties of engineering, nor deluded that engineering is essentially dreaming up ideas without the foundation of creating, analyzing, testing, and refining a solution using math and science.

If we can achieve proper pacing, we can show students engineering's potential for positive impact in the world, the great satisfactions engineers experience in creating that impact, and the rewards and challenges of doing so, while beginning to train them in the skills they will need to take on those challenges and succeed in the university setting.

For proper pacing to occur, those of us in the Clark School and other university programs must do a better job of educating high school and middle school teachers about the field of engineering, the academic capabilities their students must develop to enter the field, and the right level of engineering concepts teachers can include in their lessons. By providing such support, we can show students, parents, teachers, counselors, and administrators that introducing engineering in K through 12 education is both feasible and of great benefit to the students themselves and to progress in our nation and our world.

In my testimony I will report on current Clark School activities and propose a number of new ideas that may be of value.

Let us begin at the end of the educational process for most engineers: obtaining the bachelor of science degree. The successful undergraduate engineering student should leave the university with the following knowledge, skills, characteristics, and experiences:

1. A high awareness of the areas of opportunity and challenge in which engineering can make a positive difference in our quality of life.
2. Time spent in direct work in one or more of those areas, whether through participation in related research, internships, or volunteer and service programs.
3. The entrepreneurial drive, skills, and confidence to organize and launch an initiative—even a company—in one of those areas, where none existed before.
4. Demonstrated ability to solve open-ended problems in those areas by applying engineering methods, mathematics, and current knowledge of physics, chemistry, and/or biology.
5. Demonstrated ability to focus on a situation or problem and imagine one or more ways to improve it or solve it.
6. Evidence of a strong work ethic in pursuing assignments and activities, and an ability to learn autonomously.
7. The ability to communicate with professionals and lay people, both to express ideas and listen to and appreciate feedback.
8. The ability to work alone or in teams, and to lead teams when required.

To make it more likely that students will possess these skills and attributes on graduating from college, and indeed to increase the number of students who achieve that goal, we must ensure that students come to us from high school possessing all of the skills in some degree, and the last five in a high degree.

Thus, if the process works correctly, freshmen come to us with the ability to:

- Solve problems using mathematics and science
- Focus on an opportunity or challenge and imagine solutions
- Apply themselves at a high level, consistently over time, and not be deterred by difficulties and failures
- Communicate ideas and information through speech and writing
- Work alone or in teams, and lead when required.

If students also know about some of the areas in which engineering can make a positive difference, and have engaged in low-level aspects of engineering thinking, they are more likely to consider engineering as a path, and succeed in that path in college.

An example would be making a truss bridge, a project that many high school students do in a science or engineering class. They will build a truss bridge according to how they think it should look, how they think they can make it stronger, relying largely on experience and intuition. This is appropriate for high school.

In their mechanics class in college, students will learn the concepts of stress and strain, axial loading, material properties, and other concepts that allow them actually to design the truss, then build it, rather than simply put something together and see how it stands up to a load. This is appropriate for college.

Pre-college engineering education can make the student aware of and excited by the potential impact of engineering to improve our world, and prepare him or her for the challenges of the university engineering program.

The first step is to identify students who are proficient in mathematics and science, because without these strengths, it will not be possible for students to succeed in the field.

Next, introduce students to the many real-world opportunities to apply that proficiency—from health care to transportation to homeland security to space flight to communications. This introduction can provide the spark of excitement so that students know, at least in an elementary way, what engineering is all about. Challenging students to apply their proficiency also allows them to be creative, an important and highly satisfying aspect of engineering, which they might not have the opportunity to do except in these classes.

Throughout, pacing must be part of the process. Young students must have a firm grasp of fundamentals, especially mathematics, before they are introduced to substantial engineering concepts. Middle school is probably the right time to weave in some of the basic applications of engineering, but too early to do any rigorous engineering-type classes. The four years of high school are the right time for this. The typical high school curriculum is fairly packed, but having engineering electives available in each of the four years could be appropriate. These should be coordinated with what the students are learning in math and science.

Students must not be overwhelmed. They must have the firm grasp of the basics. If they do not, they end up not really understanding what they are doing beyond a superficial level.

The Clark School delivers an extensive variety of K through 12 programs and initiatives.

Our summer programs target students from elementary school to rising high school seniors. They include residential and non-residential offerings, and typically are one week in length. Each program allows students to explore engineering in a variety of different ways, including hands-on projects, design problems, lab tours, and presentations by faculty members. We also offer our *Introduction to Engineering Design* course to high school students (typically rising seniors). They obtain college credit for the course and a more in-depth engineering hands-on experience.

We deliver a number of programs throughout the academic year as well. Our Center for Minorities in Science and Engineering offers two:

- The ESTEEM Program brings students to campus in the summer, and arranges for them to begin a research project with a faculty mentor. Students will continue to work on the project with the mentor during the school year.
- The Maryland MESA program, meaning Mathematics, Engineering and Science Achievement, engages students from a large number of Prince George's County Public Schools in Saturday Academies, summer programs, and in-service and after school enrichment programs to prepare them for university science and math. Our Center for Minorities is a regional MESA center.

Another academic year K–12 offering is the Lead Academies offered through our Women In Engineering program. The academies introduce students to one of the Clark School's academic programs, such as aerospace engineering or bioengineering, again using demonstrations, hands-on projects, and so forth.

Evaluation of these programs' effectiveness can be a challenge, especially for the younger students. We have case by case evidence that students who participate, and their parents, become more positive about engineering and the students go on to apply to the Clark School.

Regarding formal partnerships, we have identified the twenty-five Maryland high schools that send us the greatest number of students, and sent them letters proposing closer relationships involving information exchange, opportunities for students to engage in engineering activities at the Clark School, training for teachers, and the availability of merit scholarships. We hope that this is the beginning of strong partnerships that increase awareness and involvement in engineering, and bring still more great students to the Clark School. Historically, we have worked closely with a small number of local high schools. The Top 25 program should expand this process to a much wider field.

We have produced a number of different summer programs for high school STEM teachers. They have received presentations from faculty, done hands-on projects, toured our facilities, spoken with faculty, all to enhance their understanding of engineering, and encourage them to take their new knowledge back into their classrooms. We have submitted NSF proposals (which weren't funded) for a summer educational program which, as a key element, includes high school teachers who would work closely with STEM faculty (math and engineering) and incoming at-risk university freshmen. We also work individually with teachers on request.

We do not at present incorporate engineering into College of Education programs, although these discussions have been initiated. We have arranged a meeting with the Maryland State Department of Education's STEM coordinator to explore ways to establish closer cooperation between our two organizations. We hope through this process to make a presentation about engineering education to Maryland high school math and science chairs in the summer of 2010. Through a discussion of their interests and needs, we hope to create a more extensive program that will not only assist current teachers but become the basis for including engineering in our College of Education degree and pre-service certification programs.

I would like to add a few ideas on future programs that would be pertinent to this discussion—ideas that could have a highly positive impact on our current Clark School students and current high school students.

First: "Students Without Borders." The idea is to establish a program for Clark School students of mandatory community service (40 hours per academic year) to earn credit through mentoring, tutoring, judging science competitions, and other activities with middle and high school students. We find that today's Gen Y student is excited to do something useful to help society and add social value experiences to his or her education.

Second: Online STEM Education System. Here we would use existing TV communications systems and the Internet to bring the best high school and middle school STEM teachers into the areas where they are in short supply, whether in the form of complete courses or highlight sessions that add excitement to local courses.

Third: University-Based STEM Governor's Schools. Modeling our existing and highly successful living/learning programs, create STEM living/learning programs on university campuses for academically talented and mature students who have completed 11th or even 10th grade. This would enable them to complete their university degrees early and obtain early access to internship and employment opportunities with partnering corporations and government agencies.

Fourth: Nationwide Keystone Professors Program. Modeling the Clark School's highly successful Keystone Professors Program, create an expanded, nationwide university-based program that brings the best teachers into the most elementary university STEM courses and thus improves retention of students over four years. Keystone provides funds to increase the base salaries of participating professors and to support technicians and equipment used in the courses.

Fifth: Articulated Agreements with Community Colleges. Develop agreements with community colleges to ensure that their courses align with university requirements. This will enable students automatically to transfer all credits after two years rather than require evaluation of each course for transfer.

My thanks to the Subcommittee for the opportunity to report on the Clark School's experience with K–12 engineering education and suggest a few ideas for expanded use. I will be happy to answer any additional questions, and to make myself available to work out these ideas as deemed appropriate.

BIOGRAPHY FOR DARRYLL J. PINES

Dr. Darryll Pines became Dean of the Clark School on January 5, 2009. He came to the University of Maryland in 1995 as an Assistant Professor in the Clark School and has served as Chair of the Department of Aerospace Engineering since 2006.

Under his leadership, the Department was ranked 8th overall among U.S. universities, and 5th among public schools in the *U.S. News and World Report* graduate school rankings. In addition, during his tenure as Chair, the Department has ranked in the top five in *Aviation Week and Space Technology*'s workforce undergraduate and graduate student placement study. The undergraduate program was ranked 9th during that time. Pines has been Director of the Sloan Scholars Program since 1996 and Director of the GEM Program since 1999, and he also served as Chair of the Engineering Council, Director of the NASA CUIP Program, and Director of the SAMPEX flight experiment. Last year, he served on the University's Strategic Planning Steering Committee.

During a leave of absence from the University (2003–2006), Pines served as Program Manager for the Tactical Technology Office and Defense Sciences Office of DARPA (Defense Advanced Research Projects Agency). While at DARPA, Pines initiated five new programs primarily related to the development of aerospace technologies for which he received a Distinguished Service Medal. He also held positions at the Lawrence Livermore National Laboratory (LLNL), Chevron Corporation, and Space Tethers Inc. At LLNL, Pines worked on the Clementine Spacecraft program, which discovered water near the south pole of the Moon. A replica of the spacecraft now sits in the National Air and Space Museum.

Pines' current research focuses on structural dynamics, including structural health monitoring and prognosis, smart sensors, and adaptive, morphing and biologically-inspired structures as well as the guidance, navigation, and control of aerospace vehicles. He is a Fellow of the Institute of Physics and an Associate Fellow of AIAA, and he has received an NSF Career Award.

Pines received a B.S. in mechanical engineering from the University of California, Berkeley. He earned M.S. and Ph.D. degrees in mechanical engineering from the Massachusetts Institute of Technology.

Chairman LIPINSKI. Thank you, Dr. Pines.

Mr. Sandlin.

STATEMENT OF MR. RICK SANDLIN, PRINCIPAL, MARTHA AND JOSH MORRISS MATHEMATICS AND ENGINEERING ELEMENTARY SCHOOL, TEXARKANA INDEPENDENT SCHOOL DISTRICT

Mr. SANDLIN. Chairman Lipinski, Ranking Member Ehlers and Congressman Hall and other Members of the Research and Science Subcommittee, I am certainly honored today and privileged to be here today to share with you what is taking place at Martha and Josh Morriss Mathematics and Engineering Elementary School as we attempt to implement an integrated engineering. Morriss Elementary is part of the Texarkana Independent School District (TISD) located in Texarkana, Texas. During this oral report, there will be some slides playing to show you what our campus looks like and the activities taking place.

The idea for the school began when a group of citizens, educators, engineers and business leaders under the leadership of then-Superintendent Dr. Larry Sullivan and the President of Texas A&M University–Texarkana, Dr. Stephen Hensley, determined that a high priority for the Texarkana area was to somehow close the gap between supply and demand for professionals in engineering and mathematics careers. So was born the collaboration between Texas A&M University–Texarkana and Texarkana ISD to develop a K–16 pipeline which would expose children to engineering concepts and careers at an early age. We attempt to raise the bar of excellence by requiring higher standards for our students and our teachers. Students attend Morriss on a first-come, first-served, open enrollment basis, but once enrolled, the students must meet certain academic behavior and attendance standards to remain enrolled. All teachers at Morriss must either have a Master's degree or be willing to complete a Master's degree. Our district provides the funds for the coursework and there is no cost to the teacher as long as the teacher remains with the district for four years after completing the coursework. Teachers who already have a Master's degree must also complete four additional courses of math along with two curriculum design and delivery courses. Teachers are then qualified to take the Master of Mathematics teacher certification examination.

TISD provides continuous professional development in STEM education through workshops offered through its instructional services department; plus, the American Society of Engineering Education offers a free workshop to STEM educators each year. Some of our teachers attended in Austin in 2009 and plan on returning in the summer of 2010 in Louisville, Kentucky. Our curriculum coach meets with our teachers on a regular basis in planning sessions.

With much input from the educators and engineers along with the donation of 10.6 acres of land by the Morriss family, the construction of a new elementary school became a reality. We have been very fortunate that we have been able to design a physical plant which enhances the delivery of our engineering curriculum by offering some unique features not normally found in elementary schools. Some of these unique features include exposed color coded pipes, clear wall panels and clear ceiling tiles, which allow students to view ductwork, wiring and other pipes to show them that there

is a path for everything that comes to them. Somebody had to design it, put it in place and maintain it. Also, we use irregular-shaped classrooms located in a pod setting that also has a common area. The data cabinets also with wiring is exposed. In each classroom we have a clear-case computer. There is a clear tile area in the entrance to each pod that shows pipes and rebar, and it is located in the foundation. We design each class like a lab instead of just having one lab per pod. We use tables instead of desks in order to provide hands-on activity space for teachers to use. We also have students work in groups, cooperative groups to work together. A research and design center is used to promote research in robotics. The school's file server also has an open design.

So although we are very proud of our physical plant, it is our curriculum that sets us apart from the other elementary schools. Instruction at Morriss Elementary is a student-centered, hands-on and concept-based instruction. Teachers facilitate inquiry-based learning which they tap into students' natural interest in problem solving. Classrooms are equipped with state-of-the-art technology and equipment and teachers create a learning environment where learners assume the responsibility of their own learning where student autonomy and initiative are encouraged. We are trying to raise the bar through the thrill of discovery.

Our curriculum coach plays a vital role in making sure we are implementing the engineering curriculum in the classroom daily. Each morning all grades have an engineering period first period and then we integrate the engineering concepts of that period into the other subjects whenever possible. In attempt to avoid the science fair mentality where the parents do the projects at home and then send them to school for everyone to admire, we hold at least three engineering encounters per year. These engineering encounters give parents the opportunity to view and participate in the engineering activities with the students.

Our students love robotics. In addition to daily robotics activities, our students like to compete in robotic competitions. So far we have competed at the University of Texas–Dallas and also the University of Texas at Tyler.

We strive to share the arena with our other schools and school districts by giving tours of facilities and by inviting educators to visit our classrooms. We also believe in the ripple or spillover effect which means that we are willing to share strategies that work at Morriss with teachers at our other campuses in our district.

In reality, we realize that not all 400 students at Morriss will choose careers in engineering. However, we feel that if they can learn the process of learning like an engineer, then they can use this process of learning regardless of which field they go into. This process includes the steps of imagine, plan, design, improve and share, which we adapted from Engineering is Elementary. Our students are encouraged to continue their study of engineering and mathematics after they leave Morriss by enrolling in the engineering and mathematics academy at our Texas Middle School and then they can take engineering courses at our high school at Texas High and then to go on to Texas A&M University–Texarkana to major in engineering, completing the K–16 journey.

Martha and Josh Morriss Mathematics and Engineering Elementary School is a great place for kids to explore and learn. We don't have all the answers but we do feel like the bicycle has begun to move. We certainly would extend an open invitation to anyone to visit our campus at any time. We certainly want to thank Congressman Hall for an opportunity to come today and his strong support of STEM education and also his support of Morriss Elementary.

I would like to conclude our testimony with a short video that shows the activities at Morriss and the learning process. Once again, I want to thank the Committee for the opportunity and I will be glad to answer any questions.

[Video.]

Thank you.

[The prepared statement of Mr. Sandlin follows:]

PREPARED STATEMENT OF RICK SANDLIN

1. Please describe the establishment of the Martha and Josh Morriss Mathematics and Engineering Elementary School. What was the impetus for its development?

A growing gap between the supply and demand for professionals in engineering and mathematics careers has alerted stakeholders across the Nation. At the national level, resolution of this dilemma has been identified as a federal priority via appropriation of the Science, Technology, Engineering, and Mathematics (STEM) project and the American Competitiveness Initiative unveiled by President Bush in his January 2006 State of the Union Address. Texas Senator Kay Bailey Hutchison publicly recognized the growing need for engineering education and research in Texas when she announced the creation of the Texas Academy of Science, Engineering, and Medicine in San Antonio in January 2004. The regional need for more engineers was documented in the late 1990s when Texarkana area businesses (e.g., International Paper, Domtar Paper Mill, and Alcoa) identified the need for an engineering program at Texas A&M–Texarkana as the number one community priority. The need for more regionally available engineers, coupled with the need for an increase in the quantity and quality of United States grown and educated engineers, sparked the development of the Texas A&M University–Texarkana—Texarkana ISD K–16 Engineering Collaborative.

Although the effectiveness of a K–16 engineering collaborative as a means of improving the supply and demand gap of engineers is a very logical, research-based approach, a comprehensive search has not identified another partnership of this kind across the United States. The Texas A&M University–Texarkana—Texarkana ISD K–16 Engineering Collaborative is a unique, sustainable, and replicable model that sets a gold standard for public schools and universities.

What role did partnerships with local businesses and institutions play in the development of the school?

In January 2005, Texarkana ISD convened the first meeting of the Blue Ribbon Committee, a group of parents, community and business leaders, and school district representatives. This panel's purpose was to review the school district's facilities, finances, and curriculum, and to make recommendations concerning future plans for the district. Following a series of planning sessions, the Committee recommended the establishment of a new elementary school, a school that would become a national model for K–16 collaboration in how young children can become engaged in and educated for STEM careers.

The first concrete step to this concept becoming a reality occurred in spring 2006 when the Josh Morriss, Jr. family donated 10.6 acres of land near the new 375 acre Texas A&M–Texarkana campus site for the new elementary school.

Along with the contributions of the Blue Ribbon Committee and the Josh Morriss, Jr. family, Texas A&M University–Texarkana became an integral partner in the school's development. The University's involvement included consultation in the floor plan and architectural design, in integrated curriculum development, and in professional development for teachers.

Local business leaders have found it increasingly more difficult to find and recruit highly skilled people with a strong background in Science, Engineering, and Mathe-

matics. They recognized and supported a strong STEM competency that can only be enhanced through the local school system and University.

2. What do you consider to be benefits of pre-college engineering education?

Benefits of a pre-college engineering education are produced through the delivery of an integrated STEM curriculum. When the curriculum is delivered through an inquiry based hands-on approach, students become the benefactors of becoming Critical Thinkers. A key component to delivering the curriculum at Morriss elementary, is teaching students to utilize the engineering design process (see Appendix A). By imbedding the engineering design process as part of a project based learning concept, students learn to synthesize information and continually improve on their cognitive abilities.

The number of engineers that are being produced in this country has decreased drastically over the past few decades. Less than fifty years ago over half of all engineers in the world were produced in the United States, in 1999, America produced 12 percent of all engineers globally. This preparation for the world in which our students will be expected to compete must be held to a more rigorous standard. We are meeting that challenge at the Martha and Josh Morriss Mathematics & Engineering Elementary School.

Can Engineering be added to the classroom without sacrificing core competencies in math and science?

Engineering is the perfect accompaniment to math and science and we must also make sure that technology is included in the statement because STEM education is a **"meta discipline."** When people hear the acronym, STEM, they immediately focus on the four separate disciplines. STEM is actually an integration of the four disciplines thus producing a "meta discipline." *Integrated STEM education* refers to a new name for the traditional approach to teaching science and mathematics. *Integrated STEM education* is not just the grafting of "technology" and "engineering" layers onto standard science and mathematics curricula. Instead, integrated STEM education is an approach to teaching that is larger than its academic parts.

The following statement from the National High School Alliance on STEM education describes the **"meta-discipline"** as one that "removes the traditional barriers erected between the four disciplines by integrating the four subjects into one cohesive means of teaching and learning. The engineering component puts emphasis on the process and design of solutions instead of the solutions themselves. This approach allows students to explore mathematics and science in a more personalized context, while helping them to develop the critical thinking skills that can be applied to all facets of their work and academic lives. Engineering is the method that students utilize for discovery, exploration, and problem-solving."

Morriss elementary employs a self-contained concept for the classroom setting. In other words each teacher is responsible for teaching all core subjects to the 22 students in their classroom. An example of a third grade schedule is shown below:

Morriss 3rd Grade Schedule						
8:00-9:15	9:15–10:45	10:45-11:30	11:30-12:15	12:15-1:10	1:10-2:15	2:15-3:00
Engineering	ELA	Science	Lunch /Recess	Conference /Activity Period	Mathematics	Social Studies

The daily schedule for Morriss Elementary reflects all grade levels starting out the morning with one hour of engineering. Engineering is not a typical course taught at the elementary level and thus is unique to Morriss Elementary; thus the engineering course is considered part of the core curriculum for the school. While the course schedule also reflects a normal block of time for the other core content

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areas, it is the instructional methods employed by the teachers that are uniquely different.

What are reasonable learning outcomes for engineering education at the elementary school level?

Engineering curriculum in the elementary classroom setting incorporates the *Engineering Design Process* which includes the steps: Imagine Plan, Design, Improve and Share. This five step system allows students to work through open-ended, hands on and project-based learning experiences that develop higher-order thinking skills in students. Following the methods delineated by Bloom's Taxonomy, students are able to identify problems that are to be solved, determine possible solutions, and evaluate their own work for improvements. Students will be able to:

- Reflect on attitudes toward engineers and engineering
- Develop professional relationships with engineers
- Teamwork through cooperative-learning
- Understand the tools, equipment, technology and procedures used in the design process
- Identify the problem
- Research scientific principles
- Brainstorm solutions
- Draw a diagram or schematic
- Decide which materials to use
- Create a cost-analysis based on a rubric
- Use mathematical problem-solving techniques
- Follow the plan to create a design
- Test their design
- Apply statistical analysis to data
- Modify and improve the design
- Evaluate Design and retest
- Apply statistical analysis to data
- Communicate their achievements

What do you consider to be the biggest challenges and barriers to incorporating engineering education in the elementary school classroom?

- Quality Integrated STEM education professional development
- Elementary education teacher preparation programs lack of math and science content
- Funding to help support professional development at the elementary level (beginning of the STEM pipeline)
- Buy-in of public and educators in preparing students for careers in engineering
- Females entering mathematical and engineering careers
- Student exposure to technological advances

3. What kind of curricula does the school use?

Morriss Elementary curriculum is standards-based, integrated and connected to the lives of learners. The curriculum is designed to be compelling-to move beyond information and support the transfer of learning. The goal of Morriss Elementary is to facilitate integrated, higher level critical thinking which promotes STEM education. Resources utilized in the curriculum: Engineering is Elementary from the Museum of Science in Boston, Sci-Tek, Scan-Tek, along with state-of-the-art technology and equipment. NASA engineering projects are also employed. NXT Mindstorm robotics are implemented to enhance the engineering program as well as compete in State competitions. Engineering is spiraled through a six weeks matrix that provides exposure to engineering concepts in areas of environmental, civil, Earth & space, bioengineering, electrical & mechanical and manufacturing. In order to follow the Link-Learn-Extend model, students are guided through accelerated mathematics that extend into the next grade level. Envision mathematics is the State adopted curriculum, but that is a resource that is used along with other materials such as Hands-on Equations to advance the mathematics curriculum. Materials usage is supported through the Texarkana ISD's dedication to development of STEM education as well as support from local businesses and parents.

What percentages of your teachers have engineering degrees?

Although none of the teachers at Morriss Elementary have an engineering degree, they all have an understanding of what engineers do because of a quality professional development model developed between the school district and Texas A&M University–Texarkana. Immersion was the key to understanding the engineering concepts that needed to be taught at the elementary level. Much like learning a new language, teachers were immersed in the culture of engineering through research and consulting with area engineers. Local engineers served as a sounding board during panel discussions to determine how to teach engineering at the elementary level. Many of the local engineers could not articulate what to teach at the elementary level, but were able to convey some simple concepts such as, more math and solving puzzles. Teachers quickly learned that the curriculum would have to be developed by working together in a collaborative atmosphere. By listening to engineers, Morriss was able to develop and accelerated math concept using a link-learn-extend model (see appendix A) which helped teachers push mathematics forward by a full grade level by the time a student reaches the 5th grade. The accelerated mathematics will help us fulfill the pipeline of students who need to have calculus by the 11th grade so they can enroll in the dual credit engineering courses currently taught by Texas A&M University–Texarkana.

The teachers completed four Graduate level mathematics courses and completed the Master Mathematics Teacher certification. The remainders of the three required elective courses in their Master's Degree program were science electives designed by the University to meet the needs of engineering implementation. The curriculum coach participated in a summer program (2006) through Texas A&M–College Station funded by the National Science Foundation (EBAT) that developed educator knowledge in biomedical engineering through live-animal research. She also served the National Science Foundation as a Science and Mathematics Specialist through the Texas Rural Systemic Initiative. In the summer of 2009, six teachers from Texarkana ISD attended the American Society for Engineering Education annual conference in Austin Texas and will attend the 2010 conference in Louisville, Kentucky. The Curriculum Coach and Counselor from Morriss Elementary attended the Engineering is Elementary Training for Trainers Fall 2008 to create a professional development opportunity for Morriss Elementary teachers.

Maintaining membership in professional learning communities allows Morriss teachers to share experiences and expertise with others pursuing STEM education.

What kind of teacher training and professional development opportunities do you provide for your teachers?

Providing a quality teacher professional development program for an integrated STEM curriculum was essential to establishing Morriss Elementary. The essential foundation and approach to professional development for the Morriss teachers had been established through a district led commitment to seeking methods and strategies to support changing the way students learn, and to producing students who possess critical thinking and problem solving skills and abilities. Utilizing *integrated STEM education* to promote this shift in teaching values and teaching methods provided the district with the necessary framework for implementing a dramatically different approach to teaching. This has resulted in creating a school culture that embraces teachers as facilitators. The result has been the acceptance of *integrated STEM education* and an expectation of achievement and renewed commitment to educational excellence shared by the Morriss teachers. The following information describes the expectations for professional development through required course work in order to be employed at the Morriss school.

Teachers with a Master's Degree (K–5)

Teachers who already had a Master's degree were required to take eighteen (18) hours of specific graduate level course work with Texas A&M University/Texarkana within the first two years of assignment at the school. Graduate level course work consisted of two courses in curriculum and instruction, and four courses in mathematics. The specified course work lead to a Master Teacher Certification in Mathematics (EC–4).

Teachers without a Master's Degree (K–5)

Teachers who do not currently have a Master's Degree were required to complete a Master's Degree in Curriculum and Instruction within the first three years. Teachers without a Master's degree were required to take eighteen (18) hours of specific graduate level course work with Texas A&M University/Texarkana within the first two years of assignment. The course work consisted of two courses in cur-

riculum and instruction, and four courses in mathematics. Finally, teachers had to complete the remaining 18 hours of graduate course work needed to complete a Master's Degree in Curriculum and Instruction from TAMUT. The specified course work led to a Master Teacher Certification in Mathematics (EC–4).

Two key courses were identified as being imperative to the teacher professional development program, *Curriculum Design* and *Curriculum Delivery*. The syllabus for each course presented new STEM teachers with a variety of tasks and exercises that included research and information gathering, exploration of curriculum and instruction methods, project-based classroom instruction, and self-evaluation. The courses were team taught, utilizing the expertise of the Curriculum Coordinator, Ronda Jameson, who is a former secondary mathematics teacher, along with the Curriculum Specialist, Lori Ulmer, who is a former elementary math teacher who brought experience and knowledge from outside the district to support the curriculum and instruction design process. The four-week course work was structured to foster team-work and collaborative curriculum development through the project-based outcomes designed for the course, and through modeling of these practices by the course instructors.

Emphasis on research and self-evaluation as a method for constant improvement are also an important dimension of the course work that prepare teachers to actively use technology in the classroom to access new information and ideas. Additionally, the course instructors built the course upon the combined experience of both instructors in classroom teaching. Together with their experiences in providing teacher professional development to a broad range of teachers over a number of years, essentially fostering an approach that relied on the course instructors "to think like a classroom teacher." Utilizing a research-based approach, course instructors were able to provide answers and information to support the premise of *integrated STEM education,* and also provided modeling of this approach through the method of instruction. The resulting buy-in of the new teaching methods, and of the premise of STEM's focus on engineering and mathematics, provided a solid foundation for effective curriculum development during the first year of the Morriss school.

The teacher professional development produced some non-negotiables that were to be inherent in the integrated STEM culture when designing and delivering the curriculum. The non-negotiables are:

- Hands on learning
- Constructivism
- Leadership and articulation
- Daily engineering instruction
- Alternative forms of assessment
- Concept-based instruction
- Algebraic thinking
- Cooperative learning
- Accelerated mathematics

Another key component is the monitoring and review process established to ensure the teacher professional development components are being supported. Through peer review, and collaboration during common planning time, feedback is provided on an on-going basis. This process is led by a curriculum coach, Denise Skinner, for the Morriss school. The curriculum coach is responsible for meeting with the Morriss teachers on a regular basis to continually tweak the design and delivery of the curriculum. Through classroom observations and research, the curriculum coach is able to adequately provide teacher support.

Because of the successful *integrated STEM education* professional development model with the Morriss teachers, it was replicated with the more recent secondary STEM Academy teachers which started in the summer 2009. Again the expertises of current ISD staff were utilized. Director of Curriculum and Instruction, Lori Ables, and Curriculum Coordinator, Ronda Jameson, delivered the content for the University based course work. Working with Texas A&M University–Texarkana was a vital component as they provided the adjunct status for the instructors. The University realized the need for more staff with practicum experiences. The professional development model was captured in recent study on the Morriss school by Dr. Monica Hunter from the PAST foundation. A full copy of the study can be obtained by following the link below.

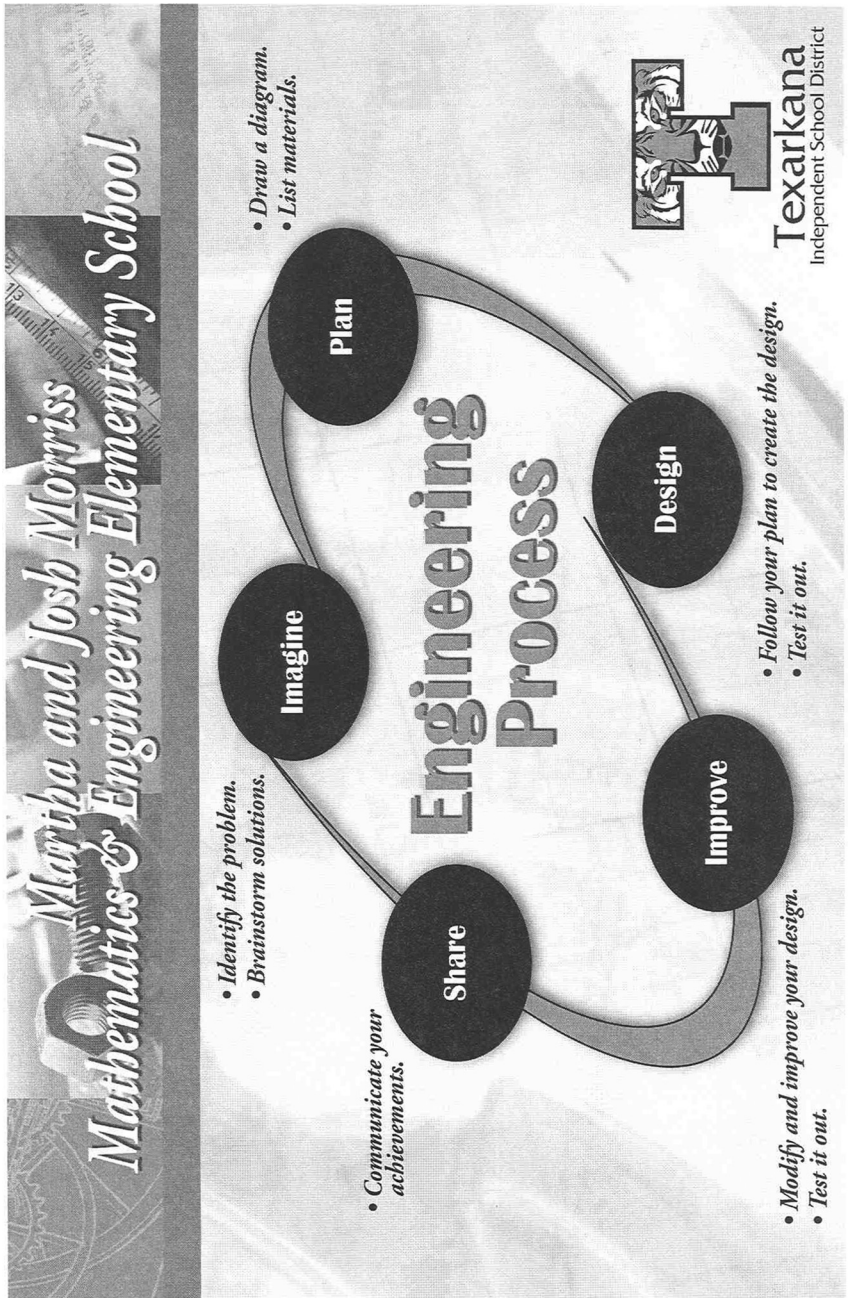
http://www.lulu.com/content/paperback-book/morriss-math-and-enginerring-elementaryschool-a-case-study-of-k-5-stem-education-program-development/7488985

4. Once a student has completed the elementary grades at your school, do they have the opportunity to go on to a STEM-focused middle school? Are these programs in place to ensure these students maintain an interest in STEM subjects as they transition to middle school and high school?

Texas A&M University–Texarkana and Texarkana Independent School District have established a vertically aligned kindergarten–16 engineering education collaborative that will be executed at four levels:

1) A K–5 public elementary school (Martha and Josh Morriss Mathematics & Engineering Elementary School) that provides a mathematics and pre-engineering integrated curriculum, Engineering Encounters (student-led, hands-on experiences shared with parents and the community), and pre-engineering thematic units (i.e., structures, forces, and gears) at each grade level (opened in fall 2007)
2) The Math, Science, and Engineering Academy, a pre-engineering school-within-a-school at Texas Middle School opened in fall 2008. Currently the STEM Academy services interested students in grades 6 and 7 with plans to expand to 8th grade in 2010.
3) Texas High School currently offers selected mathematics and science courses with pre-engineering content enrichment and dual credit engineering courses at Texas High School. A STEM Academy has recently been added to Texas High School in 2009 to service 9th grade students with plans to expand through 12th grade by 2012. The high school expansion of STEM Academies has been made possible through a grant sponsored by the Texas High School Project (THSP).
4) A choice of three engineering related programs of study at Texas A&M–Texarkana: BS in Computer and Information Sciences, BS in Electrical Engineering, and BS in Mechanical Engineering. Texas A&M–Texarkana will be accepting their first freshman class into the college of engineering in 2010.

APPENDIX A



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Martha and Josh Morriss
Mathematics & Engineering Elementary School
Mathematics Process
Link
Learn
Extend
Texarkana
Independent School District

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Grades	1st 6 Weeks	2nd 6 Weeks	3rd 6 Weeks	4th 6 Weeks	5th 6 Weeks	6th 6 Weeks
	Environmental Engineering	**Civil Engineering**	**Earth and Space Engineering**	**Bioengineering**	**Electrical and Mechanical Engineering**	**Manufacturing Engineering**
K	What is an Engineer? The Engineering Process: DSM III Investigating Water Sink or Float	*Tunnels*	Wind: Windvanes, Windsocks	*Engineering Animal Parts*	Heavy Machines Hydralic Dump Trucks and Crane pulley systems	Houses: Lincoln Logs and Legos
1	*What is an Engineer? The Engineering Process Rube Goldberg DSM Sink or Float*	Walls: EIE: A Sticky Situation:The Great Wall of China	Solids and Liquids: EIE: A Work in Process	*Animals as Engineers*	Heavy Machines Hydralic Dump Trucks and Crane pulley systems	A Chair for Little Bear (Lego Education)
2	What is an Engineer? The Engineering Process DSMIII Forces and Motion	*Pyramids*	Weather: DSM III Weather Instruments	Insects and Plants EIE: The Best of Bugs: Designing Hand Pollinators	Magnetism and Transportation: EIE The Attraction is Obvious	Transportation Vehicles (Boats, Cars, Airplanes)
3	What is an Engineer? The Engineering ProcessThe Design Process EIE: Thinking Inside the Box: Designing a Plant Package	*Lego Towers Texarkana Towers*	Balloons, Parachutes and Airplanes: DSM II Amazing Air	Organisms: EIE: Just Passing Through Designing Membranes	Energy Transfer, Conduction, and Circuitry: EIE: An Alarming Idea	*Domes and Arches*
4	What is an Engineer? The Engineering Process: EIE:Water, Water Everywhere Designing Water Filters	*Teach Engineering: Parking Garage Native American Structures*	NASA: Rockets	The Physics of Sound: EIE: Sounds Like Fun ScanTek	Melanie Kit: Carousels EIE: Catching the Wind	Exploring Force and Motion: EIE: Marvelous Machines
5	What is an Engineer? The Engineering Process Aquifers & Landfills	Geotechnical Engineering EIE: A Stick in the Mud	Space: Lunar Rovers	*Prosthetics Arteries & Heart Valves*	Roller Coasters Rube Goldberg Force & Motion	Balances and Forces: EIE: Get To The Other Side: Designing Bridges and KNEX Bridges

BIOGRAPHY FOR RICK SANDLIN

Rick Sandlin serves as Principal of the Martha and Josh Morriss Mathematics & Engineering Elementary School and is a Senior Administrator for Texarkana Independent School District (TISD) in Texarkana, Texas.

He began his career with TISD in 1974 as an elementary teacher at Highland Park and Kennedy Elementary Schools. He became Assistant Principal of Wake Village Elementary School in 1992, served as Principal of Highland Park Elementary School from 1993–1996, Principal of Nash Elementary School from 1996–2003 and was Principal of Wake Village Elementary School from 2003–2006.

In 2006, he was asked to lead the construction and development of TISD's newest state-of-the-art elementary campus—Martha and Josh Morriss Mathematics & Engineering Elementary School—which opened in August 2007. This new and innovative campus has instructional opportunities specifically in the areas of math, engineering and technology and is the foundation of TISD's collaborative effort in the development of a nationally recognized K–16 educational plan with direct ties to Texas A&M University–Texarkana College of Arts & Sciences and Education and College of Engineering.

Rick is a distinguished member of the Tiger Family and is a proven and experienced principal. He brings wisdom and a strong desire for the educational betterment of children to the district that serves as an asset for students, parents and faculty.

Rick graduated from East Texas State University at Texarkana which is now Texas A&M University at Texarkana with a B.S. in 1973 and a MBA in 1977. He is also an Adjunct Faculty member for Texarkana College where he teaches Accounting.

Rick is a member of First Baptist Church Texarkana where he serves as a Deacon.

He has been married to Kay, also an educator, for thirty-four years and they have two sons—Taylor who is the Pastor of Southland Baptist Church in San Angelo, Texas and Erick who is an attorney with the law firm of Bracewell and Giuliani located in Houston, Texas. He has two grandchildren, Sophie, age 4, and John Curtis, age 2.

DISCUSSION

Chairman LIPINSKI. Thank you, Mr. Sandlin.

At this point we will begin our first round of questions, and the Chair recognizes himself for five minutes.

Right now we are working—beginning to work on the NSF reauthorization and determine what is working, what could work better, so really focusing on NSF funding. So I wanted to start out by asking Dr. Peterson in this hearing here, what is the current level of support of NSF-funded research in other activities in K–12 engineering education, and how much of NSF's research support in this area is funded out of the engineering directorate and how much is funded through the education and human resources directorate?

Dr. PETERSON. Let me first of all begin, Chairman Lipinski, by talking about the investment that the Directorate for Education and Human Resources (EHR) has made. In 2008, about $9 million, and in 2009, about $23 million in K–12 engineering projects were supported by EHR. These came in a variety of programs, and I can provide you those specific details with exact dollar amounts, but generally speaking, they were the GK–12 Program, the NICE Program, the Math–Science Partnership Program, the Discovery for Research in K–12 and small amounts in other programs. Within the engineering directorate in 2008, we invested approximately $13 million, and in 2009, about $15 million in K–12 engineering education products. And some of these were in partnership with EHR. Primarily three areas of support provided this level of support for engineering education: the RET, or Research Experience for Teach-

ers Program; the GK–12 Program, which provides opportunities for engineering graduate students to interact with local schools; and the educational component for our Engineering Research Program. I think sometimes people who aren't very familiar—who are only superficially familiar with our Engineering Research Centers think that their primary focus and sole focus is on engineering research, but an important component of all of these centers is an outreach and education, and they often involve interactions with teachers and local school districts and provide them mechanisms to bring engineering concepts into their classroom. So approximately $8 million or $9 million over those two years was supported through the RET Program, about $7.5 million from the GK–12 Program and about $7 million from the Engineering Research Centers. And again, I can provide you other details on the smaller programs for the record.

Chairman LIPINSKI. Thank you. And to follow up, is there a comprehensive approach to the funding in these different programs?

Dr. PETERSON. We obviously try to coordinate the support that is provided and, as I said, we do partner in a number of projects. I think this is a bit of a generalization but the support that comes from EHR primarily focuses on issues related to pedagogy and the support that comes from the engineering directorate focuses more on the specific engineering content aspects.

Chairman LIPINSKI. I have—one thing I threw out there, I am not going to—I will wait until the second round to get into questions, but I just wanted to sort of put this out there to think about and maybe this will come up and I will get back to it—the definition of engineering, which is sort of where I started when thinking about this hearing because I remember when I got an undergrad degree in mechanical engineering, got a Master's at Stanford, a program called engineering economic systems, and when I was in this program at Stanford—and I had never thought about what is the definition of engineering. I just thought about the multiple different fields and how they are applied, how methods are applied, but at that point I was taught engineering is problem solving. But I think what you define as what engineering is has an impact on what we are talking about, engineering in K–12 or what can be done, what is defined as teaching engineering there. So I am just going to leave it at that and I am going to come back to it on the second round of questions, but my time is up so I am going to recognize Dr. Ehlers for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman. I have lots of questions and not enough time for all of them.

Let me start with Dr. Miaoulis. First of all, thank you for your work in the museum. I happen to think museums are one of the most effective adjuncts to elementary schools that this nation can have, and in particular your museum has achieved a pinnacle in this nation along with the Exploratorium and the Chicago Museum of Science and Industry and so forth. They play a very important role, and I assume you get busloads of students in from all over your state. We do have, or I do have a little resentment against you for stealing Patti Curtis away from us and making her spend part of her time in Boston, but she has been very effective in our STEM

efforts here and we appreciate her serving on the board that we put together.

Also, a quick comment on Homer Simpson. Probably the reason that Homer is an engineer, at least I have been told by physicist friends, is that the Simpsons were started by two physicists, and it sort of fits the mentality of physicists, I think. I have never watched a complete program so I have no idea what it is all about but it certainly seems imaginative.

You mentioned expanding and allowing math and science partnership grants to apply to engineering, and first of all, we have two types of math and science partnership grants here. The National Science Foundation has one type and the Department of Education has another type, more in the interest of getting out into the classrooms and developmental teaching. But I wasn't aware that these grants excluded engineering. Did I misunderstand you on that?

Dr. MIAOULIS. These grants—this is a general challenge we have with initiatives. There is usually language, initial language in legislation or this particular grant program, which starts in favoring STEM education, but then as you go reading further, they focus specifically on math and science teachers and math and science, so the T and E get dropped out, most times unintentionally. But once they are not in the rules, then, as the monies go to the states, the states allocate the money only for math and science programs and not for technology and engineering programs. So one of my recommendations is to direct, to be explicit in allocating funds such as through these programs to technology and engineering as well as math and science. So in new legislation, specifically spell out that curriculum in technology and engineering should be supported, as well as professional development of technology education teachers and, hopefully in the future, engineering teachers.

Mr. EHLERS. Okay. I presumed that was the case. But I was instrumental in putting these programs together, and if we are missing something, then we have to work on that, and at this time it is difficult to get another bill passed but we might be able to do something through the appropriations process. Thank you for your comment on that.

And then also just a quick response from each of the witnesses, I just wonder how—this idea of technological literacy is often discussed. How would you see that as relating to the K–12 engineering education that we are talking about here today? We will just go down the line very briefly, please, from each of you.

Dr. KATEHI. The ability to learn engineering and design, specifically in a younger age, and experiences that allow the kids to learn how to make things that are useful will help them also develop respect in understanding of technology and how technology affects quality of life and also understand the various aspects of it. And that is what we call technology literacy, the ability to use this information and—correct information—and use it to make important decisions. That, we believe, the Committee believes that that skill is fundamental to the ability of any citizen to make correct decisions, and then of course for our country to benefit from those decisions.

Mr. EHLERS. Dr. Peterson.

Dr. PETERSON. I agree very much with what Dr. Katehi said. I think if you focus on, again, the primary elements of engineering as folded into an elementary and middle school curriculum focusing on design, the basic concept is to teach problem-solving skills and with a focus in the engineering case on design aspects, but I think it is something that is applicable to anyone and helps them understand technological aspects. So whether they are going into engineering or not, I think that using that curricular approach would be beneficial.

Mr. EHLERS. Dr. Miaoulis.

Dr. MIAOULIS. What brings science to life in the classroom is engaging the kids in the way that scientists think, the inquiry process. In order to engage them in the technology area and make them technologically literate, we should also guide them to behave like engineers do, to go through the design process. So engineering in K–12 would bring to life technologies which are the result of the engineering process and significantly improve technological literacy.

Mr. EHLERS. Thank you.

Dr. Pines.

Dr. PINES. In my opinion, you first start off with asking the question, for example, this particular mobile wireless device for a kid, they use it every day. My daughter is an 8th grader and my son is a 6th grader. They know more about technology than I do, or they know how to use it, at least, but they don't know where it came from. So first is asking the hard question, how was this made. As Dr. Miaoulis mentioned, 98 percent of the things in this room were made by, in some sense, engineers or design, and it is really by making that connection that they can actually do that. They ask the first question, this thing that you are using, which is a mobile wireless device, how was it made, what are the issues that actually lead to making this, just fundamentally connecting something to the Gen Y generation that actually uses this device very feverishly today and doesn't know how it is made. And I think that is part of just the first step of technological literacy. And then, yes, the process, the analysis, the design tools and how you think about solving the problem to get to that type of device. I think we have to ask the first basic question.

Mr. EHLERS. Thank you.

Mr. Sandlin.

Mr. SANDLIN. I can certainly say in experience in 30 years that today's students—we call them the digital natives, we are the digital immigrants. They teach us. But anything that we can do that is hands-on and involves anything to do with technology, they are just like fish in the water. When they learn about robotics, that there is nothing magic about that robot, that it has to do with sensors, sound and different sensors, motion, then they have a better understanding of working together, and just as Dr. Pines said, you know, they understand that when we talk about bridges and buildings and roads, that is one thing, but when we talk about iPods and all their electronics, they get really excited about it.

Mr. EHLERS. You really hit on something and let me just briefly comment on that. My wife is an excellent cook, an excellent baker. She had to assume those duties in her home when she was 12

years old because her mother passed away early, and she taught all of our children to learn that, and I would like to point out that that is really a type of engineering too, taking components, putting them together, experimenting. My wife, she doesn't look at recipes very often. She just likes to experiment. And she is very good at it. I can give you some brownies that would make you come back for more. I think that attitude, if we can convey that to kids, experiment, try different things, whether it is in the kitchen or in the basement or whatever. That is what we are really getting at here. Let the kids learn how to experiment at an early age and build things constructively out of the materials available.

Thank you. I yield back.

Chairman LIPINSKI. Thank you, Dr. Ehlers, and I think you hit on some of the things that I had been thinking about.

The Chair now recognizes Ms. Johnson for five minutes.

Ms. JOHNSON. Thank you very much, Mr. Chairman. First, I need to apologize for being late. I had to do a speech on the Hill. And secondly, I would ask for unanimous consent to put my statement in the record.

Chairman LIPINSKI. Without objection, so ordered.

Ms. JOHNSON. Thank you. And let me thank all of the witnesses for coming. This has been a passion of mine for a long time now, and I am not sure how well we are doing. A school in Dallas, Texas, in my district is doing very well, but that is only about 20 percent of the students in the Dallas Independent School District. So I guess what I need all of you to comment on is how you get kids past the 5th or 6th grade and keep that interest in these areas. I know that early on they seem to be easy to attract, but going through the 6th and the 7th grade, the interest seems to wane.

Ms. KATEHI. Our committee discussed that very extensively, and we came to believe that there is great opportunity in starting the kids early thinking about problem solving and about design, and they can do that with simple things. When you start talking about design, you can build simple stuff that may make you do things that you could not do before at a very early age before they go to kindergarten. They can learn how to build things and they can learn how to optimize. They can learn how to solve a problem. And then you can layer on that the learning of math and science so then math and science become relevant because they become the tools towards solving something, towards doing something that works, and that direct feedback helps kids learn and then makes them like technology and then eventually a lot of these kids will select math and science as a profession. But the learning should start early, not at 5th grade. It is too late. Many of the girls——

Dr. PETERSON. Representative Johnson, I think this is a very important question, and it illustrates, I think, the challenge that we have in folding engineering concepts into the curriculum of finding material that is appropriate at each grade level. As Dr. Katehi mentioned, types of projects that would interest and encourage students in the elementary and middle schools would be different from one grade level to the next. So the challenge really is to find those types of projects that would appeal to students in each grade level to maintain their interest.

Dr. MIAOULIS. I also believe that relevance is the key. If you look at the science curricula and the math curricula at the middle school, they have nothing to do with the day-to-day life of children, and if you can connect them with the real problems that they work in teams to solve, then it all becomes relevant. I would argue that engineering should not be the last science discipline to be taught in high school. I would argue it should be the first, so in 9th grade everybody starts with engineering, realizing how you need math and science to solve the problems, and then getting hooked on math and science.

I would like to comment on Dr. Ehlers' cooking example. When I was at Tufts, we created a whole curriculum to retain engineering students which stemmed out of their personal hobbies and interests, and I used to teach a cooking class we used to call Gourmet Engineering, where I would teach principles through cooking, and the experiments were in a real kitchen laboratory and it was a very popular class. Because of this curriculum that we developed, Tufts became and still is probably the only engineering school where more students transfer from liberal arts into engineering than the other way around, with excellent retention.

Mr. EHLERS. If I may just comment, my assistant, who is a Ph.D. chemist, sent me a note saying it is really chemistry, it is not engineering. So we quickly compromised on chemical engineering.

Dr. PINES. Representative Johnson, I think one of our challenges in engineering is that we have a marketing challenge to the kids of today and the kids of the future. I would like to argue with your definition of engineering. I like to always tell kids in high school and middle school that engineers create a world that never has been for the benefit of society. Scientists study the world as it is to help understand the society but engineers create a world that never has been. So I try to link that to how kids can get excited in engineering, so one of the challenges as I mentioned in my remarks is that I believe we need to make the links for them, make it very simple. Another way to do it is to link middle school kids with elementary schools as mentors, high school kids as mentors to middle school kids, provide the continuum of what they may see in high school, what they may see in middle school, why they should stay interested in math and science, how it relates to real-world problems. Making those links and letting our young people work for us as they work for our future is what we need. We do not have such a mentoring national program that we could easily leverage and make it happen. Remember, our best human capital are our kids, our kids in college and our kids in middle school to help the lower levels. So I think those links are important to make the connections.

Mr. SANDLIN. Ms. Johnson, that is a question that we asked three or four years ago when we had a blue-ribbon committee, you know, how we can get, how can we have that supply of engineers. Industry was asking us here in Texarkana, Alcoa and International Paper, you know, we don't have local students that are going into engineering, we are hiring people that don't live in our area and we don't have that good supply. And then A&M wanted to know how can we make sure we have students coming up through the pipeline where they can have those courses and be enough students

to take the courses in engineering. So we started, we said, well, we need to beef it up in middle school and high school but we already had two courses in high school where students could get dual credit and college credit for it, so we decided to go down to the elementary and introduce them. So we are hoping that we are making it so exciting at the elementary age that there will be an interest in it. Our two groups have left us now and gone on to the middle school, and one thing that has taken place in our middle school, we have beefed up our robotics because we weren't offering that at the middle school two years ago, and then our children are going over there that were in this program, they are kind of demanding that. So it is a challenge that we try to work on every day, and it is an interest, and it is making kids aware of the different fields that they can go into.

Ms. JOHNSON. Thank you very much. My time is expired. But I want to say that the rest of these people had accents but I understood what you said very well.

Chairman LIPINSKI. Thank you, Ms. Johnson. I want to comment on Dr. Pines' characterization of science and engineering, scientists and engineers. We engineers are always trying to figure out ways to put ourselves above the scientists, so I will always remember that one.

The Chair now recognizes Mr. Hall for five minutes.

Mr. HALL. I guess my first question will be directed to Mr. Sandlin. I think you recollected Chairman Gordon, who chairs the big Committee that we are all Subcommittee Members on, and I got a glimpse of the Morriss Elementary School before our field hearing out there last year. I think Mike Ross was there, who participated. I had a guy named Thomas B. Pickens. I later learned that is Boone Pickens, III. I didn't know that was him or I would have asked him for some money for a campaign contribution. We got a glimpse of the Morriss Elementary School before our school hearing last time but I think the Committee might be interested in what a third grader's schedule is like. You touched on it in your testimony but kind of tell us what they may be doing in a typical 45-minute engineering time block. Now, I note in the morning they start with, I think, 45 minutes or an hour of engineering and then on your schedule, Morriss third grade schedule, you show an hour and a half on EL, that's English, I suppose, and some kind of language, 45 minutes on science and a 45-minute lunch and then 55-minute activity period and then an hour and a half on mathematics and then social studies. Give us an idea of that typical 45 minutes of engineering time block that is focused on civil engineering and how that relates to their other subjects that day. You have to tie it to them, I don't mean to be brutal, but to keep them from being nerds.

Mr. SANDLIN. Well, we do play basketball at Morriss. But that was a question that parents were asking, you know, as we were in the planning process, are you only going to teach math and science all day and engineering, are you going to have recess, are you going to have, you know, what are you going to do. And so we teach all the subjects that you find in any elementary school. We do teach a specific period of engineering in the mornings. We have it first period because the kids work on a team and they like to be there

on the projects, especially when they get to the point when they are putting the projects together to share, and so they kind of have pressure to be there on time, so that has cut down on our tardies a little bit, and that is a good thing, you know, hurry up, Mom, get me to school. So we do take the template and lay it down on the other subjects throughout the school day. For example, this six weeks we are in civil engineering. In kindergarten they are making some tunnels out of cardboard boxes. They also get a paper towel cone and we put it in a plastic tub like a shoebox container, and they have to create a tunnel that the car can go through, a toy car can go through just like you mentioned Tinker Tots or Tinker Toys, well, Legos are the big thing now, and so they have to design it where they can drive that little car through. We pour water in the container and if water comes out into the tunnel, then they have to go back on the improve stage and put more duct tape on it, they say. So we things like that. Second grade, I mean, first grade, they are creating walls like the Great Wall of China. Third grade, they are making towers. Fourth grade is doing parking garage right now. Fifth grade is doing tar pools. So in third grade they are building towers so they might first of all do some research on towers, what are towers, where are some in the United States, where are the tallest ones, you know, where are the most famous ones, what materials do they use to build them, things like that in that first period. And then as they move on through the day in math class when the teacher goes over geometric shapes, they might recall that the triangular shape was probably the strongest of the shapes they used. They understand what a right angle is. They understand that an acute angle is shorter than the—smaller than the right angle and obtuse is greater. So they get that hands-on and that process of learning through the project. They might do grasping by taking the tallest tower to the shortest or vice versa. They use that information in their math, what was done in engineering for the six weeks. They also might have to create a budget for the tower, you know, make sure they are in the budget of building it. So they have to worry about, you know, decimals, you know, working with decimals. They might be teaching decimals that day and working with money. In science they might talk about the nature and the forces of wind, earthquake, movement of the ground——

Mr. HALL. All that in that 45 minutes?

Mr. SANDLIN. No, sir, I have been going through the rest of the day now.

Mr. HALL. We don't want to get on with the rest of the day because this chairman just gave me five minutes.

Mr. SANDLIN. But then one last thing——

Mr. HALL. I have to be somewhere at 4:00.

Mr. SANDLIN. One last thing, and then I will be quiet about this. I was in a first-grade classroom the other day and the teachers had taken the different building materials, and they had sands and soil and granite, concrete, and she was doing a webbing, a writing exercise, and they were learning how to do adjectives and descriptive words so they were webbing off of those materials. So that is just an idea of how you can integrate the engineering concepts in the rest of your subjects during the school day, and the child kind of

ties it all together and hears it again in a different way instead of just trying to repeat it and drill and kill.

Mr. HALL. I wanted to ask you something about, you shared the qualifications of your teachers. What about the students and how are they selected to attend this institution that is a new thrust or breakthrough? Just tell us a little about the demographics of the student population. I would like to know more about cost and lack of funding. We hear that up here all the time, hear it from NASA. Norm Augustine is on the Hill today to tell us about money, about NASA, what they need. AIG can't get enough, and we don't have enough to do everything you guys want to do, but just give us an idea about how do you select these students? I see a red light over there so be pretty quick because——

Mr. SANDLIN. Well, everybody makes application to come. Three years ago when we were planning, we didn't know who was going to come or if anybody was going to be willing to leave their elementary school. We didn't want to go in and recruit kids or the principals would be highly mad at me. They would think I was trying to take all their good kids, all their good teachers. You know how competitive they are. So we didn't really know how many we were going to have. We signed up everyone from K through five that first year, the year prior to opening in 2007. We went out three years to register our kindergarten children because we wanted to make sure we had enough in the pipeline, and we had plenty. So this is our third year. We just started 2009. This is our last year of the students we registered a few years back. So this year we are going to a lottery system to where they had two weeks to sign up, about two and a half weeks to sign up from October 1st to October 16th, and their names would go into a lottery and we pull out a number according to that. We have—as far as our makeup of our students, we have about—our male and female ratio is amazing. You know, we didn't go in and try to do this, but we have 203 females and 197 males, and there is a stat right there that just fell 50/50 right down the line just about. We have about 23 percent, or 15 percent economic disadvantage. We have—we found, though, this is a way that we get more students back into our district. The middle class that was leaving our district, the urban district, are now coming back in because of what we are offering, and then we put all of our students together at grade six, so it is really building our diversity well at the middle school and the high school.

Mr. HALL. Are we getting a second shot, Mr. Chairman? We are going to have a second——

Chairman LIPINSKI. We will but we are supposed to start voting somewhere around 11:30, so we are not going to have much more time for the hearing.

Mr. HALL. Dr. Peterson answered some of the things I wanted but I did want to ask Dr. Pines some, but I will take my chances.

Chairman LIPINSKI. All right. We will do that, Mr. Hall.

Let me quickly start a second round of questions here, and the Chair will recognize himself for five minutes. I just wanted to ask a lot of the things that I was leading up at the end of the first round of questions, Dr. Ehlers had touched upon it and asked there. One thing I wanted to ask is, what about teaching professional development? Do we need to have a different way of doing

professional development for engineering, different from what we have now for science and math? Is it something that we have to newly develop? So I want to throw that question out there. Who wants to—we will start with Dr. Katehi.

Dr. KATEHI. Thank you. Yes, we need to have a different set of programs that will prepare teachers for teaching engineering design in the classroom, and engineering colleges need to take ownership in this regard. So our committee identified the need and also requested that the American Association for Engineering Schools start a national dialogue to that effect, and then trying to find ways to get engineering colleges involved.

Dr. PETERSON. I think that this is—just as the science colleges have taken ownership of the science curriculum in partnership with colleges of education, the engineering colleges really need to be able to step up and help in partnership with colleges of education to provide the course content, technical content for the engineering.

Chairman LIPINSKI. Dr. Miaoulis.

Dr. MIAOULIS. At the elementary school level, I believe that schools of education should collaborate with engineering schools to introduce at least one course in engineering design for all prospective elementary teachers so they are familiar with the process; and for the middle school and high school, again, I think engineering schools should take the lead. Also, funding for professional development should be focused in engineering as well as math and science. And since Mr. Hall mentioned NASA, I served on the NASA Advisory Committee for two years under the previous Administrator, and now the new one invited me to be a member of the new education committee. I believe that we are going to miss an opportunity if NASA does not use its wonderful and powerful engineering presence in championing engineering education nationwide. NASA should be the one that boosts K–12 engineering. It is wonderful and magical what they do. It is inspirational. And I believe that NASA should increase its educational budget and focus it on this initiative.

Chairman LIPINSKI. Thank you. Are you just saying that for the Texans up here on the dais?

Dr. Pines, did you have anything to add?

Dr. PINES. I just wanted to say that in colleges of engineering around the United States, there are at least four colleges, as it currently stands, that have programs in engineering education. They are Virginia Tech, Iowa State and Purdue, and I can't remember the last one—Clemson. Thank you. And they have instituted graduate programs in engineering education, of which they are in some cases interfacing with colleges of education, so that some of the people that come out of these programs will not necessarily become faculty at universities but actually will go into K–12 education to help stimulate educating teachers in the field to get them in engineering, which I think is great. But I think more needs to be done. So in terms of answering your question, the answer is yes, we do need a separate program for engineering educators that encourages colleges of engineering to interface with colleges of education to get more certified teachers in engineering, of the E in the STEM word.

Because we do the science and the math really well but we are not doing the E very well.

Chairman LIPINSKI. Thank you.

Mr. Sandlin, do you have anything to add?

Mr. SANDLIN. Just at the elementary level, we have found over the years that most of our teachers are well versed in the language arts and the reading area but not so well in the mathematics, and most engineers, we ask them what we can do at the elementary level to help with engineering and they say teach as much math as you can. So we would like to see mathematics in the teacher preparation program. We certainly would be interested in any type of engineer in the teacher program. We would say on professional development, we have found the best model for us is to make sure it is something that is sustainable, ongoing and that is accountable, that we have to go back in and make sure that we are doing what we said we are going to do.

Chairman LIPINSKI. Thank you. We have heard the bells. Votes have started but I think that means we have probably only seven or eight minutes here so I recognize Dr. Ehlers for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman, and I will try to be brief.

Dr. Katehi, your committee recommended that the American Society of Engineering Education, better known as ASEE, should begin a national dialogue on preparing K–12 engineering teachers to address the very different needs and circumstances of elementary and secondary teachers, and the pros and cons of establishing a formal credentialing process. My question is simple. Has ASEE been receptive of this, and what is the current status?

Dr. KATEHI. Yes, they have been and from what I understand, they have already started the dialogue. But they need to be encouraged, and the engineering colleges—ASEE is an organization and this organization can develop a plan and can develop a framework, but the colleges, the individual colleges and the universities need to take ownership of that as well. Otherwise it is not going to happen.

Mr. EHLERS. I spoke to a group of university presidents several years ago and one of them asked the question, what can we do as presidents of universities, and I said the most important thing is to get your departments of education to talk to your departments of science and math, technology, engineering, et cetera. My experience has been, visiting a number of campuses and residing on a couple, that there has been disdain between both departments, and we have just got to get them together. Thank you.

Chairman LIPINSKI. Thank you, Dr. Ehlers.

The Chair will—we don't have any questions down here? I just want to make sure. Okay. The Chair recognizes Mr. Tonko.

Mr. TONKO. Thank you, Mr. Chair. I will make this brief so that Mr. Hall can get his question in. But I know there is a lot of focus on middle school and high school for developing the engineering connection, but my opinion as an engineer in both mechanical and industrial engineering majors is that you have to start earlier than that in the elementary setting, and the expertise of math is critically important. And how do we build, not only the human infrastructure, but how do we design the construct of education so that there is teamwork done in building projects, which is the workplace

of today and certainly of the future, and how do we inspire that whole response of mathematics in the elementary setting that gets past fractions as a fear factor and gets past equations? There are fun things, I think, we can do in the elementary setting. If we don't start there, the fear of math and science, if you avoid it, the silent fear is just going to continue. How we can put a greater emphasis on elementary settings? Dr. Miaoulis.

Dr. MIAOULIS. Our broadest curriculum for K–12 is focusing on elementary schools. We have a curriculum which consists of 18 now and 20 at the end of the project—NSF has funded this project—books, and each book focuses on a child from a different part of the world. The child talks about her community and the challenge the community faces. So the little girl from India, who is the hero of one of the books, talks about quality of drinking water and the challenge of quality of drinking water in her town and how an environmental engineer in the town saved the town by building a filtration system. Then we gave the kids with the teacher help in building a filtration system in the classroom. So through storytelling, world culture, connecting math and science through engineering, we bring the whole process to life. It is used in all 50 states, our curriculum. It has reached 1.2 million children, and a recent study showed not only that kids that use the curriculum perform better than kids that did not, but also that we closed the achievement gap because we engaged children that typically didn't get engaged in math and science through real engineering.

Mr. TONKO. Anyone else want to take a stab at it? Yes, Dr. Katehi.

Dr. KATEHI. I would like to say that the Committee spoke about this. Obviously there is a great opportunity when we start this early, and there is something else we need to take into account: that the brain learns in a very sensitive way when the kids are very young, and then we abandon that and we go to very abstract learning and we start memorizing tables, and we leave away the reasons we do that and the kids cannot make the connection. So if we go back to a very early age, even before kindergarten, and start thinking about how to continue with that sensory learning and add to it a second layer of the more abstract, I think the combination of the two—which in fact can be done wonderfully through the solution of engineering problems through design—can help kids learn, and can help kids appreciate math and science as relevant tools.

Mr. TONKO. Thank you.

Mr. SANDLIN. We would—I would certainly say that we—that is right on target with what we are attempting to do, which is have cooperative groups all the way through from kindergarten up and we give them—everybody has an opportunity, a job to perform and everybody has a responsibility, and we give them an open-ended problem, and they go about solving it and they learn by discovery basically. So we want to continue that as much we can, and that is an area that we really need help on from getting that training for our staff.

Mr. TONKO. But your setting is particularly focused on math and engineering, your elementary school?

Mr. SANDLIN. No, it is focused on engineering and mathematics but we tie it into all the subject areas of the school.

Mr. TONKO. Because I think we need it across the board at all schools, at elementary schools for a number of reasons: to encourage engineering perhaps as a career, but more importantly, to develop those analytical skills, those problem-solving skills that all of society needs no matter what discipline you are going to follow in life.

Chairman LIPINSKI. Thank you, Mr. Tonko. I can never say no to a Polish mechanical engineer over there.

The Chair now recognizes Mr. Hall.

Mr. HALL. Thank you, Mr. Chairman. I was trying to think of a way they could have ever got me interested in math when I was in school. The three years I took Math 1 were very tough years. And by the way, Mr. Miaoulis, Martha and Josh Morriss Middle School is a NASA Explorer School. Thank you for your—because NASA is in a bind now, as Norm Augustine just released in his report today, and that is going to hit the papers through the day as to what recommendations he has made. And NASA, everybody else I know needs more money but schools really do and that is where we ought to be looking first, probably second and third.

Dr. Pines, I noticed that you testified that, quote, "middle school is probably the right time to weave in some of the basic engineering but too early to do any rigorous engineering-type classes." If middle school is probably the right time, are you suggesting that elementary level is too early for students to grasp the basics of engineering?

Dr. PINES. By no means.

Mr. HALL. Oh, okay. I didn't think so but I wanted to give you a chance because that is in your testimony.

Dr. PINES. I am essentialy saying that more of the structure would probably show up in middle school, that is simply my comment, but absolutely, many of our kids that are in third, fourth and fifth grade that are elementary, those that are very much interested in mathematics also need to be exposed to the concepts of engineering at the very basic level. That really would be my statement. But more structure can show up in middle school where they really can connect and actually start doing some level of analysis because by that time they are learning algebra. When they are in elementary school, they are not. They are dealing with fractions and decimals and very simplistic things. You can bring out some general concepts. But as they transition into middle school, our experience, at least at the Clark School, is that they make that connection fairly strongly. We have programs for third, fourth and fifth graders that still is a little bit of struggle to make the connections for them and see what they are looking at in terms of engineering, but they are interested. We want to keep that continuum as we go into middle school.

Mr. HALL. Anyone else want to comment on that?

Mr. SANDLIN. I will just make one comment, that, you know, we strive with—sometimes the teachers will say, well, they are just not developmentally ready for that or they are just not interested in it, but it is amazing what young children will do if you give them the opportunity to do it, and we are learning ourselves that

they can go a long ways without us realizing what they can do if we just afford them the opportunity to explore, and we certainly—you know, we want to make sure when we get to the middle school that we have students that are able to take a pre-algebra, an algebra in the seventh grade, are going to take calculus in tenth and then be ready to take the engineering courses at grades 11 and 12.

Mr. HALL. I thank you, and I yield back my time. Thank you, Mr. Chairman. You have been very generous.

Chairman LIPINSKI. Thank you, Mr. Hall. And before we bring this hearing to a close, I want to thank our witnesses for testifying before the Committee today and also thank you for all the good work that you are doing at the Museum of Science in Boston. The Subcommittee has done a lot of work here on informal science education and I know you are doing a great job there, and Mr. Sandlin, I have to say, I wish I had been able to go to your school when I was in elementary school.

Mr. SANDLIN. We have had that comment, so you are welcome to visit, anyway.

Chairman LIPINSKI. Thank you.

The record will remain open for two weeks for additional statements from the Members and for answers to any follow-up questions the Committee may ask of the witnesses.

The witnesses are excused and the hearing is now adjourned.

[Whereupon, at 11:42 a.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

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ANSWERS TO POST-HEARING QUESTIONS

Responses by Linda P.B. Katehi, Chair, Committee on K–12 Engineering Education, National Academy of Engineering, National Research Council/Center for Education, The National Academies; Chancellor, University of California, Davis

Questions submitted by Representative Marcia L. Fudge

Q1. In my district, we have experienced great success in partnering the first STEM school in the Nation within a corporate complex. In General Electric's Nela Park campus in East Cleveland we housed our first freshman class this past year. The students were able to shadow and be mentored by GE employees. This has shown to be very beneficial to both the corporation and the students. While our success is limited to only our first year's worth of data, do you think it would be valuable to raise awareness among our corporate engineering stakeholders to encourage them to also be advocates of STEM programs within their community school systems? Has there been any focus on your part to this approach? If not, how best can this type of corporate campaign be accomplished?

A1. The active participation of industry in the development and delivery of educational programs that support STEM literacy is absolutely critical and should be encouraged. Industry should be engaged visibly but this should be done in a way that 1) is sustainable (i.e., does not result in one-off initiatives that disappear once funding is gone), 2) takes into account what is known about the complex, systems nature of school reform, 3) builds on and strengthens existing networks and coalitions of higher education, industry, K–12, and 4) includes from the very beginning a plan and money for collecting outcomes data, so that the impact of interventions can be determined and programs can be modified to be more effective.

Our committee did not focus on this type of industry participation but we extensively discussed how to utilize scientists and engineers to support teachers in teaching the STEM subjects. A campaign to encourage corporations in investing in these types of activities could be done in the form of a public-private collaboration and could be encouraged via State or federal initiatives.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Thomas W. Peterson, Assistant Director, Engineering Directorate, National Science Foundation (NSF)

Questions submitted by Representative Marcia L. Fudge

Q1. In my district, we have experienced great success in partnering the first STEM school in the Nation within a corporate complex. In General Electric's Nela Park campus in East Cleveland we housed our first freshman class this past year. The students were able to shadow and be mentored by GE employees. This has shown to be very beneficial to both the corporation and the students. While our success is limited to only our first year's worth of data, do you think it would be valuable to raise awareness among our corporate engineering stakeholders to encourage them to also be advocates of STEM programs within their community school systems? Has there been any focus on your part to this approach? If not, how best can this type of corporate campaign be accomplished?

A1. The MC2 STEM High School an the Nela Park campus in East Cleveland, headquarters to General Electric's lighting and industrial unit, is truly a wonderful example of corporate involvement in education programs focused an science and engineering. I am in total agreement with her that this type of corporate engagement is crucial to the success of STEM education. This involvement serves many purposes.

Certainly, corporate partners can provide critical financial support to augment support for education coming through conventional channels. These corporate partners can also advocate far STEM programs within their communities. They can touch student's imaginations by showing them the power of innovation and creativity using real world examples from their companies. Finally, they employ the creative engineers who can be positive role models and mentors far students.

At the National Science Foundation, we encourage company involvement in all of our NSF education programs, because in addition to the points mentioned above, they wilt be employers of our students. We have many examples of educational partnerships between NSF and industry, both in the Engineering Directorate and in the Education and Human Resources Directorate.

Here are two examples of corporate involvement in STEM programs which NSF funded.

1. "Engineer Your Life" which encourages young women to pursue engineering. Its' backbone is a Coalition of over 50 companies (including GE), universities (including Ohio Slate), and engineering professional societies. Companies contribute rate models and mentors far students and teachers. See *www.engineeryourlife.org*.
2. "UTEACH Engineering" which is preparing a new high school engineering course and the teachers to deliver it. The program builds upon the success of UTEACH Natural Sciences, which was just named one of the Top 50 Innovations in American Government today by Harvard's Ash Institute for Democratic Governance and Innovation, Company involvement is key to the operation and impact of the program. Also the Industrial Advisory Boards to the 34 engineering schools in Texas are active in UTEACH as advocates, role models and mentors.

I would be happy to provide many more examples if there is an interest, but the direct answer to the question is yes, we strongly encourage and support corporate involvement in our K–12 STEM activities and have experienced many productive partnerships between NSF and regard.

Appendix 2:

Additional Material for the Record

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October 23, 2009

The Honorable Daniel Lipinski
Chairman, Subcommittee on Research and Science Education
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

The Honorable Vernon Ehlers
Ranking Member, Subcommittee on Research and Science Education
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Lipinski and Ranking Member Ehlers:

On behalf of the of the more than 144,000 members of the American Society of Civil Engineers (ASCE) thank you for holding a hearing on October 22nd on "Engineering in K-12 Education." ASCE echoes the statements of the witnesses that including engineering in K-12 education is essential to ensuring a technically literate society.

ASCE was founded in 1852 and is the country's oldest national civil engineering organization. It represents civil engineers in private practice, government, industry and academia who are dedicated to the advancement of the science and profession of civil engineering.

ASCE strongly supports the federal programs that foster an appreciation and understanding of science, technology, engineering and mathematics (STEM) at all educational levels. It is evident, however, that the technology and engineering component is sadly lacking. It is critical to provide all students, regardless of their career intentions, with an understanding of STEM concepts adequate to enable their participation in our increasingly technological society; furthermore we must prepare students who intend to pursue STEM careers with the necessary knowledge and skills in these subjects.

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ASCE supports the conclusion of the National Academy of Engineering report, "*Engineering in K-12 Education: Understanding the Status and Improving the Prospects.*" Many elementary, middle, and high school students do not receive adequate instruction in math and science, such that the possibility of studying engineering at the college level is effectively precluded. Moreover, many elementary, middle, and high school students receive little or no exposure to engineering. As a result, students who have the aptitude to be successful engineers never have an opportunity to develop an interest in this career path.

Once again, thank you for your leadership on this important issue. ASCE stands ready to help in any way we can. Please do not hesitate to contact Martin Hight, ASCE's Senior Manager of Government Relations at 202-789-7843 or mhight@asce.org for further information or help.

Sincerely,

D. Wayne Klotz, P.E., D.WRE, F.ASCE
ASCE President

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