A SYSTEMS APPROACH TO IMPROVING K–12 STEM EDUCATION

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

JULY 30, 2009

Serial No. 111–47

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

51–162PDF WASHINGTON : 2010

For sale by the Superintendent of Documents, U.S. Government Printing Office
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A SYSTEMS APPROACH TO IMPROVING K–12 STEM EDUCATION

THURSDAY, JULY 30, 2009

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

The Subcommittee met, pursuant to call, at 10:06 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Daniel Lipinski [Chairman of the Subcommittee] presiding.

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Hearing on

A Systems Approach to Improving K-12 STEM Education

Thursday, July 30, 2009
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Witness List

Dr. Wanda Ward
Acting Assistant Director, Directorate for Education and Human Resources, National Science Foundation

Ms. Maggie Daley
Chair, After School Matters

Mr. Michael Lach
Officer of Teaching and Learning, Chicago Public Schools

Dr. Donald Wink
Director of Undergraduate Studies, Department of Chemistry
Director of Graduate Studies, Learning Sciences Research Institute, University of Illinois at Chicago

Ms. Katherine Pickus
Divisional Vice President, Global Citizenship and Policy, Abbott
Vice President, Abbott Fund

HEARING CHARTER

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

A Systems Approach to Improving K–12 STEM Education

THURSDAY, JULY 30, 2009
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

On July 30, 2009 the Subcommittee on Research and Science Education of the House Committee on Science and Technology will hold a hearing to examine how the many public and private stakeholders in an urban K–12 system can work together to improve science, technology, engineering and mathematics (STEM) education inside and outside of the classroom.

2. Witnesses

- **Dr. Wanda Ward,** Acting Assistant Director, Directorate for Education and Human Resources, National Science Foundation (NSF)
- **Ms. Maggie Daley,** Chair, After School Matters
- **Mr. Michael Lach,** Officer of Teaching and Learning, Chicago Public Schools
- **Dr. Donald Wink,** Director of Undergraduate Studies, Department of Chemistry, and Director of Graduate Studies, Learning Sciences Research Institute, University of Illinois at Chicago
- **Ms. Katherine Pickus,** Divisional Vice President, Global Citizenship and Policy, Abbott

3. Overarching Questions

- Who are the many public and private stakeholders in the K–12 STEM education system? What are, or should be, their respective roles and responsibilities? What kinds of partnerships across the system are most effective at leveraging resources and intellectual capital? How do these partnerships ensure continuity in teaching and learning between the classroom and informal environments such as after-school programs?
- What are the major barriers to improving the interest and performance of K–12 students and teachers in STEM? Are there model programs or approaches to curriculum and instruction that have demonstrated how to increase student achievement and/or teacher performance? What are the most important and effective components of these programs? How are these programs evaluated for effectiveness? How can partnerships between various stakeholders in the STEM education system facilitate the identification and implementation of successful models?
- How do NSF programs support the improvement of the teaching and learning of STEM disciplines in the pre-K through 12 years? What instructional tools, resources, materials, and technologies has NSF supported to enable STEM learning? Under what conditions, and for whom, are such resources for learning most effective? How can NSF help to disseminate successful tools and resources and facilitate effective partnerships between other stakeholder groups in the STEM education system?

4. Background

A Systems Approach

A consensus now exists that improving STEM education throughout the Nation is a necessary, if not sufficient, condition for preserving our capacity for innovation and discovery and for ensuring U.S. economic strength and competitiveness in the international marketplace of the 21st century. The National Academies *Rising Above the Gathering Storm* report placed a major emphasis on the need to improve STEM education and made its top priority increasing the number of highly qualified STEM teachers. This recommendation was embraced by the 2007 *America COMPETES Act.*

Two more recent STEM education reports that have generated a lot of attention have emphasized, as part of their priority recommendations, the need for greater coordination between the many public and private stakeholders in the Nation's K–12 STEM education system. The reports are: "A National Action Plan for Addressing the Critical Needs of the U.S. STEM Education System," from the National Science Board (NSB),[1] and "The Opportunity Equation," from the Carnegie Corporation's Institute for Advanced Study.[2] The stakeholders cited in these reports include the Federal and State governments, colleges and universities, businesses, a variety of nonprofit organizations, philanthropic organizations, and of course, school districts themselves.

In a related effort, the Business Higher Education Forum just launched a new education system predictive modeling tool to "provide an organized and comprehensive approach to viewing and understanding the complex, multi-level nature of the U.S. and STEM education system." The STEM Research and Modeling Network (SRMN),[3] which provided input to the development of and now oversees the model, is composed of representatives from all of the aforementioned stakeholder groups.

The Science and Technology Committee held a hearing on the NSB report in October 2007 to review the recommendations in the report, which addressed both federal interagency coordination and coordination across all of the stakeholder groups. In response to the recommendation for greater interagency coordination, the Committee introduced H.R. 1709, the *STEM Education Coordination Bill of 2009,* which passed the House last month and has a companion bill in the Senate, S. 1210. The Committee is continuing to explore possible roles for the Federal Government in facilitating greater coordination among the full range of stakeholder groups.

K–12 STEM Education at the National Science Foundation

Science and math education is a cornerstone of the historic mission of the National Science Foundation. The *National Science Foundation Act of 1950,* which established NSF, directed NSF to support and strengthen science and math education programs at all levels. NSF carries out its K–12 mission by supporting a variety of STEM education activities, including teacher training (both in-service and preservice), curriculum development, education research, and informal education at museums, science centers and other after school settings.

Examples of NSF programs designed to improve K–12 teacher performance include the Math and Science Partnership (MSP) Program and the Robert Noyce Scholarship (Noyce) Program, both reauthorized in 2007 as part of the *America COMPETES Act.* The MSP Program funds partnerships between universities and local school districts to strengthen the science and math content knowledge of K–12 school teachers. The grants are awarded to support the creation of innovative reform programs that could be expanded to the State level if successful. The Robert Noyce Scholarship Program is designed to help recruit highly-qualified science and math teachers through grants to college and universities to give scholarships to science and math majors in return for their commitment to teach at the elementary or secondary school level.

Additional NSF programs targeted to K–12 education include Discovery Research K–12, which funds everything from basic research on learning and teaching to the development and implementation of tools, resources, curricula, models and technologies based on the research findings; Informal Science Education, which funds projects that advance informal STEM education; and Research and Evaluation on Education in Science and Engineering, which seeks to improve the methodology of education research and evaluation of education tools and models to ensure high-quality research results and effective program development. The Graduate STEM

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[1] *http://www.nsf.gov/nsb/documents/2007/stem_action.pdf*
[2] *http://www.opportunityequation.org/*
[3] *http://www.bhef.com/solutions/stem/srmn.asp*

Fellows in K–12 Education (GK–12) Program puts science and engineering graduate students into K–12 classrooms on a part-time basis during their graduate studies. Primarily this is considered a professional development program for graduate students—in particular to strengthen their communication skills and instill a deeper appreciation for the societal context for their research; however, when effectively integrated with broader university partnerships with local schools and school districts, GK–12 fellows can also contribute in a meaningful and lasting way to student and teacher performance in the classroom.

Chicago: A Large Urban School District

Last year the Committee held a hearing to learn about STEM education in Texarkana, Texas, a small town of 35,000 in northeast Texas.[4] Similarly, in today's hearing, the Committee is examining a systems approach to STEM education using Chicago as a case study for a large urban school district. Chicago Public Schools (CPS), the third largest school district in the Nation, currently operates 666 schools, including 483 elementary and middle schools, 116 high schools and 67 charter schools. Total student enrollment is nearly 408,000—nearly 20 percent of all Illinois public school students. The CPS student population is 46.2 percent African American, 41.2 percent Latino, 8.9 percent White and 3.5 percent Asian/Pacific Islander. CPS students have made some notable gains in achievement in recent years. The composite percentage of students meeting or exceeding State standards on the Illinois Student Achievement Test has risen from 47 percent in 2004 to 69.8 percent in preliminary 2009 data. The number of high school students taking at least one Advanced Placement course has doubled from less than 6,000 in 2004 to 12,464 a year ago. The district's drop-out rate has decreased by about seven percentage points since 2003 and the graduation rate has risen by almost the same amount during the same period. However, the most recent Prairie State Achievement Examination showed that more than 70 percent of high school juniors failed to meet State standards in math and science. Average math and science scores on the national ACT exam also indicate a lack of college readiness among a high percentage of CPS high school students. Improving the achievement of CPS students in math and science will require an all hands on deck, coordinated effort by local universities, businesses, and nonprofit organizations in partnership with CPS. Witnesses today will discuss several of those partnerships and the gains already demonstrated.

5. Questions for Witnesses

Wanda Ward

1. What evidence is available from NSF-funded projects to help us better understand how students develop interests in STEM fields in the pre-K through 12 years, and how can those interests be sustained across the high school to post-secondary education transition? Are there model programs or approaches to curriculum and instruction that have demonstrated how to engage students successfully in STEM areas and that lead to choice of STEM degrees and careers? What is the role of out-of-school learning in encouraging STEM interest and achievement?
2. How do NSF programs support the improvement of the teaching and learning of the STEM disciplines in the pre-K through 12 years? What programs are available to improve teachers' knowledge and abilities, and what does research tell us about the best ways to enable teachers' effectiveness in promoting learning? What types of programs and models for STEM teacher preparation, induction, and professional development show the most promise for supporting STEM teachers' learning, and what can be learned from the implementation of such programs and models?
3. What instructional tools, resources, materials, and technologies has NSF supported to enable STEM learning? Under what conditions, and for whom, are such resources for learning most effective? Does research provide insight into what kinds of instructional materials and tools are most useful in supporting learning at various levels, and for various groups of learners? How much do regional differences across the United States account for the efficacy of any given set of tools or materials?

[4] *http://science.house.gov/publications/hearings_markups_details.aspx?NewsID=2181*

Maggie Daley

1. What is After School Matters (ASM)? What kind of science, technology, engineering and mathematics (STEM) programming does ASM offer? What partnerships have you built in support of your programming—in terms of both financial support and intellectual resources?
2. How does ASM's informal learning complement the formal education students receive in the classroom? How do you work with the local school districts to develop your STEM programming and to ensure a seamless transition from the formal education of the classroom, including adherence to State or local standards, and the informal education provided by ASM? How do you assess the impact of your programs on student interest and/or achievement in STEM?
3. What are the major challenges that inhibit the interest or performance of youth in your after school STEM programs? What steps has ASM taken to address these challenges? Do you have any recommendations to the private sector or to State and federal stakeholders on how they can take better advantage of not-for-profit organizations such as ASM in their own efforts to improve STEM education?

Michael Lach

1. What is the overall state of science, technology, engineering and mathematics (STEM) education in Chicago Public Schools (CPS)? Why is it important for all students to achieve proficiency in these subjects?
2. How do you work with the local private sector, not-for-profit organizations, and colleges and universities to improve STEM education in CPS? Please describe these partnerships and activities. How do you develop such partnerships and activities, and how do you assess them in terms of impact on student achievement?
3. What are the major problems that limit the performance of students and teachers, and what do you feel is the single, most important step that the Federal Government should take to improve K–12 STEM education? What involvement have you had with math and science education programs at the National Science Foundation or other federal agencies as well as those in the State of Illinois? What are the most important and effective components of these programs?
4. What role should parents play in improving K–12 STEM education? Do you have outreach programs intended to engage parents in their children's K–12 STEM education?

Donald Wink

1. Please describe briefly the University of Illinois at Chicago's (UIC) K–12 science, technology, engineering and mathematics (STEM) education programs and initiatives, including those that involve education and professional development for math and science teachers. How have you and your colleagues worked with Chicago Public Schools in developing or revising these programs over time? What other partners—public or private—have provided funding or have otherwise been involved in the development or implementation of these programs? How do you evaluate the effectiveness of these programs and partnerships?
2. What are the major problems that limit the performance of students and teachers in STEM? What are the most important and effective components of the National Science Foundation (NSF) funded programs (including the Math and Science Partnership Program, the Robert Noyce Teacher Scholarship Program, and the Graduate STEM Fellows in K–12 Education Program) that UIC has implemented in partnership with Chicago Public Schools? Are there common lessons learned or replicable elements across UIC's various science and math programs, including those funded by NSF? How do you or can you help to disseminate these findings to other cities and regions of the country?
3. What is the most important role a university such as your own can play in improving K–12 STEM education in your own community and/or nationally? How can universities help facilitate and build partnerships with other stakeholders, including the private sector and informal education providers? What is the single, most important step that the Federal Government should take to improve K–12 STEM education?

Katherine Pickus

1. Please describe what Abbott does. What percentage of your U.S. workforce has a science, technology, engineering and/or mathematics (STEM) background? Are you able to recruit locally for these positions and if not, why not? How does investing in K–12 STEM education in the U.S. communities in which you are located benefit your own future workforce needs? Why else is it important for Abbott to be interested in K–12 STEM education?
2. How do you work with the local school districts and with colleges and universities to help build a talented STEM talent pool from which to recruit? How do you work with other companies and organizations in the private and not-for-profit sectors to improve STEM education both nationally and within your community? Please describe these activities, the kind of partnerships involved, the level of investment in such activities, and how you go about developing and assessing such activities. How do you prepare your own scientists to work with youth in or out of the schools?
3. What do you see as the biggest challenges to improving STEM education in this country? Can you provide specific examples of barriers that you have faced in your own efforts to build partnerships and invest in STEM education in your own communities? Do you have any recommendations to State or federal stakeholders on how they can take better advantage of the private sector in their own efforts to improve STEM education?

Chairman LIPINSKI. This hearing will come to order.

Good morning and welcome to this Research and Science Education Subcommittee hearing on a systems approach to improving science, technology, engineering and math education, commonly called STEM education. This is the third STEM-related hearing that this subcommittee has held this year, a fact that reflects both the national importance of the STEM fields and the complexity of STEM education reform.

The Science and Technology Committee, and our subcommittee in particular, have made STEM education a top priority. In hearings and reports we have repeatedly heard that innovation is key to maintaining a high standard of living for all Americans, and that we need more teachers and more graduates in the STEM fields if we want our country to continue to lead in the global economy. Unfortunately, American students have been lagging their international peers, while American businesses are warning about a wave of retirements without adequately trained young people to fill these vacated positions, especially in engineering fields. But we know that there is no panacea and no one entity that can solve this alone, as recent reports from the National Science Board and the Institute for Advanced Study have made clear.

Reform of our STEM education system will require coordination on multiple fronts across many diverse stakeholders. In addition to several federal agencies, there are State and local governments, school districts, universities, non-profits, businesses, community organizations, teachers, students, and—if a child is fortunate—their parents. I don't doubt that some high-level planning and coordination will be helpful, including in the movement toward common core standards in which almost all states are now engaged. The Science and Technology Committee has begun addressing coordination issues at the federal level, notably through the *STEM Education Coordination Bill of 2009*. But federal issues and even standards are only the tip of the iceberg. Implementation of any reform has to happen in the 50 states and, even more so, the 15,000 school districts across the country.

Today we focus on one school district, Chicago, which is the third largest district in the country. The witnesses represent a range of key stakeholder groups in the city of Chicago, including the school district, a large company dependent on a highly trained STEM workforce, a local university that has been a leader in K–12 reform efforts, a city-wide informal education provider, and a federal agency that has funded many of the innovative programs we will learn about today. Chicago's diverse population of over 400,000 public school students, its top-notch universities, and the commitment of local industry, the school system, and city leaders such as Ms. Daley, make it an ideal case study for understanding what works in improving STEM education, how various stakeholders in the system can work together, and what can be done at the federal level to encourage best practices across the country.

This hearing will consider the entirety of the STEM education system, with all of its partners and key leverage points. I look forward to hearing our witnesses shed some light on how we can approach systemic reform more methodically, including through strong partnerships, innovative approaches to in-school and out-of-school teaching, and rigorous assessment of old and new programs alike.

America needs to be successful in improving STEM education. Without it, we will lose our capacity for innovation and diminish our country's economic strength and competitiveness in the international marketplace. I am confident that Americans can do it, and we can maintain our world leadership. We see some pockets of success across the country. It is our job here in Washington as national leaders to make sure that we all learn from these successes and that the best possible information and tools are available to all STEM educators, and that is why you are here today. I want to hear from all of our witnesses about their insights about what has worked in Chicago, and I want to thank you for appearing before the Subcommittee today, taking the time and I am very hopeful that this will be a great opportunity for people across the country to learn about what you have done, what has worked, what has not worked, but the best way that we can all move forward for the sake of our country and our future.

With that, I will recognize Ranking Member Dr. Ehlers for an opening statement.

[The prepared statement of Chairman Lipinski follows:]

PREPARED STATEMENT OF CHAIRMAN DANIEL LIPINSKI

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Mr. EHLERS. Thank you, Mr. Chairman. It is a pleasure to participate in this. As you know, STEM education has a strong place in my heart, and I have spent many hours on it both as my professional career before coming here and also since I have come here. Today's hearing will examine how the various public and private stakeholders in an urban K–12 system can work in concert to improve science, technology, engineering and mathematics education, better known as STEM education. In particular, I am pleased that we will hear testimony from key players in the Chicago public schools, our nation's third largest school system, on the successes and challenges of implementing STEM education programs in an urban district.

As we take a closer look at the Chicago public schools, I expect we will gain a greater appreciation for the difficulties involved in encouraging our urban youth to pursue STEM-related fields. At the same time, I look forward to hearing about the role of outside groups in facilitating this type of learning. During the 110th Congress, this committee held a field hearing in Texarkana, Texas, to witness firsthand a suburban community's efforts to engage students in math and science. I expect today's case study of the Chicago public school system will offer the Committee fresh insights while building upon the observations collected in last year's hearing.

I would like to acknowledge the work of Chairman Gordon and Subcommittee Chairman Lipinski and their staff on the series of STEM-related hearings in the 111th Congress. These hearings have educated Members and the public about the problems and the necessity of improving STEM education, a topic which I am always willing to discuss. I would also like to thank our panel of experts for joining us today, and I look forward to hearing their testimony.

I yield back.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Today's hearing will examine how the various public and private stakeholders in an urban K–12 system can work in concert to improve science, technology, engineering and mathematics (STEM) education. In particular, I am pleased that we will hear testimony from key players in the Chicago Public Schools, our nation's third largest school district, on the successes and challenges of implementing STEM education programs.

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Chairman LIPINSKI. Thank you, Dr. Ehlers, and having an engineer up here and a physicist, certainly we have a little bit of experience, though mine pales in comparison to Dr. Ehlers in STEM education.

At this point, if there are Members who wish to submit additional opening statements, your statement will be added to the record at this point.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman, thank you for hosting this hearing regarding improvements to K–12 STEM Education. I appreciate the attention that is being given to advancing education in the fields of Science, Technology, Engineering, and Mathematics.

Approaches to improving STEM education should be multi-faceted and include a variety of interests. Not only should we enhance students' experiences inside of the classroom, but we should also ensure that their extracurricular activities are conducive to the pursuit of knowledge. By increasing the number of teachers who are capable and skilled in the STEM fields, students will benefit from a more enriching classroom environment. I look forward to hearing from our witnesses about specific programs that are available to improve the skills of STEM teachers and best practices.

Another element of STEM education improvements involves informal learning opportunities. Education should not stop at the classroom door. It should be incorporated into different aspects of students' lives so that they are not just achieving mediocrity, but rather, they are excelling. I am curious about the role that private institutions can play in partnering with school systems to develop robust informal STEM education opportunities and I would like the witnesses to contribute their expertise in these areas.

In closing, I'd like to thank the members of the panel for their participation in today's hearing. I hope that we can continue our efforts to improve STEM education and by doing so, promote innovation and ensure U.S. economic competitiveness in the future.

Chairman LIPINSKI. Right now I want to introduce our witnesses. First we have Dr. Wanda Ward, who is Acting Assistant Director for Education and Human Resources at the National Science Foundation. We have Mrs. Maggie Daley, who is the Chair of After School Matters, which is a unique partnership between Chicago public schools, civic leaders and industries that have created a network of programs including STEM education mentorships for teens in Chicago's under-served communities. I will now recognize Dr. Ehlers to introduce our third witness. Actually now that I look at this, I am a little mixed up because I don't have in my—is that the correct one? Okay.

Mr. EHLERS. Thank you, Mr. Chairman. It is a pleasure to introduce Mr. Michael Lach. He worked in my office for a year as an Einstein fellow, which gives you some idea of his mental capacity. As you know, the Einstein fellowships are from the Department of Energy and they do an excellent job for us. But Michael ended up in my office and I still recall asking him, you know, after we had agreed to take him on board and I was chatting with him, I said, you know, I have only met one person before in my life who was named Lach and he was a physicist at Berkeley when I was there, we actually shared an office together. It turned out to be Michael's father. But Mike did a great job in my office, one of the few interns or assistants I have ever had who instinctly understood politics, and I suspect that accounts for his success in Chicago because in Chicago it is very hard to do anything without understanding the politics of Chicago. But Mike did a great job there and did a great job in our office too and he has steadily advanced up the ranks in Chicago.

I think it is especially appropriate to look at the Chicago public school system not just because of the work that Michael has done but also because our current Secretary of Education was the leader of the Chicago schools for a few years and he has already made his mark on the Department of Education and showing great innovation and leadership in that department. So we are looking forward to good things from him there and we are looking forward to good things from Mike today.

Thank you, and with that, I yield back.

Chairman LIPINSKI. Dr. Ehlers, you are a professor for how many years?

Mr. EHLERS. Twenty-two years.

Chairman LIPINSKI. In my short time, my four years as an Assistant Professor, I know the politics in higher education might be worse than anything—more difficult than anything I have seen anywhere. We could probably go on for a long time but we will get back to introducing the witnesses here.

Dr. Donald Wink is the Director of Undergraduate Studies in the Department of Chemistry and the Director of Graduate Studies in the Learning Sciences Research Institute at the University of Illinois at Chicago, and finally Ms. Katherine Pickus is the Divisional Vice President for Global Citizenship and Policy at Abbott Labs.

As our witnesses know, you will each 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 and each Member will have five minutes to ask questions, and we will start with Dr. Ward. Dr. Ward, you are recognized for five minutes.

STATEMENT OF DR. WANDA E. WARD, ACTING ASSISTANT DIRECTOR, DIRECTORATE FOR EDUCATION AND RESOURCES, NATIONAL SCIENCE FOUNDATION (NSF)

Dr. WARD. 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 systemic change for science, technology, engineering and mathematics education.

The National Science Foundation recognizes that STEM education is at a crossroad, in need of increased attention from a broad array of stakeholders who have a common goal of promoting excellence for all learners.

Over many decades, we have seen improvements in science attainment through our systemic approach to education reform. The lessons learned and the research findings on K–12 education in formal and informal settings have been synthesized in two recent publications by the National Academy of Sciences, *Taking Science to School* and *Learning Science in Informal Environments.* NSF programs are built around many of the conclusions reached in these research publications such as, children entering school already have substantial knowledge of the natural world. What children are capable of at a particular age is the result of a complex interplay among maturation, experience and instruction. Students learn science by actively engaging in the practices of science. A range of instructional approaches is necessary as part of a full development of science proficiency, ask and answer questions and evaluate evidence when doing science and have learners develop a positive use of themselves with respect to science.

Partnering with other external stakeholders, NSF believes that the field is ready to advance current understanding of STEM education by linking novel approaches and best effective practices to STEM-specific challenges for the 21st century. Our vision will be aligned with the STEM priorities in the *America COMPETES Act* as well as the *American Recovery and Reinvestment Act.* With multi-purpose strategic thinking, we will sharpen our support on four foci: innovation in learning ecosystems of emerging areas like clean alternative energy and climate change education with an emphasis on blending formal and informal education; broadening participation to improve workforce development; enrichment of teacher education for the 21st century; and fostering cyber learning to enhance STEM education.

Recognizing that innovation plays a key role in the U.S. economic competitiveness, the role of diverse intellectual capital in spurring innovation is a great topic of interest to us at the NSF. Key issues within this ecosystem include research and understanding of the culture of innovation and the interplay between innovation and education.

Technology has the potential to transform education throughout a lifetime, enabling customized interaction with diverse learning materials on any topic and supporting continuous education at any age. In the last decade, the design of technologies and our understanding of how people learn had evolved together. NSF has played a key role in these advances. NSF can continue to lead this revolution by leveraging its investments in the productive intersections between technology and the learning sciences. Creative thinking and an integrated approach about STEM education and learning for the future will offer new challenges and new opportunities for transformative research on educational practices and learning tools.

In summary, our STEM education and workforce development vision will attend to a rich tapestry of excellence and diversity in STEM attainment, access, availability and reach across STEM lines of inquiry and geographical borders, innovation and transformation for stimulating STEM creativity for discovery and learning, depth and breadth of domains to promote STEM interdisciplinarity and seamlessness and coherence to ensure a high level of continuity across the learning continuum. STEM education and workforce for the 21st century is key to promoting and sustaining an innovative society.

Thank you very much, and I would be pleased to answer any questions that you may have.

[The prepared statement of Dr. Ward follows:]

PREPARED STATEMENT OF WANDA E. WARD

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 "Systemic Change for Science, Technology, Engineering and Mathematics (STEM) Education."

Today, I will address your concerns that focus on: (1) student interest in and pursuit of careers in science and engineering; (2) enrichment of teacher education for the improvement of teaching and learning in STEM; (3) instructional resources linked to effective STEM teaching and learning; and (4) role of out-of-school learning in STEM education. I would also like to take this opportunity to share our vision for continuing our commitment to promoting excellence in STEM education for the 21st Century.

The National Science Foundation recognizes that STEM education is at a crossroad, in need of increased attention from a broad array of stakeholders who have the common goal of promoting STEM excellence for all learners. Over many decades, we have seen improvements in science attainment through our systemic approach to education reform. The lessons learned and the research findings on K–12 education in formal and informal settings have been synthesized in two recent publications by the National Academy of Science: *Taking Science to School*[1] and *Learning Science in Informal Environments.*[2] For example, the six conclusions reached in *Taking Science to School* (page 2)[3] about what students know and how they learn are:

- Children entering school already have substantial knowledge of the natural world, much of which is implicit.
  - *Children's intuitive concepts of the natural world can be both resources and barriers to emerging understanding. These concepts can be enriched and transformed by appropriate classroom experiences.*
- What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on their prior opportunities to learn.
- Students' knowledge and experience play a critical role in their science learning, influencing all four strands of science understanding.
  - *know, use, and interpret scientific explanations of the natural world;*
  - *generate and evaluate scientific evidence and explanations;*
  - *understand the nature and development of scientific knowledge; and*
  - *participate productively in scientific practices and discourse.*
- Race and ethnicity, language, culture, gender, and socioeconomic status are among the factors that influence the knowledge and experience children bring to the classroom.
  - *Children's experiences vary with their cultural, linguistic, and economic background. Such differences mean that students arrive in the classroom with varying levels of experience with science and varying degrees of comfort with the norms of scientific practice.*

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[1] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K–8.* Committee on Science Learning, Kindergarten Through Eighth Grade. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[2] National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* Committee on Learning Science in Informal Environments. Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

[3] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K–8.* Page 2. Committee on Science Learning, Kindergarten Through Eighth Grade. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

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- Students learn science by actively engaging in the practices of science.
  - *Motivation and attitudes toward science play a critical role in science learning, fostering students' use of effective learning strategies that result in deeper understanding of science. Classroom instruction and the classroom context can be designed in ways that enhance motivation and support productive participation in science.*
- A range of instructional approaches is necessary as part of a full development of science proficiency.
  - *Children's understanding of science appears to be amenable to instruction. However, more research is needed that provides insight into the experiences and conditions that facilitate their understanding of science as a way of knowing.*

Experts also documented the many and valued roles of the teacher in the pre-college years. *Taking Science to School,* (page 180) provides an example of the influence of teachers in helping elementary and middle school students to gain an understanding of how scientific knowledge develops, including more sophisticated understanding of nature and scientific models. A teacher can create such learning environments in the following progression of promoting metaconceptual skills in grade 1–6.[4]

Grade	Teacher's Role
1	• Finds a variety of ways in which students can externally represent their thinking about the topic • Provides many experiences for students to begin to articulate the reasoning used to support ideas/beliefs
2	• Continues to provide an educational environment in which students can safely express their thoughts, without reproaches from others • Introduces concept of consistency of thinking • Models consistent and inconsistent thinking (students can readily point out when teacher is being inconsistent)
3	• Fosters metacognitive discourse among learners in order to illuminate students' internal representations • Provides lots of examples from their personal work (which is saved from year to year) of student ideas
4-6	• Provides historical examples of very important people changing their views and explanations over time • Begins to use students' external representations of their thinking as a way of evaluating their ideas/beliefs (in terms of intelligibility, plausibility, and fruitfulness) in order to (a) create, when necessary, dissatisfaction in the minds of the learner to facilitate conceptual exchange or (b) look for ways of promoting conceptual capture in the mind of the learner

Learning Science in Informal Environments points out that "a great deal of science learning, often unacknowledged, takes place outside school in informal environments—including everyday activity, designed spaces, and programs—as individuals navigate across a range of social settings; rich with educationally framed real-world phenomena, [informal science settings] are places where people can pursue and develop science interests, engage in science inquiry, and reflect on their experiences through conversations" (page 293).[5] Furthermore, the following principles are offered to promote interest in Science:

- address motivation to learn science, emotional engagement with it, and willingness to persevere over time despite encountering challenging scientific ideas and procedures

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[4] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K–8.* Page 180. Smith, C.L., Maclin, D., Houghton, C., and Hennessey, M.G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction,* 18(3), 285–316.

[5] National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* Page 293.

- *An expressed interest in science during early adolescence is a strong predictor of science degree attainment (page 44)*[6]

- learn about main scientific theories and models framing the understanding of the natural world
- ask and answer questions and evaluate evidence when doing science
- allow for dynamic refinement of scientific understanding of the natural world
- have learners develop [positive] views of themselves with respect to science.

Relatedly, findings from research materials on motivation from *Taking Science to School (page 200)* indicate that interest is tied to the quality of learning. Research on the development of interest indicates that children tend to have general or universal interests at first, which become more specific relatively quickly. The development of career interests is thus a process of continuous elimination of interests that do not fit the individual's emerging sense of self, which includes gender, social group affiliation, ability, and then personal identity.[7]

Additionally, members of cultural groups develop systematic knowledge of the natural world through participation in informal learning experiences and forms of exploration that are shaped by their cultural-historical backgrounds and the demands of particular environments and settings (page 199).[8] Such knowledge and ways of approaching nature reflect a diversity of perspectives that should be recognized in designing science learning experiences and instructional materials.

Across the areas of informal education, teacher education, instructional materials, and career development since the late 80's, EHR has supported over 50 completed projects involving higher education institutions, Chicago Public Schools and/or informal institutions, addressing all education levels. In addition, 20 of 50 active EHR research and development efforts focus on learning how to enhance K–12 education. Let me draw your attention to several past and current projects.

Chicago EHR Story/Project Examples

- In 1996, the Columbia College of Chicago was funded to teach teachers in grades seven, eight, and nine in 50 of Chicago's public schools the basics of physical science using up-to-date pedagogical techniques with exemplary materials. Each year, 40 teachers, selected from 10 of the 50 participating schools, took an intensive three-week summer program, followed by 16 after school sessions and two Saturday sessions during the school year. In-class and in-school assistance were provided in subsequent years to aid in the classroom implementation of the materials.

  For teachers

  - There has been a consistent trend in the increase of participants' content knowledge following the summer intensive workshops. Analysis of the differences between the pre-test and the post-test among the eight years of the project shows a 22 percent gain in knowledge after participation in the summer workshops.
  - There was a significant increase in the number of teachers who encouraged their students to independently design and conduct science projects (from five percent of the teachers before participating in the project to 23 percent after their participation).
  - The percentage of teachers placing a heavy emphasis on developing problem solving strategies and inquiry skills increased from 26 percent prior to the workshops to 47 percent after the workshops.

Students of the participating teachers also demonstrated gains in knowledge that, in many cases, exceeded the national urban average of 3.5 on the same tests. Overall, the fifth grade students moved from a pre-test score of 28.7 to a post test score of 33, for an average gain of 4.3. Seventh grade students also had an average gain of 4.3, moving from a fall score of 36.2 to a spring score of 40.5. English grade stu-

[6] National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* Page 44. Tai, R.H., Liu, C.Q., Maltese, A.V., and Fan, X. (2006). Planning early for careers in science. *Science*, 312, 1143–1144.

[7] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K–8.* Page 200. Hidi, S. (2001). Interest, reading, and learning: Theoretical and practical considerations. *Educational Psychology Review*, 13(3), 191–209.

[8] National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K–8.* Page 199. Ryan, R.M., Connell, J.P., and Plant, R.W. (1990). Emotions in non-directed text learning. *Learning and Individual Differences,* 2, 1–17.

dents had a slightly lower average gain of 3.9, moving from a fall score of 39.2 to spring score of 43.1.

- In 2000, the *North Central Regional Educational Laboratory Partnership for Mathematics Improvement* project implemented the reform curricula in all the schools in the Harvey School District. Grades K–5 used *MathTrailblazers* and Grades six through eight used *Connected Mathematics,* and the curricula were use as tools for developing professional communities of teachers, administrators and parents committed to improving mathematics instruction in the district. All teachers in the district who taught mathematics in Grades K–8 participated fully in the project.

  It was found that after the implementation of the project, the percentage of third, fifth and eighth grade students who did not meet State standards in mathematics decreased markedly from 56 percent, 71 percent and 96 percent in 1999 to 36 percent, 38 percent and 78 percent respectively in 2005. And the number of students exceeding the State standards increased during the same period, from five percent to 17 percent for third grade students, and from none to 4.5 percent and two percent for fifth and eighth grade students, respectively.

- In 2001, the study team of *Elementary, Secondary, and Informal Education: Forging Partnerships with Libraries* used the library setting as a strong niche for informal space science learning. Eight topics were investigated through video presentations, hands-on activities, and other supporting resources. The Lunar and Planetary Institute Education and Public Outreach staff trained public and school librarians so that they could include space science in their out-of-school-time children's programs and family/community based programs.

  More than 700 librarians have been trained in the use of Explore! Materials. A follow-up discussion with the principal investigator revealed that 30 Children's Librarians developed programs that used Explore! Materials, and each of them have continued three after-school programs that are serving 20 students per program (with the support from NASA). The results of a summative evaluation will be forthcoming.

- The Nature Museum's Teens *Exploring and Explaining Nature and Science (TEENS),* funded in 2001, is an example of an out-of-school program for building skills and educational aspirations among under-served urban students. TEENS was developed to provide students the opportunity to fulfill their service learning requirement while developing real-world job skills and learning about careers in science and technology, as well as providing the students with the necessary preparation for post-secondary study in the sciences. TEENS offered more than just science education; it provided participants with encouragement, academic assistance, and confidence-building activities. Over the duration of the project, more than 100 teenagers were reached and indicated that they would strongly encourage other youth to participate in the program for both its educational and career advantages.

  All of the students participating in the program graduated high school and 80 percent are in college. Plans are under discussion for a follow-up study regarding field of study and degree attainment. The TEENS program has now become one of the core education programs at the museum.

- In 2003, the *Induction and Mentoring in Middle Grade Science and Mathematics Accelerated Teacher Preparation Program* developed a three-year induction model for urban education, integrating university course work with full-time classroom teaching. The first year included certification course work and student teaching in their classrooms. Classroom support was twofold: mentors visited each teacher interns once a week and student-teaching supervisors visited each intern every other week.

  The second year course work focused on remaining requirements for the graduate degree. The highlight was a year-long action research project focused on improving classroom teaching. The action research projects shared a focus on integrating content-rich curriculum with inquiry-guided instruction, while increasing attention to the importance of literacy-based practices aimed at engaging a diverse student population. Regarding classroom support, mentors visited each teacher every other week to assist with their action research projects and other instruction, as needed.

The third year curriculum focused on school leadership, and the need to foster a school culture that highlights the importance of science and mathematics education. A leadership project required that each teacher work within his or her school in collaboration with colleagues to improve school curriculum and professional development activities focused on science and mathematics education. Leadership projects included developing community-based science and mathematics units (e.g., Chicago River, bird migration, urban gardening), and leading school-wide professional development workshops. Classroom support included mentor visits to each teacher once a month to assist with leadership projects and other instruction, as needed.

This project surpassed its targeted recruitment goal by seven percent and at the end, recruited a total of 107 teachers. Its success provided the basis for the subsequent NOYCE Stipend Program started in 2004, which further addressed critical shortage of qualified science and mathematics teachers in the Chicago Public Schools, particularly in urban arrears of high need.

- With the support from Robert Noyce Teacher Scholarship program, NOYCE Stipend Program was built on the successful partnership between Chicago Public Schools and the University of Illinois at Chicago (UIC). It recruited 91 qualified career-changers with a strong background in math or science to become teachers in high-need schools.
    - All of the 91 Noyce scholars received Noyce stipends, completed their graduate degree programs and earned teaching credentials in their fields through UIC's teacher certification programs. Ninety scholars completed their teaching commitment, and 73 Noyce scholars have continued to teach beyond their two-year commitment. Of those, 17 have completed their third year of teaching and 56 have completed their fourth year.
    - Moreover, eight of the Noyce scholars have gone on to become regional or district-wide curriculum and professional development leaders in math and science in CPS. Of the 13 regional science and math instructional specialists in CPS, seven specialists were supported through NOYCE program at UIC. In addition, the CPS district-wide curriculum supervisor of middle grades science is a former NOYCE Scholar.
- In 2009, UIC started NOYCE Phase II project, which continues the work begun in the previous NOYCE grant and expands its potential impact with the addition of an enhanced mentor program for new Noyce recipients. This new mentor program involves previous Noyce awardees and inducts new ones into a Noyce mentoring network. Second, the project extends the Noyce applicant pool by adding three new science certifications and introducing a one-year M.Ed. program option for secondary science education, with is available for secondary science teacher candidates in biology, earth and space science, environmental science, chemistry and physics. Over a three-year period, NOYCE Phase II project will offer 40 recruitment stipends to students in UIC secondary STEM teacher preparation programs.
- In 2004 and 2005, researchers at the University of Chicago and the University of Illinois at Chicago were funded to study how teachers and students construct shared knowledge about science topics in integrated units in primary and middle grades. This research is focusing on how students at various ages perceive concepts and how teachers communicate them. NSF is awaiting the final report of these research projects that may offer new insights for how we develop curricula and move students through the learning process.
- With a longstanding history in urban systemic reform, the University of Illinois at Chicago received an award in 2007 to conduct a multi-dimensional study of the reform efforts within the Chicago Public Schools for effective planning, implementation, scale-up, adaptation, documentation and evaluation of ongoing systemic reform in mathematics and science education in one of the Nation's largest urban public school system.

These examples demonstrate NSF's support of meritorious STEM education activities that build on our current knowledge about learning. The Foundation supports projects that create high quality learning environments (as well as developing innovative models for utilizing cyber-learning activities) that provide the opportunity for students to think in sophisticated ways and for teachers to stimulate students' basic reasoning skills, personal knowledge of the natural world, and curiosity—all in order to increase proficiency and interest in science. Moreover, the value of these early investments in science interest and proficiency can be seen in the readiness of diverse precollege populations to pursue STEM careers in higher education with the support of programs like the Advanced Technological Education; STEM Talent Expansion Program; Scholarships in Science, Technology, Engineering and Mathematics; Louis Stokes Alliances for Minority Participation; Integrative Graduate Education and Research Traineeships; Graduate Teaching Fellows in K–12 Education; and Graduate Research Fellowships—all of which are active NSF higher education STEM programs in the State of Illinois.

It is with much commitment from the Foundation, with the focal point for STEM learning housed in the Directorate of Education and Human Resources, that we find ourselves uniquely positioned to transition from strengthening or building on our knowledge base regarding education reform to being responsive to a call of transforming STEM education and workforce development for the 21st century. EHR will collaborate increasingly NSF-wide to help meet national goals in STEM education. This future cross-directorate partnering on the learning portfolio will ensure that NSF:

- Develops a responsive and potentially transformative research and development continuum for education and workforce development, with rigorous evaluation
- Promotes openness and adaptability for new fields through support for public engagement and lifelong learning
- Leverages support for innovation in STEM education through strategic partnerships and coordination
- Links funding for a foundation for scale-up and sustainability
- Stays on the cutting edge in promoting excellence in STEM education to ensure the health, competitiveness and prosperity of the Nation.

Partnering with other external stakeholders, NSF believes that the field is ready to pursue innovative ideas to advance current understanding of STEM education by linking novel approaches and best/effective practices to STEM-specific challenges for the 21st century. Our vision will be aligned with the STEM priorities in *America COMPETES Act* (ACA) and/or *American Recovery and Reinvestment Act* (ARRA). With multi-purpose strategic thinking we will sharpen our support on four foci:

- innovation in learning ecosystems of emerging areas like clean/alternative energy and climate change education with an emphasis on blending formal and informal education
- broadening participation to improve workforce development
- enrichment of teacher education for the 21st century, and
- fostering cyber-learning to enhance STEM education.

One of the areas in which the U.S. is a recognized leader, but increasingly is challenged globally, is that of innovation. Recognizing that innovation plays a key role in U.S. economic competitiveness, the role of diverse intellectual capital in spurring innovation is a topic of great interest to us at the National Science Foundation. Key issues within this ecosystem, include research and understanding of the culture of innovation and the interplay between innovation and education.

STEM teacher education is an EHR-wide activity, building on NSF's 50-plus years of experience in this domain. Through collaborations we must discover research-based advances that enable the U.S. to produce 21st century, "cyber-prepared" STEM teachers for the 21st century, "cyber-savvy" students. Hence, four areas of teacher education emphasis must inform future directions:

- Teacher education to support equity and excellence
- The undergraduate teacher preparation experience for professors
- Teacher education and mid-career entry at the graduate level
- The K–12 and policy interfaces with teacher education.

Technology has the potential to transform education throughout a lifetime, enabling customized interaction with diverse learning materials on any topic, and supporting continuous education at any age. In the last decade, the design of technologies and our understanding of how people learn have evolved together. NSF has played a key role in these advances, funding interdisciplinary programs specifically to support research and activities in the area of cyber-learning. NSF can continue to lead this revolution by leveraging its investments in the productive intersections between technology and the learning sciences.

Creative thinking about STEM education and learning for the future will offer new challenges and new opportunities for transformative research on educational practices and learning tools. In summary, our STEM education and workforce development vision for the future will attend to a rich tapestry of:

- excellence and diversity in STEM attainment;
- access, availability, and "reach" across STEM lines of inquiry and geographical borders;
- innovation and transformation for stimulating STEM creativity for discovery and learning;
- depth and breadth of domains to promote STEM interdisciplinarity; and
- seamlessness and coherence to ensure a high level of continuity across the learning continuum.

STEM education and workforce for the 21 century is key to promoting and sustaining an innovative society.

Mr. Chairman, I appreciate the opportunity to appear before the Subcommittee to speak to you on this important topic. I would be pleased to answer any questions that you may have.

BIOLOGRAPHY FOR WANDA E. WARD

Dr. Wanda E. Ward is the Acting Assistant Director for Education and Human Resources, National Science Foundation (NSF). Throughout her tenure at NSF, Ward has served in a number of science and engineering policy, planning, and program capacities in the Directorate for Education and Human Resources (1992–1997; 2006-present), Office of the NSF Director (1997–1999); and Directorate for Social, Behavioral and Economic Sciences (1999–2006). From 2001–2002 she was on assignment at the Council on Competitiveness as Chief Advisor to the initiative, BEST (Building Engineering and Science Talent), where she provided leadership in the launch and development of this public-private partnership, established to carry out the implementation of a national diversity initiative called for by the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development.

Since joining the Foundation, Dr. Ward has also led or served on several NSF and interagency task forces, working groups, commissions and committees. These include: Co-Chair, Subcommittee on Social, Behavioral and Economic Sciences (SBES), the President's National Science and Technology Council (NSTC) Committee on Science (COS , 2004–2005); NSF representative to the Interagency Working Group on the U.S. Science and Technology Workforce of the Future, NSTC COS (1997–1999); Executive Liaison to the Co-Vice-Chair of the NSTC former Committee on Education and Training (CET) and Executive Secretary of the NSTC CET Subcommittee on Excellence in Science, Mathematics, and Engineering Education (1994–1996). She has forged international research and workforce development collaborations in both developed and developing nations, including in China, Europe and Africa. Since 2007, she has served as a member of the International Social Science Council (ISSC) Committee for Developing and Transition Economies (CoDATE).

Prior to joining NSF, Dr. Ward served as tenured Associate Professor of Psychology and Founding Director of the Center for Research on Multi-Ethnic Education at the University of Oklahoma, Norman. She took the B.A. in Psychology and the Afro-American Studies Certificate from Princeton University and the Ph.D. in Psychology from Stanford University. She was awarded the Ford Foundation Fellowship, the 2005 American Psychological Association Presidential Citation, the 2006 Presidential Rank Award for Distinguished Executive and the 2006 Richard T. Louttit Award.

Chairman LIPINSKI. Thank you, Dr. Ward.

The Chair now recognizes Ms. Maggie Daley.

STATEMENT OF MS. MAGGIE DALEY, CHAIR, AFTER SCHOOL MATTERS, CHICAGO, ILLINOIS

Ms. DALEY. Thank you, Mr. Chairman and Dr. Ehlers for this opportunity to before you this morning. I am Maggie Daley, Chair of After School Matters, a non-profit organization that is dedicated to providing informal educational opportunities including STEM learning to Chicago teens. I would also like to introduce David

Sisky, our Executive Director of After School Matters, and I may consult with him from time to time during my testimony.

As you may already know, *Education Week* has reported that 75 percent of the Nobel Prize winners in the sciences report that their passion for science was first sparked in informal environments. The National Research Council stated in a recent report there is mounting evidence that structured, non-school science programs can feed or stimulate the science-specific interests of adults and children. They positively influence academic achievement for students and may expand participants' sense of future science career options.

After School Matters is one of the largest organizations serving teens during the out-of-school hours in the United States and last year we provided 30,000 program slots to Chicago teens. Today, I would like to speak about our organization's efforts and how, with the appropriate support and resources, we can realize our ambitious vision for STEM programming in the future.

Allow me to tell you more about who we are and what we do. In 1991, Gallery 37 was established, an art-based summer apprenticeship program for high school teens, on an undeveloped parcel of land named Block 37 in downtown Chicago. In the year 2000, key funding from the Robert Wood Johnson Foundation, aimed at promoting healthy development of our youth by scaling up quality programs, allowed the successful apprenticeship structure of Gallery 37 to be applied to programs in other disciplines and the creation of After School Matters.

After School Matters is an intermediary organization that engages hundreds of paid instructors from informal education communities to work with thousands of teens in our programs. These instructors create and submit their curricula through a request for proposals process that promotes creativity and diversity in the programs we offer and it allows us to be intentional when addressing workforce trends. Teens in Tech 37, our technology programs, work with industry professionals on authentic projects and areas such as web design, manufacturing, engineering, media production and computers. Our programs enable skill building through hands-on activities that spark teens' interest in technology.

Our robotics program, funded by the Motorola Foundation, is an example of the success of Tech 37. In each program of robotics, teens design and build robots to compete in two unique sporting events. Additionally, Motorola helped us to secure engineering mentors to support these teens.

Recognizing that more teens must be exposed to informal science opportunities if we are to maintain global competitiveness, Abbott partnered with us in 2006 to create Science 37. These programs provide connections with the city's growing science sectors and teens develop a new appreciation for science and an awareness of potential science careers. Lab 101 is a Science 37 program created in partnership with Abbott and Dr. Don Wink of the University of Illinois in Chicago. It introduces teens to laboratory procedures and techniques and teens visit Abbott's facilities to learn about the science and business of global health care.

After School Matters broke into partnership between Abbott and the Chicago Public Schools to renovate a laboratory at Foreman High School, site of the Lab 101 programs. When it opens this fall, the lab will be used for Lab 101 after school and normal classes during the school day. Such collaboration demonstrates the strength of our partnership with the Chicago Public Schools. We want to complement and reinforce the STEM concepts and the State standards that are delivered in the high school classroom.

One illustration of the relationship between After School Matters and the school day learning is found in the following statistics from the Chicago Public School Department of Career and College Preparation. After School Matters participants with a GPA of 3.0 to 3.4 enrolled in college at a higher rate than non-participants and 71 percent versus 63 percent for the district in 2006. Additionally, research from the Chapin Hall Center for Children at the University of Chicago found that teens who participate in After School Matters programs have higher graduation rates, lower dropout rates and fewer course failures than teens who do not participate.

Of course, we also face challenges but we must meet them head on with innovative thinking and creative solutions. For example, teens who join our core program model, the apprenticeship, receive stipends and financial incentives to participate and as a reinforcement of the structure of the workplace. Since apprenticeships take place in job-like settings, this investment in our youth makes it possible for the most economically disadvantaged teens to experience the working world that awaits them after graduation.

We know we must do more. Our vision for the next three years includes doubling our current number of Tech 37 program slots to 7,000 while tripling our Science 37 program slots to 3,500. However, this ambitious vision is weighed down by fiscal realities. Due to the substantial reductions in government funding and the anticipated reductions in corporate and foundation giving for this fiscal year, our directors were forced to decrease our budget by a third, which is $7.2 million. We have taken significant measures to manage costs and maximize our program offerings but these measures were unable to prevent the elimination of one-third of our total program slots in the coming year. Restoring these 10,000 slots, let alone building additional STEM programming, is impossible without additional support.

I would like to make a few recommendations on how the private sector and State and federal stakeholders can take better advantage of nonprofit organizations like After School Matters to improve STEM education. The government must increase the support of informal education including out-of-school time programming such as After School Matters, given the increasing evidence of the important role in reaching America's youth. Understanding that evaluation and reporting is priority, the government needs to provide additional resources to non-profits to be able to engage evaluators to assess outcomes of programs. If government grant application and reporting processes were simplified and streamlined, we could add more internal resources to ensure program quality and effectiveness.

I encourage the private sector to broaden partnerships to maximize investments with non-profits, focusing on long-term sustainability and a vision that supports existing successful programs. With this kind of support, informal educators could move the cause of STEM learning forward, and no one is better poised to make a difference than us. We have a 20-year history of success with proven program models. We are integrated into the communities we serve, and most importantly, we have access to a diverse, curious and eager audience who with the right spark of inspiration will change not only the course of their own lives but also the future of our country.

On behalf of After School Matters, I am grateful for your time and attention and I would be pleased to answer any questions you may have.

[The prepared statement of Ms. Daley follows:]

PREPARED STATEMENT OF MAGGIE DALEY

Mr. Chairman and distinguished Members of the Subcommittee, thank you for this opportunity to appear before you this morning. I am Maggie Daley, Chair of After School Matters, a non-profit organization dedicated to providing informal educational opportunities, including STEM learning, to high school teens in Chicago.

As you may already know, *Education Week* reported in 2006 that 75 percent of Nobel Prize winners in the sciences said that their passion for science was first sparked in informal environments.[1] The Institute for Advanced Study recently recommended "increas[ing] the science and math content in out-of-school time programming through project-based, real-world activities" in order to mobilize the Nation for math and science learning.[2] And the National Research Council stated in a recent report that, "There is mounting evidence that structured, non-school science programs can feed or stimulate the science-specific interests of adults and children, may positively influence academic achievement for students, and may expand participants' sense of future science career options."[3]

It is clear that any plan for expanding the reach and effectiveness of science and technology education in our country must give informal educators a prominent role. As one of the largest organizations serving teens during the out-of-school hours in the United States, After School Matters can offer a unique perspective on how that role can be implemented. Today, I would like to speak about our organization's efforts to broaden participation and promote diversity in STEM learning, and how, with the appropriate support and resources, we can realize our ambitious vision for STEM programming in the future.

Who We Are

First, allow me to tell you more about who we are and what we do. The mission of After School Matters is to create a network of out-of-school time opportunities, including apprenticeship and drop-in programs, for teens in under-served communities. Our leadership role among schools, neighborhoods, government agencies, and community and teaching organizations is unique. We leverage key public partnerships with the City of Chicago, Chicago Public Schools, the Chicago Park District, the Chicago Department of Family and Support Services, the Chicago Department of Cultural Affairs, and the Chicago Public Library. Chicago Public School principals and liaisons, Chicago Park District specialists, Chicago Public Library staff, and community leaders work together to support an expansive array of programming for teenagers. And by anchoring out-of-school time opportunities around community organizations and "campuses"—each consisting of a public high school and a nearby park and library—After School Matters maximizes the use of existing public infrastructure and invigorates neighborhoods.

In 1991, I collaborated with Lois Weisberg, Commissioner of Chicago's Department of Cultural Affairs, to establish gallery37, an arts-based summer apprenticeship program for high school teens, on an undeveloped parcel of land named Block 37 in downtown Chicago. In 2000, key funding from the Robert Wood Johnson Foun-

[1] Friedman, Lucy N. and Jane Quinn. "Science by Stealth." *Education Week*, 22 Feb. 2006: 45,48,49.

[2] Institute for Advanced Study (2009). *The opportunity equation: Transforming mathematics and science education for citizenship and the global economy.* Commission on Mathematics and Science Education.

[3] National Research Council (2009). *Learning science in informal environments: People, places, and pursuits.* Committee on Learning Science in Informal Environments. Philip Bell, Bruce Lewenstein, Andrew W. Shouse, and Michael A. Feder, editors. Board on Science Education, Center for Education, Division of Behavioral and Social Science and Education. Washington, DC: The National Academies Press.

dation aimed at promoting healthy development of our youth by scaling up quality programs allowed the successful apprenticeship structure of gallery37 to be applied to technology, communications, and sports programming. These programs became known as After School Matters, an umbrella organization for all areas of out-of-school time opportunities (including science, which was added in 2006). Last year, nearly two decades after those first programs on Block 37, After School Matters provided 30,000 out-of-school program slots at 63 high schools and more than 100 community-based organizations throughout the city.[4]

African Americans comprise 68 percent of our program participants, while 23 percent are Latino. Of the remaining population, three percent are Caucasian, two percent are Asian/Asian-American & Pacific Islander, one percent are Native American, and another three percent identified themselves as "other." As you can see, making STEM a priority at After School Matters automatically promotes diversity within STEM fields. Our community programs also expose STEM learning to those who are either outside of the public school system or require additional support, such as the physically and cognitively disabled, teen parents, dropouts, limited English speakers, ex-offenders, Chicago Housing Authority residents, students attending alternative schools, and lesbian, gay, bisexual, transgender, and questioning (LGBTQ) teens.

In creating out-of-school opportunities, After School Matters employs three primary program models: clubs, "drop-in" programs without attendance requirements in which teens socialize with their peers and explore new interests in a safe, structured environment; apprenticeships, our core model in which teens learn marketable skills in a professional atmosphere from an industry expert or artistic master; and internships, supervised positions that appropriately utilize teens' skills while allowing them the opportunity to train in a real work environment. Collectively, this structure is known as the "Ladder of Opportunity." Teens can start on any "rung" as long as they have the requisite skills, commitment, and maturity.

After School Matters is distinctive in that we operate as an intermediary organization. We engage community and teaching organizations, as well as independent instructors, to create and teach curricula through a Request for Proposals (RFP) process. This method promotes diversity and creativity in the programs we offer, provides the organization with the flexibility necessary to meet teens' ever-changing interests, allows us to be more intentional when addressing workforce trends, and results in an extraordinarily wide range of out-of-school time opportunities for teens.

This structure also allows us to engage hundreds of paid instructors from the informal education community to work with the tens of thousands of teens in our programs. In this way, we integrate After School Matters directly into the communities that we serve. Our instructors treat teens with respect, listen to what they say, recognize their abilities and talents, have high expectations for their work, and provide them with opportunities for leadership. Caring instructors with real-world expertise are central to keeping teens engaged and invested in our programs.

We also work with formal educators like Columbia College, Harold Washington College, and the University of Illinois, Chicago. Past collaborations have included programs in chemistry, physics, media and technology, economics, and financial literacy.

tech37

In 2000, we expanded from the arts programs of gallery37 into communications and athletics via words37 and sports37. We also took note of the dramatic growth of the technology sector during the late 1990s and anticipated the increasing demand for skilled workers in the coming years. In response, After School Matters partnered with Internet companies and technology entrepreneurs to establish tech37.

Teens in tech37 programs work with industry professionals on authentic projects in areas such as Web design, manufacturing, engineering, media production, and computer technology. Our programs enable skill-building through hands-on activities and spark teens' interest in technology for personal and professional development. They also afford teens the opportunity to refine their critical workplace skills, including problem solving, teamwork, and communication. With practice, teens become more adept at using these skills, which they will take with them to the job market and their future academic endeavors.

Here are just a few examples of the exciting experiences that we provide for our tech37 teens:

ROBOTICS

[4] See attachment: After School Matters Campus Map.

The Motorola Foundation partners with After School Matters to implement robotics programming based on the guidelines of the US FIRST organization.[5] During the program, robotics teams design and build robots to compete in two unique sporting events, the FIRST Tech Challenge (FTC) and the FIRST Robotics Competition (FRC). The robot for the FTC event is compact, roughly the size of small suitcase, and is built from a standard kit of parts. The robot for the FRC event is larger, averaging six feet tall by three feet across, and each team must determine not only the design but also the construction materials. In addition to providing us with a generous grant, Motorola helped After School Matters secure engineering mentors to support our newer teams.

Over the last three years, three of our robotics teams have qualified for the annual FIRST Championships in Atlanta, GA, which brings together thousands of teen engineers from across the country and around the world.

WEB FOR THE FUTURE

The Web for the Future program tasks teens with building professional, multi-page Web sites in order to promote fictitious companies. They master digital media tools as they design logos, graphics, and branding. At the end of the program, teens have created fully functional Web sites that can be used in their portfolios and viewed on the Internet.

HI-TECH MANUFACTURING

Hi-Tech Manufacturing introduces students to Computer-Aided Design (CAD) and computerized machining. Teens design simple mechanical parts and then write computer programs to construct the parts on an industrial lathe or mill. Teens also learn math skills related to manufacturing (including basic Trigonometry), print reading, and precision measuring. Additionally, manufacturing careers are explained, promoted, and demonstrated through field trips and guest speakers.

science37

While tech37 is a valuable part of our strategy to build STEM education, exposing teens to informal science opportunities must be a priority if we are to maintain and increase the Nation's economic strength, scientific innovation, and global competitiveness. Recognizing this fact, Abbott approached us in 2006 to discuss how we might work together to achieve this goal. With generous support and valuable input from Abbott, science37 was born.

Our science37 programs strengthen teens' scientific aptitude while piquing their intellectual curiosity by directly connecting them with the city's growing science and biotechnology sectors. Teens in these programs develop a new appreciation for science, an understanding of its relevance in their lives, and an awareness of potential science careers.

To help us build science37, the Abbott Fund has also provided the services of an educational consulting firm with substantial experience in the science arena. This firm is helping us coordinate roundtable discussions with Chicago's leading informal science educators, including all of the major museums, to find new ways to collaborate and extend the reach of STEM learning across the city.

The following programs highlight the success we have had with science37 in a relatively short period of time:

LAB 101

Abbott and Don Wink of the University of Illinois, Chicago, partner with us to provide Lab 101, a program that introduces teens to basic and intermediary laboratory procedures and techniques. Abbott scientists have made several trips to this and other science37 programs to share their perspectives on STEM careers. The Lab 101 teens have also visited Abbott Molecular in Des Plaines, Illinois and Abbott's corporate headquarters in Abbott Park, Illinois to learn about the science and business of global health care and medical research.

SUMMER SCIENCE EXPERIENCE

Funded by Abbott and the National Science Foundation, teens in the Summer Science Experience at Harold Washington College conduct experiments based around air quality, water purity, and the use of plants to remove soil contaminants. The teens' work on density with sugar solutions was crafted into a Class-

[5] For Inspiration and Recognition of Science and Technology (FIRST). More information is available at *www.usfirst.com*.

room Activity and published in the August 2008 issue of the peer-reviewed *Journal of Chemical Education*.

T–POINT: BUILDING DEMAND FOR MATH AMONG CHICAGO YOUTH

The T–Point (or "turning point") program trains teens to become Math Literacy Workers and teaches them Lesson Planning, Creating and Delivering Workshops, Math Instruction and Critical College Preparatory Math Skills. Teens then create and deliver math literacy workshops to middle school students. Being mentored by teens in an informal setting can make the content of programs more engaging for younger students because they often admire and emulate teens. When teen mentors provide guidance through respectful communication and positive attention, youth become more invested in learning.

Both tech37 and science37 have made significant strides towards broadening teen participation in STEM learning, but we know that we must do more to make certain that science and technology are viable career paths for the next generation.

Collaboration with Chicago Public Schools

While After School Matters strives to make its programs more than just an extension of the school day for under-served teens, we want to complement and reinforce the STEM concepts and State standards that are delivered in high school classrooms. Our strategy to meet this goal revolves around our partnership with Chicago Public Schools.

Chief Executive Officer of Chicago Public Schools, Ron Huberman, has been pivotal to the strength of this partnership, continuing on in the tradition of the previous Chief Executive Officer, now U.S. Secretary of Education, Arne Duncan. Mr. Huberman has made it clear that he intends to build on the success we have achieved in the past and to support our long-term goal of offering After School Matters programs in every public high school in the city.[6] In turn, we support Chicago Public Schools initiatives like Freshman Connections, in which we provide special summer programming to middle school teens who are transitioning to high school in the fall.

In order to more closely align the two organizations, we have created a regional system similar to the one used by Chicago Public Schools. Each region is assigned a director and each high school or community site is assigned a program specialist. Before the beginning of a program cycle, the director and specialist meet with the principals and liaisons of our partner high schools to discuss their programming needs and how After School Matters can support their existing priorities. These discussions directly affect the selection of After School Matters programming for each school.

One illustration of the relationship between After School Matters and school day learning is found in the following statistics from the Chicago Public School Department of Career and College Preparation:

- In 2006, After School Matters participants with a GPA of 3.0–3.4 enrolled in college at a higher rate: 71.9 percent compared to 63.5 percent for the district. These participants were also more likely to attend a four-year college and to attend school full time than their district counterparts.
- Graduating Latino students who participated in After School Matters programs in 2006 had higher college enrollment rates compared to their district counterparts: 50 percent versus 38.9 percent for the district.

In terms of STEM programming, we offer another way for schools to break through teens' preconceptions. Our hands-on, project-based programs get teens excited about scientific and technological ideas that might once have seemed dull or mystifying. That enthusiasm is then carried over to their formal education and energizes their STEM learning during the school day.

After School Matters also assisted in brokering a partnership between the Abbott Fund and Chicago Public Schools to renovate a laboratory at Foreman High School. When it opens this fall, the lab space will be used for the Lab 101 program after school and science classes during the school day.

Assessment

Quality assurance is important to After School Matters, because consistent quality in our programs increases their impact on each teen participant. In turn, this impact on teens increases the impact that teens have on their communities.

[6] See attachment: Ron Huberman letter.

After School Matters program specialists are a critical part of the quality assurance process. They support quality by linking with schools, community organizations, instructors, and teens to make the connections necessary to successfully facilitate programs. Program specialists visit programs regularly to collect feedback from teens and instructors. They also use teen participation as a key indicator of quality, since young people quickly choose to leave programs that are not engaging.

As part of our ongoing commitment to excellence, After School Matters also participates in independent research that evaluates the effectiveness of our programs and services. Several top researchers have evaluated After School Matters programs and the findings have been used to continuously enhance and strengthen the organization's work.

One of the most compelling studies was conducted in 2006 by the Chapin Hall Center for Children at the University of Chicago. Researchers examined the relationship between student participation in After School Matters programs and high school graduation. They followed a group of 3,411 students in 12 Chicago high schools for four years and came to these important conclusions:[7]

- Teens who participate in After School Matters [programs] have higher graduation rates and lower drop-out rates than teens who do not participate.
- Teens in After School Matters [programs] have higher school attendance than those who do not participate.
- Teens in After School Matters programs have fewer course failures than teens who do not participate.

After School Matters programs have also been evaluated by Dr. Robert Halpern, a nationally-recognized authority on youth development at the Erikson Institute. For two years, Dr. Halpern documented the activities of teens and instructors in After School Matters apprenticeship programs. The findings concluded that After School Matters programs:[8]

- Produce positive effects in several areas such as improving teens' abilities to work in groups, communicate effectively, plan and meet deadlines, and cooperate with flexibility;
- Give teens a sense of what it means to be an adult, in both thought and responsibility, and illustrate what it takes to become skilled at a task;
- Teach students not only about the specific discipline that was the focus of their apprenticeship (e.g., arts, technology), but also about how to approach tasks related to the discipline, such as conducting research or envisioning the end product; and
- Enhance students' knowledge of various vocational skills such as how to apply and interview for a position, the importance of regular and prompt attendance, and guidelines for appropriate behavior.

While we understand the need to evaluate our programs in more specific detail, such as the direct effect of STEM learning, our limited resources preclude that kind of critical work at this time. However, Abbott has provided direction towards such in-depth examination by helping us acquire pre- and post-program surveys for science37 teens that will gauge our impact on their understanding, interest, and appreciation of science. Once these surveys have been reviewed, we will have a glimpse into the lasting effect we are having on the Nation's future workforce.

However, the results of these surveys will provide only a glimpse of that impact. In order to engage in the kind of thoughtful and detailed analysis that is necessary to create compelling STEM programming, After School Matters and other non-profits across the country will need more financial resources to engage experts who can devise, implement, and interpret such studies.

Challenges

Evaluation is not the only challenge that After School Matters must face when it comes to broadening teen participation in STEM learning. As mentioned throughout my testimony, we focus on the most under-served high school teens in the city. In Chicago's public schools, 84.9 percent of teens are considered to be "low-income" and qualify for the federal free and reduced lunch program.

[7] Goerge, Robert, Gretchen R. Cusick, Miriam Wasserman, and Robert Matthew Gladden. (2007). "After-School Programs and Academic Impact: A Study of Chicago's After School Matters." Chapin Hall Center for Children: Issue Brief #112.

[8] Halpern, Robert. "After-School Matters in Chicago: Apprenticeship as a Model for Youth Programming." *Youth & Society*. 38.2 (2006): 203–235.

The communities these teens live in are also struggling in terms of public support and infrastructure. The facilities and equipment needed for programming in their neighborhoods are often either outdated or unavailable. As a result, the availability of high-quality, affordable, out-of-school time programs can be very limited. This can be especially problematic for STEM learning, since teens in these communities often believe that science and technology are boring or irrelevant to their lives.

After School Matters has met these challenges with innovative thinking and beneficial partnerships. All of our programs are free to Chicago residents. Teens who join our core program model—the apprenticeship—receive stipends as financial incentive to participate and as reinforcement of the structure of the workplace. Since apprenticeships take place in job-like settings, this investment in our youth makes it possible for the most economically disadvantaged teens to experience the working world that awaits them after graduation.

We also work hard to guarantee that our programming is meaningful to these teens. We strive to focus on areas that directly affect them, such as health care, teen pregnancy prevention, and financial literacy. One advanced program in biotechnology illustrated how advances in that field might one day end the scourge of diseases that plague their communities, like AIDS and lupus.

We are also piloting "hybrid" programs, which combine STEM learning with other, seemingly unrelated disciplines. One example is "The Science of Art" program that just concluded at Harold Washington College. The program reconnected teens to the Renaissance spirit, a time when art was intertwined with science, as in the works of Leonardo da Vinci. An example of teens discovering this association was when they created cyanotype prints: the prints required the mixture of two chemicals to make a solution that was reactive to ultraviolet light and then "developing" paper painted with the solution in the sun. One of the teens in the program said she had always found science difficult, but that the program "created a bridge between art and science" and made the STEM learning easier to understand.

We have made a great deal of progress in bolstering STEM among our city's youth. But there is so much more that needs to be done. Our vision for the next three years includes doubling our current number of tech37 program slots to 7000 while tripling our science37 program slots to 3500.

However, this ambitious vision is currently weighed down by fiscal realities. Due to substantial reductions in government funding and the anticipated reductions in corporate and foundation giving for this fiscal year, our Board of Directors was forced to decrease our budget by $7.3M. We have taken significant measures to manage costs and maximize our program offerings, including laying off staff, freezing staff salaries and vacant positions, consolidating staff functions, instituting unpaid furlough days, and increasing employee contributions to benefits. Additionally, teen stipends and instructor fees were reduced by ten percent.

But none of these measures were able to prevent the elimination of one-third of our total program slots in the coming year. Restoring these 10,000 slots, let alone building additional STEM programming, is impossible without additional support.

Furthermore, the largest roadblock in the growth of science37 is finding qualified field professionals to serve as instructors. Again, we are an intermediary organization; we have no curricula or instructors of our own. We need to realize additional connections to the science community, to retired professionals, to graduate students, and to others whose schedules would enable them to run programs in the afternoon and early evening hours. We also need to further develop informal educators to deepen their knowledge of science concepts, to gain cultural competence with our diverse population, and, as stated by the Taking Science to School report by the National Research Council, to learn "to teach for science proficiency." [9]

In order to be a leader in out-of-school time STEM education in Chicago, we need funding to hire a full-time position that would focus solely on the cultivation of STEM programming and instructors. We have the will, the desire, and the proven ability to take these steps to make STEM a priority in our city. All we lack are the means.

Recommendations

The challenges of After School Matters are similar to those felt by non-profit informal educators across the Nation. Therefore, there needs to be a national response. I would like to make a few recommendations on how the private sector and State

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[9] National Research Council (2007). *Taking science to school: Learning and teaching science in grades K–8*. Committee on Science Learning, Kindergarten through Eighth Grade. Richard A. Duschl, Heid A. Scheingruber, and Andrew W. Shouse, editors. Washington, DC: The National Academies Press.

and federal stakeholders can take better advantage of non-profit organizations like After School Matters to improve STEM education.

Government support

Federal and State governments should provide clear direction on STEM learning, such as those outlined in *The Opportunity Equation* by the Institute for Advanced Study, including the call for increased science and math content in out-of-school time programming through project-based, real world activities.[10]

The government should increase its support of informal education—including out-of-school time programming such as After School Matters—given the increasing evidence of its important role in teaching America's youth.

Government funding

Corporations have only so many resources that they can offer their home cities, let alone informal educators across the country. Increased government funding is vital to the continued efforts of informal STEM educators and is the only way to ensure continued expansion of our efforts. We cannot do it alone.

Furthermore, the government should relax its more demanding assessment requirements for non-profits, since organizations are often mandated to apply all funding to programming. If assessment is a priority, then resources above and beyond programming dollars should be made available for non-profits to engage assessment experts.

Private sector and foundation awareness

The private sector and foundations could ease the burden on non-profits by allowing more of their gifts to be unrestricted, so that organizations can apply funding in the most effective way possible to serve their missions. Long-term investments are also pivotal to ensuring program sustainability. And by funding existing models and proven practices, this support will build upon each organization's programmatic momentum.

Private sector participation

The private sector should follow the example of companies such as Abbott and Motorola and become full participants in the informal STEM education community by providing human resources as well as funding. They should foster a corporate culture that allows their employees to give their time to informal education. Encouraging current or retired staff to contribute to out-of-school time initiatives by visiting or instructing programs during the work week could quickly increase the quantity and refine the quality of our STEM programs.

With this kind of support, informal educators across the country could move the cause of STEM learning forward. And no one is better poised to lead the charge than After School Matters. We have a twenty-year history of successful and swift growth with proven program models. We have unique relationships with city partners that allow us to work on an unparalleled scope with tens of thousands of teens. We are integrated into the communities we serve through the local informal educators that we hire to provide programs. And, most importantly, we have access to a diverse, curious, and eager audience who, with the right spark of inspiration, could change, not only the course of their own lives, but also the future of their community, their city, and their country.

On behalf of After School Matters, I thank you for your time and attention. I would be pleased to answer any questions that you may have.

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[10] Institute for Advanced Study (2009). *The opportunity equation: Transforming mathematics and science education for citizenship and the global economy.* Commission on Mathematics and Science Education.

CHICAGO PUBLIC SCHOOLS | CPS

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Ron Huberman
Chief Executive Officer

July 27, 2009

Mrs. Maggie Daley
Chair
After School Matters
66 East Randolph Street
Chicago, IL 60601

Dear Mrs. Daley,

On behalf of Chicago Public Schools (CPS), I am writing to affirm the success and impact of After School Matters and the leadership role it has taken in promoting teens' interest in science and technology.

Chicago Public Schools (CPS) has partnered with After School Matters for almost a decade in order to provide the city's underserved teens with opportunities to explore career possibilities and develop marketable job skills. During that time, tens of thousands of Chicago high school students have been inspired by their experiences with After School Matters' programming in the arts, communications, sports, science, and technology.

For its part, CPS has gladly shared its facilities and staff beyond the normal confines of the school day. In return, After School Matters has contracted with industry experts, working professionals, neighborhood leaders, and teaching organizations to provide engaging curricula and instructors for informal out-of-school time programming. This past school year, our combined resources have resulted in programs at 63 high schools and over 100 community sites across the city.

As the country's focus on STEM education has grown, so, too, has the desire of CPS and After School Matters to bolster teens' experience with science and technology. Exposing teens to technology and promoting its mastery has long been the province of After School Matters tech37 programs. These opportunities have included engaging, hands-on activities in areas such as Web design, computer refurbishment, media production, manufacturing, and robotics. As the effect of technology on our lives multiplies, I am grateful After School Matters continues to prepare a new generation for this increasingly "high tech" century.

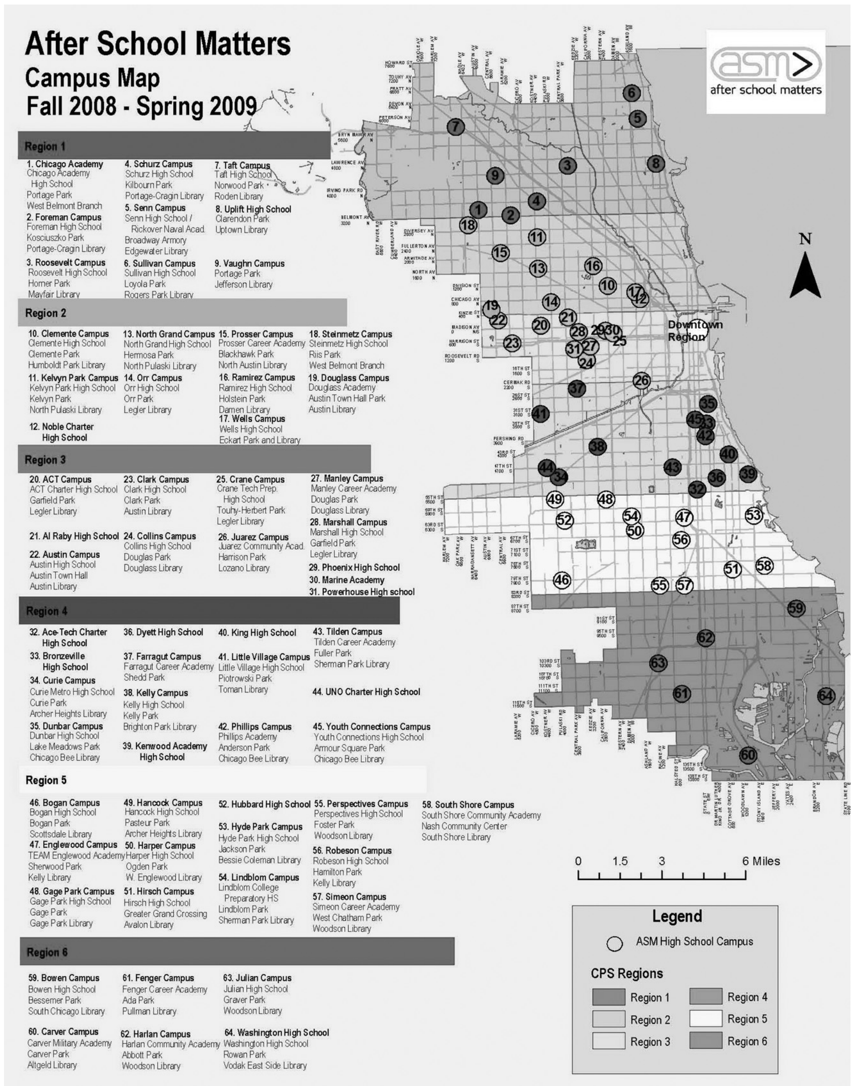
Science37 provides programs that actively nurture intellectual curiosity and connects Chicago teens with the city's growing science sectors. Its instructors are inquisitive, science-trained professionals from area high schools, universities, non-profits, public agencies, industrial laboratories, and innovative corporations that want to introduce teens to the excitement of scientific exploration and discovery. Teens develop and demonstrate a greater understanding of the principles behind a wide array of scientific subjects from ecology to physics to bioscience and beyond.

Educate • Inspire • Transform

With a continued, mutually beneficial relationship between Chicago Public Schools and After School Matters and an ongoing commitment to the importance of STEM learning, Chicago will be better prepared to face the challenges of the coming decades. By fanning the flames of interest in science and technology in the youth of today, tomorrow's leaders will be able to meet those challenges and thrive in the global, knowledge-based economy.

Sincerely,

Ron Huberman


After School Matters
Campus Map
Fall 2008 - Spring 2009
after school matters
Region 1
1. Chicago Academy
Chicago Academy High School
Portage Park
West Belmont Branch
2. Foreman Campus
Foreman High School
Kosciuszko Park
Portage-Cragin Library
3. Roosevelt Campus
Roosevelt High School
Horner Park
Mayfair Library
4. Schurz Campus
Schurz High School
Kilbourn Park
Portage-Cragin Library
5. Senn Campus
Senn High School / Rickover Naval Acad.
Broadway Armory
Edgewater Library
6. Sullivan Campus
Sullivan High School
Loyola Park
Rogers Park Library
7. Taft Campus
Taft High School
Norwood Park
Roden Library
8. Uplift High School
Clarendon Park
Uptown Library
9. Vaughn Campus
Portage Park
Jefferson Library
Region 2
10. Clemente Campus
Clemente High School
Clemente Park
Humboldt Park Library
11. Kelvyn Park Campus
Kelvyn Park High School
Kelvyn Park
North Pulaski Library
12. Noble Charter High School
13. North Grand Campus
North Grand High School
Hermosa Park
North Pulaski Library
14. Orr Campus
Orr High School
Orr Park
Legler Library
15. Prosser Campus
Prosser Career Academy
Blackhawk Park
North Austin Library
16. Ramirez Campus
Ramirez High School
Holstein Park
Damen Library
17. Wells Campus
Wells High School
Eckart Park and Library
18. Steinmetz Campus
Steinmetz High School
Riis Park
West Belmont Branch
19. Douglass Campus
Douglass Academy
Austin Town Hall Park
Austin Library
Region 3
20. ACT Campus
ACT Charter High School
Garfield Park
Legler Library
21. Al Raby High School
22. Austin Campus
Austin High School
Austin Town Hall
Austin Library
23. Clark Campus
Clark High School
Clark Park
Austin Library
24. Collins Campus
Collins High School
Douglas Park
Douglass Library
25. Crane Campus
Crane Tech Prep. High School
Touhy-Herbert Park
Legler Library
26. Juarez Campus
Juarez Community Acad.
Harrison Park
Lozano Library
27. Manley Campus
Manley Career Academy
Douglas Park
Douglass Library
28. Marshall Campus
Marshall High School
Garfield Park
Legler Library
29. Phoenix High School
30. Marine Academy
31. Powerhouse High school
Region 4
32. Ace-Tech Charter High School
33. Bronzeville High School
34. Curie Campus
Curie Metro High School
Curie Park
Archer Heights Library
35. Dunbar Campus
Dunbar High School
Lake Meadows Park
Chicago Bee Library
36. Dyett High School
37. Farragut Campus
Farragut Career Academy
Shedd Park
38. Kelly Campus
Kelly High School
Kelly Park
Brighton Park Library
39. Kenwood Academy High School
40. King High School
41. Little Village Campus
Little Village High School
Piotrowski Park
Toman Library
42. Phillips Campus
Phillips Academy
Anderson Park
Chicago Bee Library
43. Tilden Campus
Tilden Career Academy
Fuller Park
Sherman Park Library
44. UNO Charter High School
45. Youth Connections Campus
Youth Connections High School
Armour Square Park
Chicago Bee Library
Region 5
46. Bogan Campus
Bogan High School
Bogan Park
Scottsdale Library
47. Englewood Campus
TEAM Englewood Academy
Sherwood Park
Kelly Library
48. Gage Park Campus
Gage Park High School
Gage Park
Gage Park Library
49. Hancock Campus
Hancock High School
Pasteur Park
Archer Heights Library
50. Harper Campus
Harper High School
Ogden Park
W. Englewood Library
51. Hirsch Campus
Hirsch High School
Greater Grand Crossing
Avalon Library
52. Hubbard High School
53. Hyde Park Campus
Hyde Park High School
Jackson Park
Bessie Coleman Library
54. Lindblom Campus
Lindblom College Preparatory HS
Lindblom Park
Sherman Park Library
55. Perspectives Campus
Perspectives High School
Foster Park
Woodson Library
56. Robeson Campus
Robeson High School
Hamilton Park
Kelly Library
57. Simeon Campus
Simeon Career Academy
West Chatham Park
Woodson Library
58. South Shore Campus
South Shore Community Academy
Nash Community Center
South Shore Library
Region 6
59. Bowen Campus
Bowen High School
Bessemer Park
South Chicago Library
60. Carver Campus
Carver Military Academy
Carver Park
Altgeld Library
61. Fenger Campus
Fenger Career Academy
Ada Park
Pullman Library
62. Harlan Campus
Harlan Community Academy
Abbott Park
Woodson Library
63. Julian Campus
Julian High School
Graver Park
Woodson Library
64. Washington High School
Washington High School
Rowan Park
Vodak East Side Library
Downtown Region
N
0 1.5 3 6 Miles
Legend
ASM High School Campus
CPS Regions
Region 1
Region 2
Region 3
Region 4
Region 5
Region 6

BIOGRAPHY FOR MAGGIE DALEY

Maggie Daley is First Lady of the City of Chicago and one of the city's leading advocates for children and youth. She is Chair of After School Matters, whose goal is to engage Chicago's teens in purposeful and meaningful activities after school and in the summer. Starting in 1991 with 220 teens in the gallery37 summer program, it has grown to include over 28,000 high school students this academic year. This increase is a result of an active and resourceful board of civic and corporate leaders; partnering with community-based organizations, non-profit groups, and the Chicago Public Schools, Parks and Libraries.

Maggie also chairs the Chicago Cultural Center Foundation Board, which develops citizen, corporate and foundation support for the center, where the public is exposed, free of charge, to a rich multi-cultural experience in the arts. Its goal is to inspire the public, and at the same time help young people become immersed in cultural arts education.

Maggie was President of Pathways Awareness Foundation from 1991 until 2004. Pathways Awareness Foundation is dedicated to increasing knowledge about the benefit of early detection and early therapy for infants and children with physical challenges. It aims to support parents by providing knowledge, information, and a sense of community. A Medical Round Table of prominent professionals partners with the foundation to heighten awareness as to the utmost importance of early intervention.

In 1992, President Clinton appointed Maggie to the President's Committee for the Arts & Humanities (PCAH). The PCAH serves as a bridge between the public and private sector in supporting arts and humanities. Maggie currently serves on the Board of Directors for several Chicago non-profit organizations and foundations, including Children at the Crossroads Foundation and The Chapin Hall Center for Children at University of Chicago.

Chairman LIPINSKI. Thank you, Ms. Daley.

The Chair now recognizes Mr. Michael Lach.

STATEMENT OF MR. MICHAEL C. LACH, OFFICER OF TEACHING AND LEARNING, CHICAGO PUBLIC SCHOOLS

Mr. LACH. Mr. Chairman, Members of the Subcommittee, thank you for inviting me here today to speak to you about this issue. It is an honor to sit before you alongside colleagues who I have worked with and learned much from. I am the Officer for Teaching and Learning for the Chicago Public Schools. Our school system consists of over 600 schools, nearly 25,000 teachers and more than 400,000 students. I began my career as a high school science teacher and have played a leadership role in the design and execution of CPS's science, technology, engineering and mathematics programs for the past five years.

We have made great progress with math and science instruction in Chicago. Student performance has risen considerably over the past five years, and the rate of improvement is faster than that of the rest of the state. To do this, we developed a comprehensive plan to coordinate all aspects of math and science improvement. This includes creating a vision for high-quality instruction, building a support infrastructure to provide high-quality, content-rich professional development to thousands of teachers over the course of an academic year, forced partnerships with local businesses, museums, laboratories and universities to increase content knowledge of our teachers and enhanced our after-school offerings to include mathematics and science enrichment.

We have done this in a challenging context. 85 percent of our students come from low-income families. Our resources are low. Illinois ranks 47th in the Nation in the level of State support for education. Our capacity is limited. Less than five percent of our K–8 teachers possess a State endorsement in mathematics. The Chicago Public Schools is extremely decentralized. By State code, decisions about local school budgets, curriculum and principal contracts are made by an elected body called the Local School Council, not the chief executive officer or the school board.

While I feel proud of the accomplishments to date, there is still much work to do. An achievement gap remains in many of our schools. The number of students meeting and exceeding standards remains far too low. Our high schools in particular still have graduation rates that are unacceptable. Improving schools at scale is complicated, time-intensive work and I am reminded again and again of the need to approach these challenges with real humility.

The gaps we face in the resources and capacity limitations have been built on five key strategies we have used to drive things ahead. The first is teacher quality. We know that teachers need to know the subjects they teach. Part of our systems approach involves using our university colleagues to help us increase the content knowledge of teachers. Much of this work originated with National Science Foundation Resources including the CUSP grant which enabled us to provide tuition stipends for teachers to go back to school and learn the mathematics and science they needed to.

A second key strategy is to provide core support for classroom instruction. Again, we used our neighbors and our partners. For instance, the University of Chicago on the south side of the city is the center for instruction in K–5 mathematics, again thanks to pioneering NSF work around curriculum development. At the high school level, we partner with many local and national institutions including UIC, the Illinois Institute of Technology, Carnegie Mellon University, and the Field Museum to provide coaching, professional development, training and curriculum support for our teachers.

We know that extended learning opportunities are essential. As Ms. Daley mentioned, enhancing after-school experiences for kids is tremendously important. There is no better astronomy lesson in Chicago than going to the Adler Planetarium and seeing the sky show. There is no better horticulture lesson than going to the Chicago Botanic Gardens and learning to cultivate and grow a garden.

We have also been pretty aggressive about creating new schools. Our Renaissance 2010 program involves the painful process of closing down schools and creating new ones. We are proud to have created several math- and science-focused schools over the course of that time period.

We have done this with extensive partnerships throughout all aspects of the city. I will highlight a few principles that underscore the kinds of partnerships that I think are important. We have been able to do this because of coherence. We have had a comprehensive vision and system of support for several years, and that coherence enables us to help partners organize themselves so their work aligns with ours. Having so many high-quality partners is really, really helpful. It gives us a sort of buyer's advantage when we talk about other work. For instance, there was a local university that wanted to do wonderful collaboration with arts and science content. We were able to go to them and say, you know, you really need to explicitly connect this to our curriculum, and they were able to make those kind of changes.

Having catalysts from the Federal Government has been incredibly powerful. Funding sources and grants enable us to leverage new resources and create the kind of innovations that we need to move things ahead.

Lastly, we have made a lot of progress by centralizing our supports. We find the general population does not understand science and mathematics very well or its practice. Sadly, many of our school administrators share that same lack of understanding. By really providing a coordinated central support, we can drive that kind of work.

Too often, children in Chicago are considered disadvantaged because of the many social issues that confront them. Without taking anything away from the situation in which our children grow up, the word 'disadvantaged' has always troubled me. Where STEM education is concerned, I believe that growing up in Chicago can and should be considered an advantage. Our students grow up right next door to world-class universities, businesses, museums and laboratories. These institutions can and should be considered part of the overall system of mathematics and science improvement, and our collective work to date has shown that when such a system is aligned and pointing in the same direction, that system works to serve the students of Chicago. Thank you.

[The prepared statement of Mr. Lach follows:]

PREPARED STATEMENT OF MICHAEL C. LACH

Mr. Chairman, Members of the Subcommittee, thank you for inviting me here today to speak to you about this issue. It is an honor to sit before you alongside colleagues whom I've worked with and learned much from.

Introduction

I am the Officer of Teaching and Learning for the Chicago Public Schools. The Chicago Public School system consists of over 600 schools, nearly 25,000 teachers, and more than 400,000 students. I began my career as a high school science teacher, and have played a leadership role in the design and execution of CPS's science, technology, engineering, and mathematics education programs for the past five years.

We have made great progress with mathematics and science instruction in Chicago. Student performance has risen considerably over the past five years, and the rate of improvement is faster than that of the state. (See Figure 1 and Figure 2.) To do this, we developed a comprehensive plan to coordinate all aspects of mathematics and science improvement, which we call the Chicago Math & Science Initiative. As part of this work, we created a vision for high quality instruction; built the support infrastructure to provide high quality, content-rich professional development to thousands of teachers over the course of an academic year; forged partnerships with local businesses, museums, laboratories, and universities to increase the content knowledge of our teachers; and enhanced our after-school offerings to include mathematics and science enrichment.

We've done this in a challenging context. Eighty-five percent of our students come from low-income families. Our resources are low; Illinois ranks 47th in the Nation in the level of State support for education. Our capacity is limited—less than five percent of our K–8 teachers possess a State endorsement in mathematics. The Chicago Public Schools is an extremely decentralized school district. By State law, decisions about local school budgets, principal contracts, and curriculum are made by an elected body called the "Local School Council," not the Chief Executive Officer.

While I feel proud of the accomplishments to date, there still is much work to do. An achievement gap remains in many of our schools. The number of students meeting and exceeding standards remains far too low. Our high schools, in particular, still have graduation rates that are not acceptable. Improving schools at scale is a complicated, time-intensive work, and I'm reminded again and again at the need to approach these challenges with true humility.

Working Together

The gaps we face, and the resource and capacity limitations that we operate under, make it unconscionable for us to turn down assistance. So my most important point today is that we really depend on the assistance and partnership of others—the local community groups, colleges and universities, museums and laboratories as well as the Federal Government to advance our work. I'll talk now about the major components of our strategy and the mechanisms by which we intend to continue the progress we've shown.

Teacher Quality

Teachers need to know the subjects they teach. That's a pretty fundamental tenant of teaching and learning. In Chicago and Illinois, we've struggled to both attract and hire teachers with appropriate content-level backgrounds. Building on an earlier National Science Foundation grant called the Chicago Urban Systemic Partnership, we helped local universities create content-rich courses that enabled teachers to earn State endorsements in mathematics and science. Now, most local colleges and universities offer courses that help teachers supplement their teaching certificates with content-based credentials, and we've changed our internal staffing procedures to place an emphasis on teachers with strong content background. That said, there's still a considerable way to go: in the Fall of 2008, we opened 82 K–8 elementary schools without a single adult with a State mathematics endorsement on their faculty.

The district's role in working with our university partners was to convene and organize the conversations with them. With the CUSP grant and with the bully pulpit of the Chicago Public Schools, we've created a community of interested university faculty members and academic deans with whom we work on a regular basis to design and manage these courses. The district has offered financial support to teachers to earn content-based endorsements, and this "carrot" has certainly helped us encourage local universities to change the curriculum and structure of their teacher credentialing programs.

Core Support for Classroom Instruction

A major part of our strategy has been to provide a complete suite of instructional supports to schools—textbooks, assessments, in-school instructional coaching, and workshop professional development—to help improve the quality of instruction within classrooms. Again, here we have relied on public and private stakeholders to help develop this work.

We relied heavily on instructional materials developed locally—such as *Everyday Mathematics* from the University of Chicago—both because they were high quality but also because we had an implementation center in our backyard. Where we didn't have a strong center of expertise, we helped create one: The Center for Mathematics and Science Education at Loyola University is now the headquarters for middle grades science education in the city of Chicago. On State assessments to date, schools that implement these programs consistently outperform schools that do not.

At the high school level, we've created a market system around instructional supports using both public and private entities. Each year, we contract with partners—including the Illinois Institute of Technology, the University of Illinois at Chicago (UIC), Loyola University, and Northwestern University, as well as for-profit entities associated with the University of Texas at Austin and Carnegie Mellon University—to provide a similar suite of instructional materials, in-school instructional coaching, and teacher training. Through a combination of carrots and sticks, high schools utilize these services to improve their instructional performance.

The district itself plays a major role in this work: most of the funding for these supports comes from district or foundation funds, and we work extensively to develop the partnership arrangements to ensure sufficient capacity both internally and externally to move the work ahead.

Extended Learning Opportunities

We also know that there are some aspects of mathematics and science that are hard to learn in the classroom. There's no better astronomy lesson than watching the star show at the Adler Planetarium. There's no better botany lesson than spending a few hours at the Chicago Botanical Gardens. We work with local museums and community groups to create after-school clubs focused on science and mathematics; these programs often provide the spark that ignites a student's interest in STEM disciplines. And "Science 37," a component of After School Matters, provides science experiences for students after school time.

We've also created summer internship programs and student and teacher research opportunities, sometimes using the GK–12 programs of the NSF, and other times using business funding. These programs enable both teachers and students to experience the real-life work of scientists and engineers, providing a learning experience that is modern and directly connected to the real work.

For the past three years, the City of Chicago has held a "Science In The City" celebration, a week-long carnival that demonstrates that Chicago is a city of science to children of all ages. This event originated with the public schools, and we continue to play a leadership role in the design and execution of this event.

The district's role in this area is much more limited, primarily due to funding constraints. Centrally, we help develop a few after-school programs and partnerships, such as the annual science fair competition in cooperation with the Museum of Science and Industry, and the You Be A Chemist! competition with Harold Washington Community College. We're currently exploring mechanisms that will make the myriad of after-school and extended learning experiences more accessible to schools and communities, with the goal of increasing participation and coherence throughout the city.

New Schools

New school creation has been a hallmark of the Chicago Public Schools. We're pleased to have created several new schools with an emphasis on mathematics and science. For instance UIC College Prep high school, run by the Noble Street Charter Management Organization, provides a rigorous high school experience coupled with extensive health science learning thanks to the partnership with UIC's Medical School. Several business partners have helped fund and develop our networks of charter schools, connecting their technical resources with our school children right at their school.

Undergirding Systems and Structures

It's important to highlight the fact that the above strategies are grounded in a context of strong school accountability, a mechanism to work with external partners on program evaluation, and a new focus on performance management for all aspects of the educational enterprise. This systems approach has enabled much of the improved student achievement that the Chicago schools have enabled over the past half-decade.

Implications

What does it take to sustain and build such partnerships?

Coherence

A comprehensive system of supports for students within Chicago would not be possible without a coherent strategy for STEM education. In Chicago, we've maintained a consistent strategy for several years, with sustained leadership. A coherent direction enables relationships to deepen and work to improve.

Quality and Capacity

In Chicago, we're fortunate to have a wealth of capacity around STEM education work. This is important, as it enables us to exert sort of "buyer's leverage" in our partnerships. For instance, when one local university wanted to run summer programs focused on the integration of arts and science, but didn't have much direct curricular connection, we were able to convince them to change the direction of their work. When a local museum wanted to focus on teacher professional development and "edutainment" but didn't have a strong cadre of scientists or science educators, we had a strong position from which to promote coherence and the importance of content knowledge.

Catalysts

Federal resources often are catalysts to make partnerships and connections even stronger. The Chicago Transformative Teacher Institute grant that Dr. Wink and I are co-PIs of is an example of this; as a result of National Science Foundation funding, we've created an even deeper partnership thanks to this work. Much of the groundwork for our progress in Chicago was set by a series of NSF grants over the years; it's important for the Federal Government to realize the importance of this role as strategic and financial decisions are made.

Centralization

There's currently considerable debate in the education world about the degree and nature of centralization within school systems. Systems that foster innovation and entrepreneurship push decisions and resources closest to schools and classrooms, and when they are coupled with strong accountability systems, local communities can easily gauge success. Yet the general public doesn't understand science or its practice; a 2006 *Education Week* poll showed that 66 percent of principals do not feel that upgrading math and science education is a priority.[1] Moreover, without strong content knowledge and considerable instructional capacity, it's difficult to design strong mathematics and science programs. Ultimately, this is a question about the best way to scale up improvements, and it remains a particularly vexing question for State and district administrators and policy-makers alike. The mathematics and science education experience in CPS, where centrally designed and managed high-quality supports are available to schools via market-like systems, and where improvements can be demonstrated when those supports are effectively implemented, offers a viable model to consider.

Too often, the children in Chicago are considered "disadvantaged," because of the many social issues that confront them. Without taking anything from the situation in which our children grow up, the word disadvantaged has always troubled me. Where STEM education is concerned, I believe that growing up in Chicago can and should be considered an advantage. Our students grow up right next door to world-class universities, businesses, museums, and laboratories. These institutions can and should be considered part of the overall system of mathematics and science improvement, and our collective work to date has shown that when such a system is aligned and pointing in the same direction, the system works to serve the students of Chicago.

Figures

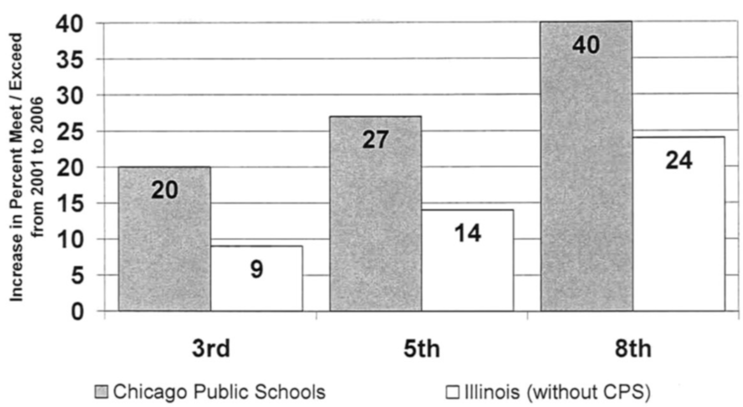


Figure 1: CPS Mathematics Performance on the Illinois Standards Achievement Test versus Illinois, 2001-2006

[1] From Public Agenda's Quality Counts survey 2006.

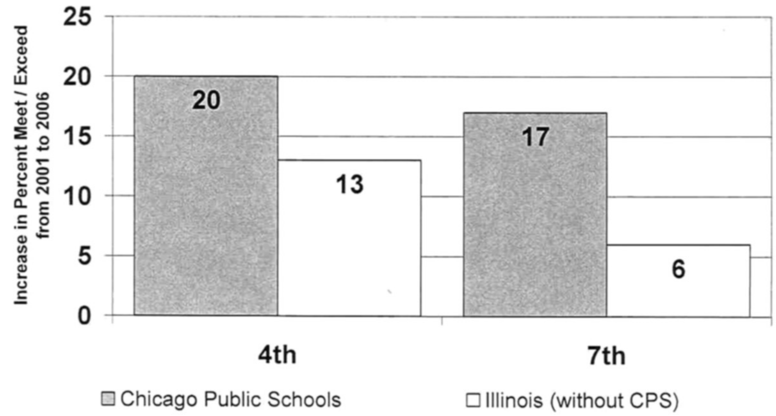


Figure 2: CPS Science Performance on the Illinois Standards Achievement Test, 2001-2006

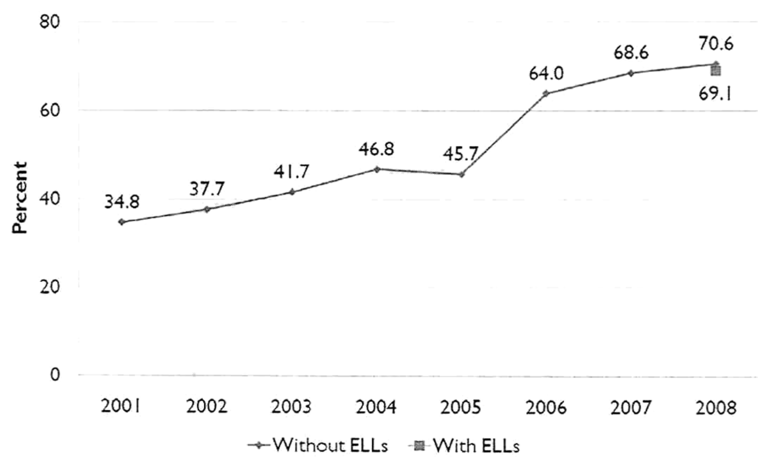


Figure 3: ISAT Mathematics Performance, Percent Of Students Meeting or Exceeding State Standards, 2001-2008

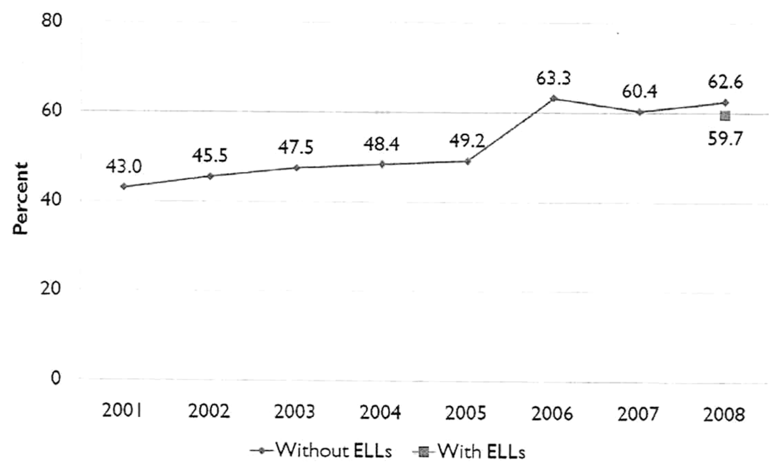


Figure 4: ISAT Science Performance, Percent of Students Meeting or Exceeding State Standards, 2001-2008

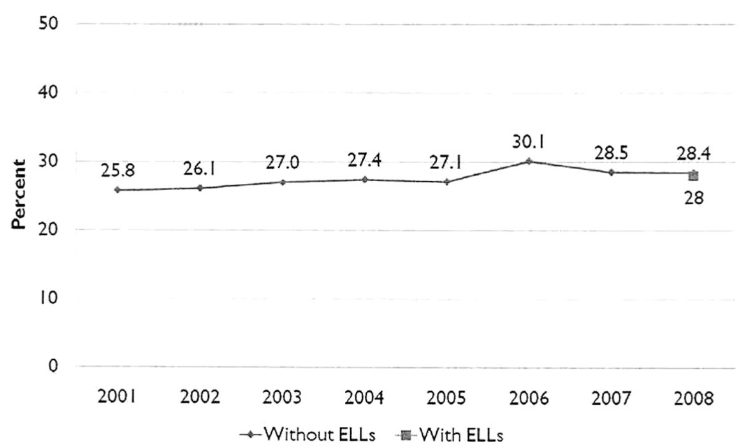


Figure 5: PSAE Mathematics Performance, Percent Of Students Meeting Or Exceeding State Standards, 2001 to 2008

Figure 6: PSAE Science Performance, Percent Of Students Meeting or Exceeding State Standards, 2001-2008

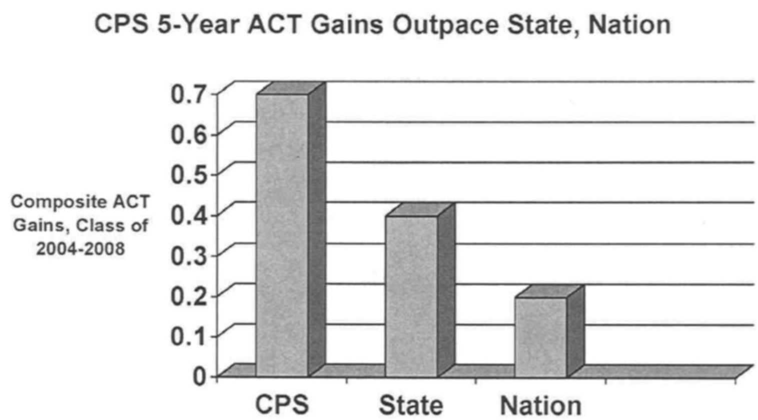


Figure 7: CPS ACT Gains Outpace The State And Nation

BIOGRAPHY FOR MICHAEL C. LACH

Michael C. Lach is currently Officer of Teaching and Learning for the Chicago Public Schools, overseeing curriculum and instruction in the 600 schools comprise the Nation's third largest school district. Mr. Lach began teaching high school biology and general science at Alceé Fortier Senior High School in New Orleans in 1990 as a charter member of Teach For America, the national teacher corps. After three years in Louisiana, he joined the national office of Teach For America as Director of Program Design, developing a portfolio based alternative-certification system that was adopted by several states. Returning to the science classroom in 1994 in New York City Public Schools, and then back to Chicago in 1995 to Lake View High School, he was named one of Radio Shack's Top 100 Technology Teachers, earned National Board Certification, and was named Illinois Physics Teacher of the Year. He has served as an Albert Einstein Distinguished Educator Fellow, advising Congressman Vernon Ehlers (R–MI) on science, technology and education issues. He was lead curriculum developer for the Investigations in Environmental Science curriculum developed at the Center for Learning Technologies in Urban Schools at Northwestern University and published by It's About Time, Inc. As an administrator, he has led the district's efforts in science and mathematics instruction in a variety of roles between 2003 and 2007. He has written extensively about science teaching and learning for publications such as *The Science Teacher*, *The American Biology Teacher*, and *Scientific American*. He earned a Bachelor's degree in physics from Carleton College, and Master's degrees from Columbia University and Northeastern Illinois University.

Chairman LIPINSKI. Thank you, Mr. Lach.

I now recognize Dr. Donald Wink.

STATEMENT OF DR. DONALD J. WINK, PROFESSOR OF CHEMISTRY; DIRECTOR OF UNDERGRADUATE STUDIES, DEPARTMENT OF CHEMISTRY; DIRECTOR OF GRADUATE STUDIES, LEARNING SCIENCES RESEARCH INSTITUTE, UNIVERSITY OF ILLINOIS AT CHICAGO

Dr. WINK. Chairman Lipinski, Ranking Member Ehlers and distinguished Members of the Subcommittee, please accept my thanks for the opportunity to testify today on the subject of how universities can engage in partnership efforts to address important questions about the systems that will improve K–12 STEM education.

I think it is particularly meaningful to testify in the context of the work at the University of Illinois at Chicago. UIC is proud of the work of its faculty, staff and students as they pursue the same goals of excellence in research, service, teaching and patient care that are found at other research-run universities with significant health science programs. But at UIC, we also have the ability, the opportunity and the duty as one of the Nation's few urban land grant institutions to focus important parts of our work on the opportunities and challenges of one of the world's great cities. In this, we acknowledge the importance of the support we receive from foundations, the private sector, the city, the state and of course the Federal Government. Are important in establishing priorities for our work but NSF is especially strong in requiring that our work draw from and often contribute to the research literature itself.

Through all of this, we try to address the central need for reforming STEM K–12 education: improving instruction. But improving instruction requires many different parts of the K–12 system to work well and in tandem. This includes K–12 administrative systems that use distributed leadership to support well-assessed learning by all students, school culture including safety of course but also a sense of content rigor, relevance and inquiry that must be shared by teachers, students and parents. In addition, teachers need to be skilled in the reflected practice that is a necessary part of the work of any professional and they need to be given the time and the training to do this. Finally, students must engage and be supported in developing a growth mindset informed by deep inquiry-based interest in science that develops over time. If these are available, then the research literature is clear: classroom instruction will change and student outcomes will improve. In Chicago, I am proud to be part of a very large number of individuals committed to making those components a well-orchestrated system for our students in the roles that the university can play.

There are several overlapping activities in which UIC faculty, staff and students support improvement in K–12 STEM education ranging from teacher education to the ways in which we educate the undergraduates who come to our campus from K–12 systems. I note that within these there is one important gap: how to translate STEM research into K–12 practice. That was why it was so interesting for me to learn about and have the change to work with Dr. Linda Marton and her colleagues at Foreman High School on the avid support of the Science 37 program. This environment will not just engage students, as Abbott has shown. It is also a way to engage STEM experts.

We hope that all these different activities will be included in our new NSF-funded math and science partnership grant, the Chicago Transformation Teacher Institute program. The CTTI, as it is known, will train 160 math or science teachers in cohorts from 20 different schools in current mathematics, physical science and life and environmental science content. These teachers will also receive workshops on leadership and on the design and implementation of curricula, particularly at creating rigorous AP and capstone courses for 12th grade in schools where previously there were few examples of such offerings. At the same time, these teachers will continue to teach in earlier grades, providing further development of all four years of a high school curriculum.

As we talk about systems, I think it is meaningful to note that the CTTI, though unique, is also an outgrowth of previous work by the district with support of NSF, especially the NSF-funded Chicago Urban Systemic Program and the district's comprehensive plan, the Chicago Math and Science Initiative. One outcome of this was the Algebra Initiative, which put the mathematics departments at UIC, DePaul and the University of Chicago in close support of CPS teachers and led to many ideas for the CTTI.

In addition, the CTTI is intimately connected to the work of the Chicago High School Transformation Project, which was funded by the Chicago Board of Education with a significant assist from the Bill and Melinda Gates Foundation. The High School Transformation Project further strengthened the relationship of CPS with UIC, IIT, Loyola and Northwestern in the area of science and gave us experiences in supporting curricular change that are now brought to bear in the CTTI. Finally, the CTTI is a deep research project addressing how university-based training can affect the elements of school capacity, teacher practice and students outcomes.

I thank you for listening to these remarks and I welcome the opportunity to answer your questions.

[The prepared statement of Dr. Wink follows:]

PREPARED STATEMENT OF DONALD J. WINK

Chairman Lipinski, Ranking Member Ehlers, and distinguished Members of the Subcommittee on Research and Science Education, I offer my sincere gratitude for the opportunity to testify about the efforts of my colleagues and I at the University of Illinois at Chicago in our work with the Chicago Public Schools. UIC and other institutions of higher education in the Chicago area are proud to part of a STEM education system that extends from preschool to graduate school.[1]

[1] I have prepared this testimony and am responsible for its content, but I do wish to acknowledge that many individuals contributed material for this testimony. They are cited in different

Continued

I would like to take a few moments, if I may, to describe the very special situation of the University of Illinois at Chicago. The University is part of the land grant institution for the State of Illinois but, in contrast to many other land grant institutions, we are located very much in the center of the city and at the intersection of many transportation routes. This is by design, for we are a campus that, from our start, has focused on integrating its research, scholarship, service, and patient care on the needs of the city, combining a research university's ability to create fundamental new knowledge with the exciting opportunity to link that knowledge to the needs of the city where possible. In addition, our diverse undergraduate student population reflects the demographics of northeastern Illinois; almost one third of our students are under-represented minorities and no single group is in the majority. We are also academically diverse, with strong programs in STEM and the health sciences, associated with our large medical sciences campus.

Of course, today the focus will be on our work in association with K–12 teaching. In this case, much has occurred in the last twenty years that, as I will discuss, exemplifies how universities can benefit from close partnerships with public school districts, often supported by federal and private funding. I should also point out that, while I will focus on UIC, it is fortunate that in Chicago there are several other institutions of higher education that are involved with systemic change in the district. In many cases they are working collaboratively with each other and I will be citing their work, also.

I have been asked to comment in three areas, which I take in sequence. But before I do so, I would like to present a logic model for this work that provides a structure for our work and my further remarks.

Our model of a STEM education system sees K–12 school systems and universities as part of a cycle that includes students educated in K–12 who move on for more specific training in higher education. The colleges and universities have the opportunity to educate these students further, in specific disciplines, so those students are able to participate in STEM and health science careers. In addition, colleges and universities affect K–12 education by producing teachers, who need deep disciplinary knowledge and the skills to be able to work well with the diverse learners in K–12 settings. Further, colleges and universities work with existing teachers, both to provide deeper training in current topics in STEM and in STEM education and to receive from those teachers a better understanding of the actual issues that matter in K–12 STEM classrooms. The systematic study of these endeavors produces educational research. Finally, districts and universities together engage in work to bring this research into practice. This logic model is affected by others who participate in the STEM enterprise, including of course public and private employers, who both employ STEM graduates and, in some cases, actively work with K–12 schools and institutions of higher education in preparing better students. Also, the model is focused on the university as a partner. Clearly, the vitality of Chicago's informal science programs, through After School Matters, the museum community, and the media are all essential parts of STEM education, though poorly represented in this model itself.

This picture is all well and good on paper, but in practice it requires three other elements that don't always fit on a traditional organizational chart: strong, enduring, relationships among the individuals and the institutions involved; leadership dedicated to this interaction within and among institutions; and research-based knowledge of effective ways to carry out instruction and to support change. Relationships, leadership, and research are not just one-time events but they depend on excellent communication over time. Conversely, things that hamper relationships, undermine effective leadership, and stymie the translation of research into practice are all dangers to effective STEM education systems work. Also, a central part of the translation of the model into effective practice is to note the context of our work, and of the work done in our district. UIC and its partners enthusiastically embrace the idea that urban education is an opportunity for truly exciting work. The work is also very challenging as we strive to bring educational excellence to all students. Hence, understanding well how urban schools work is present into all of our efforts, for example in our Noyce, GK–12, and MSP programs.

In the figures on the next page, I show two examples of how aspects of this logic model have informed our work in Chicago. The first shows the graphical description my colleagues and I used in organizing our most recent NSF GK–12 project. For

places. In addition, three individuals who helped me with additional review and comment are John Baldwin, Steve Tozer, and Carole Mitchener of UIC, Stacy Wenzel of the Center for Science and Mathematics education at Loyola University Chicago, and Dean Grosshandler of the Northwestern University Office of Science, Technology, Engineering, and Math Education Partnerships.

this, we identified specific learning communities that would be essential to the success of the project, and who would be affected by the project. In the second figure I present the logic and research model that we are using in our current NSF Math and Science Partnership project. In this case, there is a flow of events, capturing more clearly both the cyclical nature of our plans and the outcomes we have identified for our research and evaluation program. In both cases, the interconnections—the way things happen—depend on people working together, informed by research.

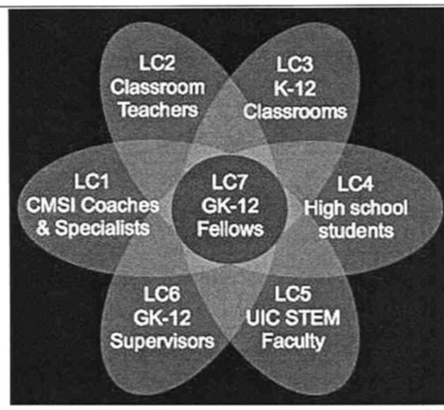


Figure 1: Relationship of learning communities with the NSF GK-12 project, "Scientists, Kids, and Teachers," (NSF DGE-0338328). CMSI refers to the CPS's *Chicago Math + Science Initiative*

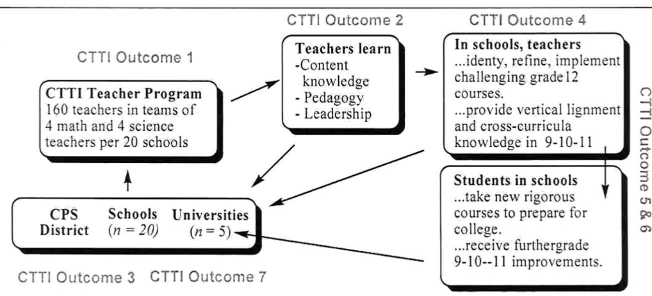


Figure 2: Logic model and outcome mapping for NSF MSP project, "The Chicago Transformation Teacher Institutes," (NSF DUE-0928669)

1. Brief description of the University of Illinois at Chicago's (UIC) K–12 science, technology, engineering and mathematics (STEM) education programs and initiatives.

In the table below I list nine different ways UIC's STEM education programs and initiatives for the last twenty years have impacted K–12 STEM. I will illustrate many with one or two specific examples. Note that this also means that I am leaving out many other equally interesting examples, so this is not a comprehensive description of all activity, just of all types of activity. Also, the particular ways in which our support from the NSF Noyce, GK–12, and MSP programs impact STEM K–12 education are deferred until the next question for my testimony.

Table 1: Areas of activity for UIC and partner programs in K-12 STEM education

Area	Activities
(a) Teacher education	For individuals who have already entered the K-12 teaching workforce. This includes formal coursework, workshops, professional development, and teacher participation
(b) Teacher preparation	For individuals prior to entry into K-12 teacher workforce. Includes formal degree and alternative certification programs.
(c) Classrooms	Work within K-12 STEM classrooms including specific instructional work by K-12 teachers.
(d) Learning	Research and development work on STEM learning, including out-of-classroom instructional work, applied to K-12 learners.
(e) School leadership	Development of leadership systems for schools, including school and district administrators, coaching, and leadership within specific K-12 STEM content areas.
(f) K-12 systems	Research and development work on system-wide issues, including district policies, analysis of outcomes, and standards for instruction and assessment.
(g) Instructional materials development	Creating and implementing formal materials for use in K-12 schools, including textbooks and technology environments.
(h) Linking STEM research to K-12	Programs to bring current STEM laboratory research work into contact with K-12 settings, directly or indirectly.
(i) Higher education policy and practices	Activities to change the ways in which UIC works with K-12 programs, at the level of the district, the school, and (especially) the students who enroll in STEM programs in college.

(a) Teacher education

Current teachers are the most important part of the K–12 STEM enterprise for the simple reason that they provide the vast majority of the instruction to the students. As with any professional practice, however, the education of a teacher should never cease. Teacher learning occurs in many different forms, including the ways in which a teacher learns about her own students and her own teaching and shifts practice accordingly. For the University, teacher education activity primarily consists of outreach through courses and workshops.

One particular example of such teacher education work is *The Algebra Initiative.* This is a partnership of CPS, DePaul University, the University of Chicago, and UIC with leadership provided by, among others, John Baldwin at UIC, Lynn Narasimhan at DePaul, and Paul Sally at Chicago. Each University offers a one-year course of study for participating teachers. The funding for the program has come from the district through tuition support and from the Chicago Community Trust. Teachers who will teach algebra in an elementary or middle school are required to complete this program by the CPS if their school is to meet the district requirements for offering Algebra I in eighth grade, a key requirement for rigorous work in high school and, ultimately, college. As described by the CPS, "Topics included in the course sequence are the structure of algebra, linear equations and inequalities, graphing linear equations, algebraic identities, arithmetic sequences, introduction to quadratics, and using algebra to model problems." In this case, then, the faculty at the university provide direct content training to teachers, making use of the concept that a deep understanding of content that is specific to a course, in this case algebra, is essential for effective teaching (Monk 1994; Hill et al., 2005). Thus, *The Algebra Initiative* has university faculty providing their content expertise in the context of a much wider, district-supported effort, backed up by mandates for teacher certification from the Chicago Board of Education, which requires that teachers pass an exam written by the university partners to teach algebra in 8th grade. This program has increased the number of formally qualified 8th grade algebra teachers in Chicago from 43 in 2004 to over 300. Through this work, over half the elementary schools in the system now can have qualified algebra instruction.

(b) Teacher preparation

Although the education of a teacher is an ongoing process it begins with preparation and initial certification. Specific and creative work to reform how this is done makes use of support from the NSF Noyce Teacher Scholars program, described in much more detail later on. Here, I want to bring in a different aspect of teacher preparation: the "normal" path pursued by students who enroll in a traditional preparation programs as undergraduates. It is of course vital that STEM teachers understand content deeply, and we are proud of the disciplinary rigor associated with the degree programs in science and mathematics teaching. But, especially for undergraduates, it is important that students in teacher preparation tracks are taught content at least in part with an eye to their future careers as teachers. This is part of the reason why UIC, in partnership with several area community colleges, received NSF support for the *Chicago Collaborative for Excellence in Teacher Preparation* (NSF DUE 9852167). That project built upon and expanded relationships between the UIC College of Education and STEM departments teaching content courses. That project resulted in several new courses for UIC, including planning for what became a set of three content courses and one capstone course in the natural sciences, which received further support through an NSF CCLI grant (NSF DUE 0311624). The implementation of the three content courses at UIC and its partner institutions (Varelas et al., 2008) has been accompanied by research and dissemination work that demonstrates the gains that occur for this population of students when instruction is provided in a context rich inquiry environment. In this case, we have research to back the claim that these courses do positively impact student attitudes towards science (Wink et al., 2009) and the learning of content itself (Plotnick et al., 2009). As of July, 2009 more than 240 students have participated in these courses at UIC with a retention rate towards a teaching degree over 50 percent and an overall retention rate of more than 80 percent that is well above the norm.

(c) Classrooms

Thus far, the programs I have described are located at the University. However, work in actual classrooms and schools is also essential. For example, Maria Varelas and Chris Pappas in the UIC College of Education have recently concluded the NSF-funded portion (NSF, DRL–0411593) on "Integrated Science-Literacy in Urban Early Elementary Classrooms (ISLE). This was fundamentally a research project that also engaged teachers in the collaborative work to:

- Integrate children's literature and non-fiction books with hands-on explorations and various other representational tools, such as writing, drawing, and acting out, in order to strengthen their teaching and their students' learning of science;
- Develop interactive teaching practices helping students build on their own experiences and understandings and both learn and enjoy science;
- Conduct a teacher inquiry that will inform their practice;
- Develop more flexibility with scientific knowledge and ways to engage their students with it;
- Appreciate the funds of knowledge that young children from sociocultural, ethnolinguistic, and socioeconomic groups that are usually under-represented, under-served, and underestimated bring to the classroom.

The ISLE project is an important example of how UIC research can be interwoven with actual instructional work, advancing both learning and classroom practice in a way that directly informs the research community through conventional presentations and publications (for example, Pappas et al., 2009; Varelas et al., 2008; Tucker-Raymond et al., 2007). The new modes of instruction also become the basis of materials for other teachers, and hence ISLE continues beyond the NSF phase in the form of continuing professional development.

(d) Learning

Another way in which UIC faculty connect research with K–12 instruction and learning is to take a learning sciences approach, and I am proud to be among the faculty who, led by Susan Goldman and James Pellegrino, have initiated the UIC Learning Sciences Research Institute (LSRI). Among its goals is to be a locus for studies that look at some of the fundamental issues in learning and bring them to bear on specific classroom questions. One of the ways this matters most is in questions of how to teach using emergent technological tools. Josh Radinsky, for example, studies the learning that can occur using the tools of Geographic Information

Systems (GIS). In collaboration with other Learning Sciences researchers, he has designed and studied classroom environments that incorporate GIS as a tool in social studies classrooms, part of a larger project in how representations of data are, or are not, made meaningful to students (Radinsky et al., 2005; 2008). This also was supported through NSF's educational research programs (NSF, DRL 0337598) and has direct implications for science teaching (Radinsky, 2008).

(e) School leadership

Teaching does not occur in a vacuum and there are too many examples of excellent opportunities that are not sustained because of issues within the school that are outside of the control of the teacher. Hence, for effective STEM education to develop and continue, school leadership must provide the environment and the resources needed by teachers. At UIC, Steve Tozer and his colleagues in the College of Education have for the past six years been implementing and documenting an innovative program in *Urban Education Leadership* that focuses on improving student learning through developing instructional leadership at the school level. The program teaches aspiring and practicing principals to work productively with leadership teams in the schools. Specific course work and coaching occurs in the area of science and mathematics: while it is not possible for all school administrators to be trained in how to teach these areas, it is a core goal of the UEL program to ensure that they are all well versed in how different disciplines require different approaches to teaching, such as the use of inquiry curricula. The program also emphasizes leadership by teams (Mayrowetz, 2008), and for high schools, this places department chairs in particularly central roles in building new school cultures for student academic success. In the departmentalized high school, students benefit from program coherence throughout the department, which requires department-level systems, structures, and leadership to achieve them. The program has received recognition in part because it measures the success of its graduates by their impact on student learning outcomes in schools, and its principals now lead 10 percent of Chicago's 130 high schools. It has therefore generated over a million dollars annually from such sources as the CPS, Eli Broad Foundation, McCormick Foundation, the Chicago Community Trust, Fry Foundation, McDougal Family Foundation, and the W. Clement Stone Foundation.

(f) K–12 systems

The logic model I presented at the outset and the areas of activity for UIC work with K–12 STEM education derive, in part, from the work of many researchers. In Chicago, the tradition of studying the K–12 system (and beyond) is a rich one, especially in the last fifteen years. This is perhaps best known in the work of the Consortium on Chicago School Research, based at the University of Chicago (Roderick et al., 2009). The CCSR has had many projects that overlap with UIC work, and much of the work in STEM has included the contributions of Stacy Wenzel, now Associate Research Professor at the Loyola Center for Science and Math Education.

Several groups are responsible for the extensive data collection that underpins this work, most importantly CPS itself through its office of Research, Evaluation, and Accountability. Some of this was spurred by NSF through the Chicago Urban Systemic Program grant, which I discuss in more detail later on. Wenzel is now PI on *Scale Up of Math and Science K–12 Education Reform in a Large Urban District*, an exploratory capacity-building grant from the NSF (DRL 0733550). The project studies the systemic reform of math and science education in the Chicago Public Schools from 2002 to 2008. (Deiger et al., 2009; Wenzel et al., 2009).

The task of finding out how students perform on K–12 assessments begs the question: what will be assessed? In the era of NCLB and in the face of 50 different sets of State standards, this is a daunting question, especially at the national level. Recent moves to align or even share standards among the states will help there, but so too it is vital that K–12 STEM systems understand how assessment should drive, not just follow, instruction. This is very much the them of the work of my colleague Jim Pellegrino in learning sciences. He has served as head of several National Research Council study committees, including the committee that issued the NSF-funded report *Knowing What Students Know: The Science and Design of Educational Assessment* (2001). He served on the NSF-funded NRC Committee on *Test Design for K–12 Science Achievement*. Dr. Pellegrino was currently a Co-PI on an NSF ROLE project *Making the Invisible Visible: Children and Teachers Learning about Physical States and State Changes* (DRL 0529648). He is also PI on a recent project with the College Board (DRL 0525575) *From Research to Practice: Redesigning AP Science Courses to Advance Science Literacy and Support Learning with Understanding*. From these will come both general concepts about assessment and also specific recommendations on how assessment should be used in K–12 STEM education. One way this occurs in partnership with CPS is through a grant (NSF, DRL–0732090) on the assessments embedded in math curricula and their role in supporting the teaching and learning process. This work specifically works with CPS-adopted curricula (themselves NSF-developed) that are already being implemented in schools.

(g) Instructional materials development

One of the least considered partners in K–12 teaching, and indeed in all teaching, are those who develop and sustain materials for the classroom. These materials include textbooks and technology. As I have discussed, this is sometimes the outcome of research and teacher education programs. But there are other projects that have materials development as their major thrust. At UIC, this has occurred in the context of the *Teaching Integrated Math and Science* program, initiated in the 1980's with NSF support. The project was founded by two UIC faculty members, physicist Howard Goldberg (retired) and mathematician Philip Wagreich. It has received more than $20 million in external funding since 1990 from the National Science Foundation (NSF), the State of Illinois Scientific Literacy Project, and Eisenhower funds, as well as direct support from school districts for professional development activities. Commercialization has occurred through three different products: *Math Trailblazers,* now its 3rd edition, *TIMS Laboratory Experiments,* which are used in both math and science instruction, and teacher education materials, the *Teacher Enhancement Resource Modules.* The project is very much alive, providing the basis for both professional development of current teachers, reform-based materials for use in teacher preparation, and a basis of research work on mathematics learning (Brown et al., 2009; Castro-Superfine et al., 2009). In its most recent NSF-supported revision, the project conducted three years of research in *Math Trailblazers* classrooms. Based on the results of the research the curriculum was revised and field tested for an additional three years, using overall more than 200 teachers in 40 schools in 16 districts in eight states in either the research or field test. Thus, university-based materials development, fully connected to professional development and the tools of university research, provide an important venue to study and support multiple components of K–12 STEM education. More than 70 schools in CPS alone are using the curriculum, representing close to 20 percent of the district's K–8 programs.

(h) Linking STEM research to K–12

The previous seven areas of activity are all ones that, in principle and in practice, can be done separately from a university like UIC. Indeed, important partners in K–12 STEM education reform are private and government research agencies; alternative certification programs; and publishers and independent curriculum developers. But, besides granting degrees, UIC also has the potential to add much to K–12 STEM teaching because it is a research university with extensive work in all STEM and health research fields. As I discuss later, there are too few examples of this kind of work to translate current research into K–12 settings. There is good support for bringing teacher and teacher candidates into teaching, including through Research Experience for Teachers programs such as the UIC-based Chicago Science Teacher Research Program (NSF–EEC 0502272 and 0743068), led by Andreas Linninger, a Chemical Engineering Professor. In those cases, the transfer of STEM research to K–12 depends on the future work of the teacher. Direct curriculum impact is a different story. One very effective example is the collaboration between Vera Pless, a distinguished Mathematics Professor, and Janet Beissinger of the LSRI. With NSF Instructional Materials Development support (DRL 0099220) they developed a now commercialized textbook to teach middle school students cryptography, *The Cryptoclub.* This drew upon Pless and Beissinger's own expertise in the area of codes to bring important concepts in mathematics, including number theory, to a classroom experience that fully engages students. More recently, they have opened up this community to others through a follow-on project to make *The Cryptoclub* and its mathematics available for informal learning after school and online (DRL 0840313). The Cryptoclub example points to the ways in which university faculty can identify the fundamental content, in this case mathematics, that underlies their work, then link it to an important application that, properly managed, brings dramatic current research areas into the experience of students.

Another possible way to link research and high school science, at least, may arise as an outcome of the recent work of NSF Chemistry Division through its *Undergraduate Research Collaborative* program. The five URC's seek to develop methods to bring science research into the early years of the undergraduate STEM curriculum. One, led by Gabriela Weaver of Purdue and with myself as a co-PI, is the Center for Authentic Science Practice in Education (CASPiE; NSF–CHE 0418902). CASPiE is based on modules written by science and engineering faculty to permit students to learn the skills needed to carry out actual research in an area, such as anti-oxidants or bio-sensors, and then to engage in the research itself (Weaver et al., 2006; 2008). Recently, with support of an RET supplement to Nina Hike Teague of CPS's Curie High School, we have shown that CASPiE modules can also be used in high school settings, with in the informal setting of science fair projects for CPS schools.

Finally, the informal science community has a particular role to play here. As I mentioned, my discussion draws mostly from university examples. But universities have much to learn about the translation of research into forms accessible to the public from the informal science community. That is why I was particularly enthusiastic last year when Dr. Linda Marton of Foreman High School invited us to assist in their After School Matters program, which is supported specifically by Abbott. This linkage continues into next year and from this work we expect to have a clearer picture of how a university STEM partner, UIC, can use the ASM context as a means for bringing research into the broader context within K–12 settings.

(i) Higher education policy and practices

The final area of activity where UIC should be active as a member of the K–12 STEM system is with its own courses, curricula, and programs. Earlier I mentioned that, at least in mathematics and in natural sciences, the courses taken by pre-elementary education majors have become an environment where content is taught using reformed pedagogy. The institutionalization of some aspects of this by the University is a direct result of the linkage that we have established between our teacher preparation programs and our future students. After all, every student who graduates from high school was taught for 13 or more years by university-trained teachers, and at UIC NSF Course Curriculum and Laboratory Improvement program has impacted some of these future teachers.

While reforms have begun to occur in some teacher preparation programs, a gap remains for the general student population that finishes CPS intent on a STEM career. Data from the CCSR (Roderick, 2006) shows that fewer than 30 percent of graduating seniors in 1998, 1999, 2002 and 2003 enrolled in a four college within a year of graduation, and only 35 percent of those from the 1998 and 1999 cohorts had graduated within six years, meaning that a stunning 90 percent of graduating seniors did not complete a four year degree in that time span.

These numbers have spurred many changes within CPS, including focused attempts to increase retention to graduation, to address specific problems that prevent college-bound students from matriculating (such as simply completing the FAFSA, which is hardly a simple process), and economic challenges. UIC, for its part, has begun to look at its own retention of students, which now hovers at about 50 percent of all entering first year students. Part of this comes from learning more about the students themselves, an a recent NSF "Science Technology, Engineering, and Mathematics Talent Expansion Program (STEP)" grant has begun to affect STEM students in general and STEM teaching in particular. Much more needs to be done on the campus, and a Provost-level working group has been established to be more systematic in examining the critical supports needed for wider success in STEM majors.

2 (a) What are the major problems that limit the performance of students and teachers in STEM?

If we consider the logic model presented earlier, there are several things that can occur that limit the performance of teachers and students in STEM. These occur in the context of the systems itself, within schools, within classrooms, and with students themselves. The simplest answer to this question is "quality of instruction." But it is all too easy to hear that and think that this can be fixed by providing better teachers, or better textbooks, or better buildings. Instead, we need to consider how schools actually work and to recognize that systematic issues must be addressed so that quality instruction can be used by teachers.

Systematic barriers to reform are those that prevent the identification, adoption, and sustenance of effectiveness in STEM teaching. Some of these occur at the level of the K–12 administrative units such as State boards or district management teams. Inconsistency, including a sense that particular changes are only temporary, also contribute to a reluctance on the part of teachers and students to engage fully in changes. Also, the systems present in higher education to teach STEM students and to prepare future teachers may be antiquated, based more on a tradition of re-producing the professoriate than in working with diverse learners. Faculty who take pride in staying abreast of the latest research in their field will instead fall back on personal empiricism when thinking about their own teaching, dismissing the relevance of educational research to their own practice.

Within schools, a culture of rigor, relevance, and openness to learning are all needed for effective STEM teaching. However, there are many cases where the culture of the school may not value rigor for all subjects and for all students. Similarly, engaging curricula are often neglected, despite strong evidence that students will work much harder and remain in school if they know why content is valuable for people's lives, including those of themselves and their community. Safety for students and for learning is needed, and when safety is compromised, learning is sure to suffer. Finally, schools need to have the equipment, including appropriate technology, needed for current curricula.

It is important that we be honest that teachers are sometimes a challenge for effective learning. Often this is because of gaps in their training, not their own goals. For example, lack of content knowledge, lack of pedagogical content knowledge, and a lack of experience with contemporary STEM research trends can all lead to instruction that is ineffective and stagnant. Many of the reasons for these challenges come from both a shortage of time with students to focus on math and science content and a shortage of time for professional learning and preparation for their math and science instruction. For example, researchers found that it was not uncommon for CPS teachers and administrators to struggle and fail to set up school schedules with required amounts of protected instructional time for middle grade math and science lessons. Many of these same teachers also were not able to debrief with a content expert in math or science coach who visited their classrooms—there was not time in their schedule to fit in a 15-minute reflective conversation with the coach following the observed or co-taught lesson. On the other hand, teachers that are given the time and support for ongoing professional development, reflective practice involving strong school-based teams, and deep engagement with trends in current STEM research can begin to overcome these challenges quickly.

Finally, we need to understand better ways to motivate students. Because of the emphasis on the economic necessity of increasing the number of students in the STEM pipeline, students often are not given the opportunity and encouragement to experience the wonder and joy of doing STEM. These opportunities are necessary for continued and deeper engagement that lead to a growth mindset (Dweck). Similarly, students may be led to believe that discoveries/payoffs come easily and they are not helped to see the relationship between hard work and satisfaction. Another UIC project, led by Marty Gartzman, is developing materials for double period algebra that melds solid mathematics with careful attention to student motivation. An interesting perspective on this was recently provided by a student-led project, Voices of Youth in Chicago Education (*http://www.voyceproject.org/*). Using surveys, ethnography, and review of statistics, students from several high schools and community organizations examined multiple dimensions of teaching and the challenges of retaining and supporting students. Four areas of focus: rigor, relevance, effective teaching, and safety and security, were highlighted. When these are compromised, the VOYCE findings suggests student outcomes suffer.

2 (b) What are the most important and effective components of the National Science Foundation (NSF) funded programs (including the Math and Science Partnership Program, the Robert Noyce Teacher Scholarship Program, and the Graduate STEM Fellows in K–12 Education Program) that UIC has implemented in partnership with Chicago Public Schools?

This question will be addressed in four parts. First, I will recount some of the outcomes of the NSF-funded *Chicago Urban Systemic Program* (NSF, DRL–0085115), a systemic change grant that has spawned many different efforts in the district and with its partners. Then, I will discuss the work that occurred in our GK–12 programs that impacted how we understand partnerships through the agency of STEM graduate fellows. Finally, I will present the plans that we have for a new Noyce Teacher Scholarship program, building upon a previous effort, and the ways in which our *Chicago Transformation Teacher Institutes* draw from and expand upon the different activities we have established in the past.

The Chicago Urban Systemic Program (NSF, DRL–0085115)

The CUSP design supported a comprehensive math and science district reform effort focused on teacher professional development on content knowledge and around the use of specific math and science standards-based curricula. To strengthen content knowledge, elementary school teachers enrolled in university programs that gave them the subject matter content to apply for and receive State of Illinois endorsements to teach math and science in middle grades classrooms. Evaluation of this project resulted in extensive formative and summative research reports and several national conference presentations. See *http://research.cps.k12.il.us/cps/accountweb/Evaluation* for a partial list of and access to these reports. The CUSP final report to NSF (Feranchak, 2006), documents the following outcomes of the program:

- *Developed district mathematics and science infrastructure capacity.* The CPS plan for mathematics and science improvement—the Chicago Math and Science Initiative (CMSI)—was formulated through CUSP. CMSI has continued in the district after the cessation of CUSP funding. During the project period, CPS significantly increased its support for mathematics and science improvement from $5.2 million ($2.2 million from NSF) in 2002 to $15 million in 2006 ($2.8 million from NSF). Since the cessation of CUSP the district has continued its support, including a substantial part of the HSTP (see below).
- *Improved professional development offerings and greater numbers of teachers served.* By the end of the grant period, over 6,000 teachers per year were receiving direct professional development in mathematics and science. This represents a 106 percent increase in teachers served annually over the initial year. During the 2005–06 school year 2,560 elementary teachers from 268 different schools attended 37,000 person-hours of CUSP mathematics professional development. In the following year (after CUSP ended), 2,237 elementary teachers from 290 different schools attended a total of 24,677 person-hours of grade-specific, curriculum-specific mathematics professional development. In several hundred cases, this allowed teachers to receive certification for middle school math or science, significantly decreasing the number of uncertified teachers in those classrooms. And recent data show that the vast majority of individuals who have obtained a math endorsement (>90 percent) have done so through this program, as is also the case for the majority of those who got endorsements in science.
- *Improved student achievement.* The six-year change from the beginning of CUSP in 2000 find higher gains in the percentages of CPS elementary students, compared to percentages of Illinois students statewide, who met or exceeded State standards on Illinois State tests (ISAT) in mathematics and science. More importantly, student achievement gains in schools implementing one of the district-supported standards-based curricula for the second year in 2004–05 were greater than in other district schools (both those in their first year of implementation and those not implementing at all).

UIC Graduate Fellows in K–12 Education (DUE–9997537) and Scientists, Kids, and Teachers (SKIT): A GK–12 Partnership with the Chicago Public Schools (DGE–0338328).

These two successive GK–12 fellows programs represent a very important place wherein UIC STEM faculty were able to forge important relationships with the CPS through the specific activities of STEM graduate students working in middle and high school mathematics and science. The initial grant enabled us to take existing outreach programs and to add graduate fellow support to some of the schools that were involved. This included, for example, a partnership between UIC and Crane High School, part of the CPS Math Science Technology Academy (MSTA) program that paired specific high schools with different support systems within UIC. In this program graduate fellows brought their content knowledge to questions of teaching high school chemistry, environmental science, and physics, assisting teachers in new ways to engage students (Wink et al., 2004) that drew on the graduate student's expertise in studying ecosystem engineering. At the same time, a research program for the program allowed us to characterize systematically some of the ways in which STEM graduate students encounter the environment of the urban classroom (Christodoulou et al., 2009).

The second GK–12 project took a very different approach to the placement of graduate students. Here, the different placements were specifically targeted at schools that were participating in aspects of the Chicago Math + Science Initiative, which was at that point emerging from the work on CUSP and related programs. CMSI targets school-based change in different ways. For example, fellows worked in bringing the Beissinger/Pless cryptography program to the National Teachers Academy (NTA), a district professional development school. In other cases, support of specific high school science curricula identified for district support within CMSI was aided by Fellows in schools and STEM faculty participation in professional development sessions. Thematically, then, the program focused on helping the district and its schools make change in projects that the district was already implementing, making SKIT into more of a responsive, not an intrusive, influence on schools.

One of the best examples of a partnership that was furthered through the SKIT program was in the work of computer scientist Tom Moher and his graduate students. Moher is a learning sciences researcher with a focus on the development ''embedded phenomena'' in teaching. Within this approach, the classroom becomes the locus of a technology-enabled science experience, including studies of earthquakes, the solar system, and most recently an environment, *WallCology,* that simulates the process of learning about animal populations. In the SKIT program, his graduate students were able to carry out an iterative process of implementation and research in conjunction with two CMSI-associated schools, NTA and Dawes Elementary School. Besides general information on the ways in which embedded phenomenon can be implemented well (Malcolm et al., 2008), they also developed materials to support the specific learning outcomes of *WallCology* (Moher et al., 2008).

The second GK–12 project, by design, included a plan for sustainability associated with funding support from CPS or other external partners. Early in the program, funding for Fellows to work at NTA was obtained as part of the district support for UIC's partnership in that school. In this case, the specific benefit of Fellows for teachers implementing reformed CMSI-designated curricula was demonstrated. This became important shortly afterwards when the CPS brought forth its plans for the High School Transformation project. In their response to that project, Loyola University and UIC included a plan, funded by the district, for graduate assistant support of the reformed curricula in the first three years of high school science at eleven CPS schools. Thus, a key outcome of the SKIT grant has been the establishment of an ongoing, independent support and rationale for graduate students within university/district partnerships.

Robert Noyce Scholarship Program (DUE–335748) and UIC–CPS Noyce II Program (DUE–833089).

These two implementations of Noyce Scholarship programs are led by Carole Mitchener of UIC's College of Education. The first program targeted career changers who planned on teaching in middle school mathematics or science (MGS/MGM students) or high school mathematics. MGS/MGM offered career-changers a three-year induction and mentoring experience while they earned teacher certification and a Master's degree. During that time, they taught full-time for three years in a high-need school in Chicago. MGS/MGM adopted the idea that it was crucial that very early in their preparation, teachers experience the relevance of the practice-based approach to professional development discussed earlier, and to appreciate it as one that they could continue, and build from, throughout their teaching careers. MGS/MGM sought to achieve this largely by devoting much of the second year of the curriculum to supporting each beginning teacher in an extended action research inquiry into his/her own practice in his/her own classroom. Ninety-one individuals received stipends and all completed their degree and all but one completed the required teaching. What is perhaps more important is that, as of 2008, 73 of them had completed either three or four years of teaching, suggesting that the program is successful at both preparing and inducting teachers. This success reflects the lessons learned through the accompanying research effort that examined how teacher identity is built around ''a vision for a quality and inclusive science curriculum implicating science content, teaching methods, and relationships with their students'' (Proweller and Mitchener, 2004). Another important outcome of the program with implications for future work is that eight of the original program's scholars have now moved into CPS math and science leadership positions. This significantly strengthens the relationship between UIC and CPS.

The Phase II Noyce project continues work begun in the previous Noyce grant with secondary mathematics teacher candidates and expands its potential impact with the addition of an enhanced mentor program for new Noyce recipients. This new mentor program involves previous Noyce awardees and inducts new ones into a Noyce mentoring network. Second, the project extends the Noyce applicant pool by adding three new science certifications and introducing a one-year M.Ed. program option for secondary science, which is available for secondary science teacher candidates in biology, Earth and space science, environmental science, chemistry and physics. The project supports the recruitment and retention of career-changers with strong STEM backgrounds and STEM undergraduates who want to teach in high-need areas in CPS. These goals will be attained by awarding stipends based on academic merit, with attention to diversifying the teacher workforce and a commitment to serving high-need schools. Over a three-year period the UIC–CPS Noyce II project is offering 40 recruitment stipends to students in UIC STEM secondary teacher preparation programs who commit to teaching in Chicago Public Schools. New teachers have the opportunity to conduct action research during their induction phase as they work to construct a defensible and inclusive practice.

Both Noyce programs provide new teachers learning opportunities to engage in extended action research projects (teacher inquiry) toward improving their classroom practice (Mitchener & Jackson, 2006). New teachers benefit when given an opportunity to examine their practice in relation to student learning over an extended time period. New teachers target an area for improvement and with support from a professional learning community make needed changes. Using student learning data as a guide, beginning teachers work at reducing discrepancies between what they learned about good practice and what they implement in their classrooms. Action research projects are then shared with the larger school community.

The Chicago Transformation Teacher Institutes (NSF, DUE 0928669)

The Chicago Transformation Teacher Institutes (CTTI) is our new Math Science Partnership teacher institute program, funded earlier this month with support of funds allocated to NSF through the *American Recovery and Reinvestment Act.* In this case, the CTTI is an additional and essential part of existing system-wide reform efforts, not a new effort in itself. Thus, I will describe the context of the CTTI within the wider CPS High School Transformation project, since the two are intimately linked.

The CPS HSTP project was started in 2005–6 by the Chicago Board of Education with extensive support from the Board and the Bill and Melinda Gates Foundation with its largest ever single grant to a school district. One prominent strategy within the HSTP is a whole-school support program focused on the work of *Instructional Development Systems* (IDS). An IDS is a provider of comprehensive professional and materials development spanning grades 9–11 with a coherent program in mathematics, science, or English (e.g., Wink et al., 2008). Teachers and administrators in the IDS schools then receive:

- Rigorous curriculum options with innovative, nationally recognized and research-based materials.
- Supports for teachers using these curriculum options, including intensive coaching, professional development, networking, and in-school planning coordinated by a school lead in the subject.
- Direct leadership support for principals.
- Formative and summative assessment systems responsive to the specific curricula but also aligned carefully with the state-wide Prairie State Academic Examination (PSAE), a two-day exam in the 11th grade that comprises the ACT and subject-area tests including in science and mathematics.

The IDS program began with 14 schools implementing the ninth-grade curriculum in 2006–07; these schools are now implementing the tenth- and eleventh-grade curricula. Another 11 schools formed a second cohort that began in 2007–8 and a third cohort of 20 schools have joined in 2008–9. The science IDSs are all based at universities (IIT, Northwestern, Loyola/UIC) that are part of the CTTI. The CTTI mathematics participants (UIC and DePaul) are also involved in HSTP and other district high school teacher support programs.

All of the math and science IDS programs focus on a strategy to *implement,* not develop, reformed curricula. All six of the math and science IDS partners are using curricula developed in part with NSF support (*Cognitive Tutor, Agile Mind, CME* in math and curricula from BSCS, the American Chemical Society, It's About Time, and Northwestern University's environmental science curricula in science), or enhanced under the specific direction of inquiry-based teacher education programs (Glencoe biology and chemistry, in conjunction with IIT and the Field Museum). Thus, they respond to the district's own initiative to identify and support reform curricula.

The HSTP–IDS program has now established a full set of supports for grade 9–10–11 science and math. This includes a set of assessments to support teachers in formative assessment of students and also to be used in a summative manner at the end of the course. In all cases, the curricula and assessments are to point to increasing student success on the Illinois *Prairie State Achievement Exam,* given in April of the junior year. The first cohort of IDS-supported students have just taken the PSAE in Spring, 2009, and the outcomes for those students and for subsequent cohorts will be a key evaluation metric for the program overall.

From CUSP and HSTP to CTTI.

The significant impact of the CUSP program on the district, including its contribution to the formation of CMSI and the conceptualization of HSTP, means that the district and its university partners have much more experience in how to support school change. For example, a key component of the HSTP IDS is the adaptation and implementation of curricula identified by CPS. A similar approach will be used within CTTI.

It is important to note that CTTI is not a replacement for CUSP or HSTP. Rather, CTTI is an essential *new* initiative to carry through on the work of CUSP and HSTP by completing the district's strategy for high school science and mathematics (with 12th grade strategies) and enhancing the work of teachers in grades 9–10–11. This new program, though, is based on leaders who are *on the staff of the schools themselves,* giving schools the capacity to carry out their own course implementation strategies and in-school planning to address challenges and to identify new opportunities.

During the program CTTI will have 160 teachers in four cohorts each of 20 science and 20 math teachers. They will come from 20 different schools, chosen through an application process with specific commitments required from the school. CTTI teachers will implement effective school-based changes in 12th grade curricula even as they continue to participate in and impact the curricula in grades 9–10–11.

The CTTI teacher program will include two components in addition to networking programs:

a. **Course work** in three areas essential to strong high school instruction: mathematics, physical science, and life and environmental science. The courses provide for increased content knowledge by teachers, including how the content is found in the contemporary issues and current research. It also supports growth of deep knowledge required for strong cross-curricula work.

b. **Workshops on leadership and teaching** that provide increased skills in how to use content to understand classroom practices, including in instructional design, selection of classroom materials, pedagogy, and assessment of student knowledge. Leadership workshops, developed from the Urban Education Leadership program, enhance the ability of teacher-leaders to support stronger teams within schools' departments and are developed with a program that already works on a parallel effort with CPS school principals, allowing for close alignment of the development of teachers, teacher-leaders, and administrators (Monk, 2008).

This work is embedded in research and institutional change strategies that also drive the CTTI research. In particular, we have adopted a logic model (Newmann et al., 2000) wherein **deep content knowledge + pedagogical skills + leadership training** for teachers changes **school capacity** to implement and support innovative math and science curricula. In turn, this affects **teacher practice** and improves **student outcomes.** Taken together, the teacher program and logic model let us formulate a key research question for our work: *What are the effects of providing teacher content and content-specific pedagogical training and leadership development on the elements of school capacity, teacher practice, and student outcomes?*

It is also expected that the CTTI will impact the ways in which higher education institutions work with the CPS and, especially, with the students who come from CPS high schools. University faculty, prior to teaching CTTI courses, will themselves receive training on reformed pedagogy, to align CTTI courses and their other college teaching with the practices we know to best support student learning of science and mathematics. The longer term impact on the Universities will occur as part of the discussion of what it means to have students emerging from high schools that, until now, have few graduates directly prepared for University study. The CTTI faculty will be charged as change agents that acquire enhanced understanding of the potential (and obstacles) inherent in rigorous high school courses. This understanding will then become the basis of advisory materials they will generate for campus recruitment and retention programs. Thus, these faculty become the means by which CTTI high schools re-envision outcomes for their students to include Chicago four-year institutions and, conversely, become the means by which Chicago universities re-envision what they can do to provide more equitable access to CTTI high school students.

Finally, the CTTI program was conceived of as a research project from its start. Thus, the key research question of our work is articulated into multiple areas of inquiry. In association with the logic model presented earlier (Figure 2), these areas of inquiry will be:

1. **Teachers' experiences in program.** CTTI expects teachers to attend courses (Outcome 1), gain content knowledge and leadership skills (Outcome 2) and then apply what they learn through team work at their school (Outcome 4) that will improve instruction in grade 9–10–11 courses (Outcome 5) and will yield revised and/or new challenging grade 12 courses (Outcome 6).
2. **Student experience and performance.** Students taught by CTTI teachers are expected to achieve more at in grade 9–10–11 courses (Outcome 5) and enroll in and achieve in revised/new grade 12 courses (Outcome 6). Their preparation in CTTI taught courses should also support their college readiness shown through test scores and success in courses at CTTI universities (Outcome 7).
3. **Institutional change.** The CTTI university partners will share knowledge of math, science and leadership with schools through high quality courses (Outcome 1). The district and its schools will create the policies and practices to allow teachers to work together productively at school meetings (Outcome 3), to improve instruction (Outcome 5), and to change grade 12 courses (Outcome 6). The work of these teachers (Outcomes 4–6) in turn, changes and sustains their schools. Universities will learn from the CTTI project how to better serve entering CPS students (Outcome 7) and may attract some of the CTTI teachers into their regular graduate programs (Outcome 1).

2 (c) Are there common lessons learned or replicable elements across UIC's various science and math programs, including those funded by NSF?

Experiences with STEM education reform in Chicago over the past decade suggest several lessons. Some of these have been summarized before (Roderick et al., 2009; Wenzel et al., 2009). But key points include:

- Invest in **people and relationships.** Even when people change roles and positions, the knowledge and skills that are supported by programs and trusting relationships travel with them.
- Work with **existing products.** A key idea behind most of the reform efforts is that the development of new materials can take years and several iterations. Earlier work in STEM K–12 education has, especially at the high school, provided many materials that are sufficient for reform of STEM education. New materials are needed, but much quicker change can be accomplished by implementing those quality products that do exist.
- Work with **existing research.** In almost every case I have discussed, the reform effort drew on extensive prior research. This is absolutely essential in a complex system, where prior research can identify those conditions that can dramatically affect the outcomes. This can range from specific questions of learning—how do students understand what is on a computer screen?—to system-wide questions—what does distributed leadership mean to change in a school?
- Don't leave out the **principal.** The principal is a key figure in setting up a school with adequate time for instruction and for teachers' professional development and reflection.
- Incorporate as appropriate **K–12 data on student performance** throughout the outreach and research work of the university. Thanks to the outcomes of CUSP and the hard work of Bret Feranchak and others in CPS's Office of Research, Evaluation, and Accountability, data is now available on student outcomes in many different areas. Improving the use of this data in our programs is now the next step, with of course appropriate privacy and confidentiality safeguards.
- **University-based systems** must be developed for program coordination. The history of reform at many of the institutions relied necessarily on the efforts of small teams or even single individuals. However, this is not sustainable and partnerships now require coordination among different units within the university. Many of these are already established: the Center for Science and Math Education at Loyola; IIT's Institute for Math and Science Education; Northwestern's Office of Science, Technology, Engineering, and Math Education Partnerships; and UIC's Learning Sciences Research Institute. This should be the norm in the future.

2 (d) How do you or can you help to disseminate these findings to other cities and regions of the country?

In this case, there are three levels to my answer. The first is simple: to make use of existing scholarly channels, including peer-review journals and conferences. It is easy to believe this will occur, but only if it is the case that funding agencies, such as the NSF, insist on full use of the existing literature as the basis of education reform. But direct person-to-person communication is also necessary, especially to support collaboration. In Chicago, a very early success in the development of multi-institutional communication was done through an Illinois Board of Higher Education grant to establish a collaborative of institutions associated with teacher preparation and undergraduate STEM teaching. This gave rise to an annual series of conferences, entitled "Excellence in Teaching Undergraduate Science and Mathematics: National and Chicago Perspectives." These bring national plenary speakers and local STEM education reform participants together three times a year to discuss new ideas, report on progress of ongoing projects, and to maintain connections that drive many other STEM education reforms.

The second level of answer is something that the NSF has answered well in many ways. That is by having large systemic change programs such as the MSP's, the GK–12 Fellows programs, and the Noyce Teacher Scholarship programs *required* to share information through annual conferences and through NSF-associated web sites such as MSPNet. In this case, the sharing of ideas and outcomes at this level—not quite social networking, but close—permits rapid dissemination of preliminary findings to those who need the information most quickly. It is interesting to me that one of the features of MSPnet is that it is intrusive, with reminders of information and activities now provided to me weekly. Similar work occurs with GK–12 and I am pleased to learn that the same is occurring for Noyce.

The third level of possible dissemination is one that I have largely left out until now. It is through the actions of the states and their individual boards of education. These organizations are each independent, as befits our federal system. But their importance as partners in STEM education reform cannot be underestimated. Improved communication about efforts nationally and locally will, most logically, require that State boards both be told what is going on and that they listen and act accordingly. Federal mandates to do this in association with block grants may be timely.

3 (a) What is the most important role a university such as your own can play in improving K–12 STEM education in your own community and/ or nationally? How can universities help facilitate and build partnerships with other stakeholders, including the private sector and informal education providers?

I will take this question in two steps. First, we need to remember that whatever universities can do, it has to be in the context of a reform system. Second, I will note particular examples of how particular areas of strength for universities can be developed and used.

The most important thing universities can do is demonstrate that existing schools can move from low to high performance in math and science by assisting in organizing the adult learning in the school around what we know about effective STEM instruction. This requires partnership between universities and school systems that ordinary preparation programs do not require. Simply put, the principal and teacher leadership of academic departments must work together with universities to change instructional practices in each school, which requires collaboration around such fundamental issues as curriculum, instructional approaches, common formative assessments of students at collaboratively-set checkpoints, and so on. This kind of approach should be foregrounded in teacher preparation work so that new teachers are ready for it, but teacher preparation is itself a weak lever for improving school-wide performance since new teachers are novices who should be ready to work in a reformed environment but not expected to create it. If you put one of those novices into a school properly organized for STEM success, that teacher will thrive and get the job done. Thus, the same linkages that improve school practice also provide a place for new teachers to work effectively, greatly improving the likely outcomes of teacher preparation work.

As to what universities may do in specific ways, my opening review shows nine different areas of work in which universities can work in improving K–12 education. I hope I have provided part of an answer to this in the examples I cited in those areas. But there are other components of our work that are not captured well there, since they represent the effect of systems or units within the university. I will cite a few of those now, drawing on other institutions in the Chicago area that, I believe, exemplify how universities can systematically link their work to K–12 STEM education. Five specific ways in which this can be done are:

- The creation and use of a **university coordinating office** for STEM education.
- Close linkage of K–12 STEM education work to the **undergraduate mission** of an institution.
- Use of **laboratory-based research on education** in STEM education reform work.
- A consistent focus on addressing **emergent professional development opportunities** in a flexible and responsive way.
- Development and sustenance of **deep connections between university STEM and education programs** that bridge colleges within universities.

Northwestern University provides an example of a how a **university coordinating office** can facilitate the work of the university in K–12 STEM education, through its Office of Science, Technology, Engineering, and Math Education Partnerships (OSEP). OSEP uses its expertise in curriculum, technology, and program design math (STEM) research projects with NU researchers. These partnerships provide several benefits to the community that would not exist without this innovative form of collaboration for better programs, increased competitiveness, and especially leveraged resources through their ongoing connections of Northwestern faculty and researchers with a network of schools and informal educational institutions.

DePaul University shows how the **undergraduate mission of a university** can be incorporated as a foundation for K–12 STEM outreach, specifically by supporting strong community based relationships with schools to support, enable, and sustain K–12 innovation. The mathematics and science faculty there have a deep commitment to teacher education, reflecting DePaul's recognition that strong school-campus partnerships are vital to their success as a university. Hence, they have an NSF STEP grant that partners with community colleges to address transition issues, and they also provide their own incoming students with strong bridge programs to enable college success. At the same time, as we have seen, DePaul's activity as a leader of *The Algebra Initiative* and, now, in the CTTI, enables them to bring their own expertise in STEM and STEM education to support change in K–12 settings.

The Department for Math and Science Education of IIT points to the role of "big picture" thinking about science as a foundation for STEM education reform. The work of Norman Lederman and his colleagues in studying the ways in which the nature of science does, or does not, translate into classroom practice has fundamentally altered the discussion of what to teach in science, and also how to teach it. This is an excellent example of the role that **laboratory-based research on education** can translate into practice, including specific attention to the ways in which teachers shape and utilize their own concepts of the nature of science. IIT's program includes a doctoral level program that is just now graduating the first of a set of students trained in both educational research and the deep philosophical underpinnings of science, math, and education; this group is sure to have an impact on the future of K–12 STEM education in Chicago.

Loyola University Chicago, with the Center for Science and Math Education led by David Slavsky, is an example of how a university can become a key provider of **emergent professional development opportunities** in specific support of State and district policies and needs. For example, as the HSTP was beginning the possibility of teaching a "physics first" curriculum was set aside, at least for a while, because of the lack of trained physics teachers in the district schools. Loyola moved immediately to the task of creating a university course-based program that would fill this gap, using State teacher development funds. This built upon the many years of CSME work in support of the Chicago CMSI middle school program, enabling Loyola to be especially responsive to pressing needs. CSME also incorporates a full research unit within its programs, giving it specific strength in studying change in schools in a way that immediately affects practice.

Finally, I suggest that UIC provides specific examples of the gains that can be had when there are **deep connections between university STEM and education programs.** Within this testimony I have cited several examples of NSF grants that have come to UIC to enable our work in K–12 STEM education. What may not be apparent is that, with no exception, all of those grants have a PI, co-PI or senior personnel that is a STEM faculty member, like John Baldwin, Tom Moher, or myself, and someone from our College of Education, such as Maria Varelas, Carole Mitchener, or Steve Tozer. These are not just collaborations of convenience; rather, they reflect many years of work together, presenting a model for the fluid and productive interaction of different units on a research university campus. It is only natural, then, that a unit like the Learning Sciences Research Institute has been created to provide an interdisciplinary setting for further work by many of these researchers.

What is the single, most important step that the Federal Government should take to improve K–12 STEM education?

The most important single step is to ensure that funding mechanisms are aware of the strengths of different partners so that new projects draw on those strengths and, where necessary, address weakness. This should be targeted at what we know are the critical issues in schools: (a) demonstrating measurable increases in student learning by (b) improving classroom instruction through (c) improving each school's internal capacity (systems, procedures, and adult learning) through (d) improved teacher and administrative leadership in each school. This is the specific model of the CTTI (Figure 2), in reverse. It represents, we feel, the most cost-effective and scalable lever for change over a ten year period. Leadership issues are critical here, since virtually all principals nationwide will turn over in that ten-year period. Thus, developing leaders to carry forward reform in the short- and long-term is vital, and the Federal Government, especially through the MSP and Noyce programs, is already moving ahead on that task.

There are different ways federal support can impact the partners in this effort. For example, for universities, the Federal Government should support (ideally through NSF) university projects that develop teacher knowledge and K–12 school improvement using new knowledge developed by university researchers. This support draws upon what universities can do well on their own and emphasizes that within K–12 STEM education. This includes teacher education, preparation, and research both in classrooms and in laboratory settings. Ensuring that more of what occurs in K–12 education makes use of those areas of strength is essential, and clearly this is a central theme within the NSF Math Science Partnership program.

Districts and schools, in contrast, possess strengths of policy, instructional support, and teacher support. It is often difficult for them to use these strengths productively and consistently over the extended time required for systemic change. Thus, federal support for longer-term projects that implement rigorous, research-based changes in schools would be an important component of supporting change. Linking this to what is known to enable change—leadership, reflective teaching, use of reformed curricula—should also be expected.

The creativity and vision of informal science partners, including museums, industry, and after school programs, give them strength in the vital step of creating new environments to engage students, teachers, and families in the excitement of cutting-edge science. The role of informal science, including careful research on informal science settings, is much-neglected as a means of translating research into accessible forms.

Finally, as I have suggested at different points, the Federal Government needs to support work over extended time periods, something that is already done, for example, in the Long-Term Ecological Research centers. We should collect data over 10–20 years to provide broad, district level data on curriculum, and initiatives to give us the data we need to make strong claims.

Coda

I would like to close with two items that have not yet been discussed in this testimony but that I think are essential to our work and to the reform of STEM K–12 education.

The first point is to return to the central role of relationships over time to the reform of any program, especially within a large and complex system such as an urban K–12 district. In this, individuals matter, and I want to tip my hat in particular to the role of Dr. Marty Gartzman in many of the efforts I have discussed. He is trained in biology but also worked for many years as a project manager in the UIC Institute for Math and Science Education, the group formed around the TIMS effort that, later, became one of the foundations for the Learning Sciences program. In this he developed deep connections with K–12 schools and many dozens of teachers. He helped design our first systematic efforts to reform teacher education at UIC and to start our GK–12 program. Then, he was tapped to lead the CPS' effort in its Office of Math and Science, managing some of the most effective work in CMSI and beyond. More recently, he has returned to UIC in a special role to help coordinate our work in K–12 and, especially, in high schools, having now helped to start our campus' first charter school, which is drawing many of our health professional units into educational innovation for the first time. The point here is that our effectiveness in many areas depends on the skills and relationships of Dr.

Gartzman. Recognizing and valuing the role of such change agents, should not be overlooked.

The second point is that all of our work comes from a shared belief in STEM education as vital to the future of our nation and its people, especially the children who will be seeing our country through to its tercentennial and beyond. Technological, medical, and environmental challenges loom, and they will be addressed in this period by the STEM workforce we are training today. This is very much the philosophy behind the *America COMPETES Act,* which carries through on many important ideas already. But even as we agree on that I want to remind us that learning about science and mathematics is also important to the life of every person, especially in a democracy. I want to recall that, 100 years ago this Fall, John Dewey, who I proudly note was an active participant in the life of the Hull House settlement that is now part of UIC's campus, gave an address to the American Association for the Advancement of Science entitled "Science as Subject-matter and as Method." In it he outlined, somewhat tongue-in-cheek, the seeming gap between the rich, connected learning expected of students in the humanities and the dry, rote learning of the sciences. He argued, though, that the learning the *methods* of scientific inquiry is equally important to learning the content, and not just for the sake of science and technology. Thus, as he wrote for the conclusion for his address:

> If ever we are to be governed by intelligence, not by things and by words, science must have something to say about *what* we do, and not merely about *how* we may do it most easily and economically. . .. Actively to participate in the making of knowledge is the highest prerogative of man and the only warrant of his freedom. When our schools truly become laboratories of knowledge-making, not mills fitted out with information-hoppers, there will no longer be need to discuss the place of science in education.

Literature cited

Beissinger, J. & Pless, V. (2006) *The Cryptoclub: Using Mathematics to Make and Break Secret Codes.* Natick, Mass.: A K Peters, Ltd.

Brown, S., Pitvorec, K., Ditto, C., & Kelso, C. (2009). Reconceiving the intended curriculum: An investigation of elementary whole number lessons. *Journal for Research in Mathematics Education,* 40, pp. 363–393.

Castro-Superfine, A., Kelso, C., and Beal, S. (2009). Examining the process of developing a research-based mathematics curriculum and its policy implications. *Journal of Mathematical Behavior,* submitted.

Christodoulou, N., Varelas, M., & Wenzel, S. (2009). Experiences and Curricular Conceptions: Subject Matter Experts Work in Urban Secondary Science and Mathematics Classrooms. *Journal of Research on Science Teaching,* 46, 1–26.

Deiger, M., Fendt, C., Feranchak, B., Hurtig, J., Shefner, R., Slavsky, D. and S. Wenzel. (2009). Working draft on Math and Science Education Systemic Reform in Chicago, 2002–2008. A product of NSF grant to Loyola University Chicago *Scale up of Math and Science K–12 Education Reform in a Large Urban District.* Available at web site *http://www.luc.edu/cse/programs/SCALEUP.shtml*

Dweck, C.S. (2006). *Mindset: The new psychology of success.* New York: Random House.

Hill, H.C., Rowan, B. & Ball, D.L. (2005), Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement, *American Educational Research Journal* 42(2) 371–406.

Hwang, J.-H. (2008). Different approaches of teaching in chemistry/membrane targeting mechanism of human sphingosine kinase 1. Ph.D. Thesis, University of Illinois at Chicago.

Malcolm, P., Moher, T., Bhatt, D., Uphoff, B., & Lopez-Silva, B. (2008) Embodying Scientific Concepts in the Physical Space of the Classroom. *Proc. 7th International Conference on Interaction Design and Children* (IDC 2008), 234–241.

Mayrowetz, D. (2008) Making Sense of Distributed Leadership: Exploring the Multiple Usages of the Concept in the Field. *Educational Administration Quarterly,* 44, 424–435.

Mitchener, C.P. & Jackson, W.M. (Spring, 2006). Conducting Action Research: A University-School Collaboration in Support of Middle Grade Science. *Spectrum: The Journal of the Illinois Science Teachers Association,* 32(1), 48–55.

Moher, T., Uphoff, B., Bhatt, D., Lopez-Silva, B. & Malcolm, P. (2008) WallCology: Designing Interaction Affordances for Learner Engagement in Authentic

Science Inquiry. *Proc. ACM Conference on Human Factors in Computing Systems* (CHI 2008), 163–172.

Monk, D.H. (1994) Subject Area Preparation of Secondary Mathematics and Science Teachers and Student Achievement, *Economics of Education Review,* 13(2), 125–145.

Pappas, C.C., & Varelas, M, with Gill, S., Ortiz, I., & Keblawe-Shamah, N. (2009). Multimodal books in science-literacy units: Language and visual images for meaning making. *Language Arts,* 86(3), 201–211.

Plotnick, R., Fan, Q., Varelas, M. (2009). An Integrated Earth Science, Astronomy, and Physics Course for Elementary Education Majors. *J. Geoscience Educ.* 57(2) 152–158.

Proweller, A. & Mitchener, C. (2004). Building teacher identity with urban youth: Voices of beginning middle school science teachers in an alternative certification program. *Journal of Research in Science Teaching,* 41, 1044.

Radinsky, J. (2008). Students roles in group-work with visual data: A site of science learning. *Cognition & Instruction,* 26(2): 145–194.

Radinsky, J., Loh, B. & Lukasik, J. (2008). GIS tools for historical inquiry: Issues for classroom-centered design. *Journal of the Association of History and Computing,* XI(2): no page numbers, online journal.

Radinsky, J., Smolin, L.I., and K. Lawless (2005). Collaborative Curriculum Design as a Vehicle for Professional Development. In Vrasidas, C. and G. Glass (Eds.), *Preparing Teachers to Teach with Technology:* 369–380. Current Perspectives on Applied Information Technologies. Greenwich, CT: Information Age Publishing.

Roderick, M., Nagaoka, J., Allensworth, E., Coca, V., Correa, M., & Stoker (2006). *From High School to the Future: A First Look at Chicago Public School Graduates' College Enrollment, College Preparation, and Graduation from Four-Year Colleges.* Chicago: Chicago Consortium on School Research. Online at: *http://ccsr.uchicago.edu/publications/Postsecondary.pdf* with revision at: *http://ccsr.uchicago.edu/downloads/4732hs_report_addendum-13.pdf* (last accessed July, 2009).

Roderick, M., Easton, J.Q., & Sebring, P.B. (2009). *Consortium on Chicago School Research: A New Model for the Role of Research in Supporting Urban School Reform.* Chicago: Chicago Consortium on School Research. Online at: *http://ccsr.uchicago.edu/publications/CCSR%20Model%20Report-final.pdf* (last accessed July 2009).

Tucker-Raymond, E., Varelas, M., & Pappas, C.C. with Korzh, A. & Wentland, A. (2007). "They probably aren't named Rachel:" Young children's emergent multimodal narratives of scientist identities. *Cultural Studies in Science Education,* 1(3), 559–592.

Varelas, M, Plotnick, P., Wink, D., Fan, Q., and Harris, Y. (2008). Inquiry and Connections in Integrated Science Content Courses for Elementary Education Majors," *J. Coll. Sci. Teach.,* 37(5), 40–47.

Varelas, M., Pappas, C.C., Kane, J., & Arsenault, A. with Hankes, J., & Cowan, B.M. (2008). Urban primary-grade children think and talk science: Curricular and instructional practices that nurture participation and argumentation. *Science Education,* 92(1), 65–95.

Weaver, G.C., Russell, C.B., & Wink, D.J. (2008). Inquiry-based and research-based laboratory pedagogies in undergraduate science. *Nature Chemical Biology,* 4, 577–580.

Weaver, G.C., Wink, D., Varma-Nelson, P., Lytle, F., Morris, R., Fornes, W., Russell, C., Boone, W.J. (2006). Developing a New Model to Provide First and Second-Year Undergraduates with Chemistry Research Experience: Early Findings of the Center for Authentic Science Practice in Education (CASPiE), *Chemical Educator,* 11, 125–129.

Wenzel, S., Mayrowetz, D., Bartley, J., Tavormina, M.J., Shefner, R., Shuman, C., Feranchak, B. and C. Fendt. (April 16, 2009). Systemic urban math and science K–12 reform explored through a systemic collaborative research process. Symposium presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Wink, D.J. & Hwang, J.-H. (2008). Pennies and Eggs: Initiation into Inquiry Learning for Pre-service Elementary Education Teachers. *J. Chem. Educ.* 85(3), 396–8.

Wink, D.J., Daubenmire, P.L., Brennan, S.K., & Cunningham, S.A. (2008). "Bringing Standards-based Chemistry Instruction to an Urban School District. In

Chemistry and the National Science Education Standards, 2nd Ed., Stacey Lowery Bretz, Ed., Washington, DC: American Chemical Society.

Wink, D.J., Ellefson, J., Nishimura, M., Perry, D., Wenzel, S., Hwang, J.-H (2009). Fostering Pre-Service Teacher Identity through Student-Initiated Reflective Projects. *Feminist Teacher,* 19(1), 31–46.

Wink, D.J., Haqque, S., & Zavitz, D. (2004). Teacher-scientist partnership for innovation in high school environmental science. *Spectrum: The Journal of the Illinois Science Teachers Association*, 30(3), 11–14.

BIOGRAPHY FOR DONALD J. WINK

Education

University of Chicago—S.B., 1980, Chemistry
Harvard University—Ph.D., 1985, Inorganic Chemistry

Professional Experience

New York University: Chemistry
1985–1992—Assistant Professor

University of Illinois at Chicago: Chemistry
1992–2000—Associate Professor
2000–present—Professor
2000–2005—Acting Head and Head
2006–present—Director of Undergraduate Studies

University of Illinois at Chicago: Learning Sciences
2006–present—Program Faculty
2007–present—Director of Graduate Studies

Publications most directly related to current testimony:

1. "Synthesis and Characterization of Aldol Condensation Products from Unknown Aldehydes and Ketones: An Inquiry-Based Experiment in the Undergraduate Laboratory," by Nicholas G. Angelo, Laura K. Henchey, Adam J. Waxman, Donald Wink, James W. Canary, and Paramjit S. Arora, *J. Chem. Educ.,* 2007, 84, 1816–1819.
2. "Inquiry-based and research-based laboratory pedagogies in undergraduate science" by Gabriela C. Weaver, Cianán B. Russell & Donald J. Wink, *Nature Chemical Biology*, 2008, 4, 577–580.
3. "Evaluation of the Center for Authentic Science Practice in Education (CASPiE) model of undergraduate research," by Donald J. Wink* and Gabriela C. Weaver. Commissioned paper for National Academy of Sciences Board of Science Education, 2008: *http://www7.nationalacademies.org/bose/Wink_Weaver_CommissionedPaper.pdf*
4. "Bringing Standards-based Chemistry Instruction to an Urban School District," by Donald J. Wink, Patrick L. Daubenmire, Sarah K. Brennan, and Stephanie A. Cunningham, *Chemistry and the National Science Education Standards,* 2nd Ed., 2008, American Chemical Society: Washington, DC. *http://portal.acs.org/portal/fileFetch/C/WPCP_010699/pdf/WPCP_010699.pdf*
5. "Fostering Pre-Service Teacher Identity through Student-Initiated Reflective Projects," by Donald J. Wink, Julie Ellefson, Marlynne Nishimura, Dana Perry, Stacy Wenzel, and Jeong-hye Hwang Choe, *Feminist Teacher,* 2009, 19, 31–46.

Publications in other areas:

6. "Developing a New Model to Provide First and Second-Year Undergraduates with Chemistry Research Experience: Early Findings of the Center for Authentic Science Practice in Education (CASPiE)," by Gabriela C. Weaver, Donald Wink, Pratibha Varma-Nelson, Fred Lytle, Robert Morris, William Fornes, Cianán Russell, and William J. Boone, *Chemical Educator,* 2006, 11, 125–129.
7. "Connections between Pedagogical and Epistemological Constructivism: Questions for Teaching and Research in Chemistry," by Donald J. Wink, *Foundations of Chemistry,* 2006, 8, 111–151.

8. "Pennies and Eggs: Initiation into Inquiry Learning for Pre-service Elementary Education Teachers," by Donald J. Wink and Jeong Hye Hwang, *J. Chem. Educ.*, 2008, 85, 396–398.
9. "Inquiry and Connections in Integrated Science Content Courses for Elementary Education Majors," by Maria Varelas, Roy Plotnick, Donald Wink, Qian Fan, and Yvonne Harris, *J. Coll. Sci. Teach.*, 2008, 37(5), 40–47.
10. "Structure and Reactivity of Alkynyl Ruthenium Alkylidenes" by S.Y. Yun, M. Kim, D. Lee, and D.J. Wink, *J. Amer. Chem. Soc.*, 2009, 130, 24–25.

Current Support

1. "Chicago Transformation Teacher Institutes," PI on this *ca.* $5,000,000 grant to five Chicago-area institutions of higher education in partnership with the CPS. July 1, 2009–June 30, 2014.
2. "Science Approach A: Inquiry to Build Content," Chicago Board of Education High School Transformation Project, January 1, 2006–June 30, 2010. I am a co-PI on this *ca.* $3,000,000 grant to provide comprehensive curriculum and professional development to Chicago Public Schools. Loyola University Chicago is the lead institution (David Slavsky, PI). The UIC subcontract will be approximately $900,000.
3. "The Center for Authentic Science Practice in Education," National Science Foundation, Chemistry Division, August 16, 2005–August 31, 2009. I am a co-PI on this $2,400,000 grant. Purdue University is the lead institution. The UIC subcontract is for $300,000 over five years.
4. "Scientists, Kids, and Teachers (SKIT): A GK–12 Partnership with the Chicago Public Schools," National Science Foundation, Division of Graduate Education, January 1, 2004–December 31, 2008, $1,979,787. I am the PI.
5. "Research on Student Understanding of Solution Phenomena in College Chemistry," National Science Foundation, Division of Undergraduate Education, September 1, 2008–August 31, 2010. I am the PI.

Synergistic Activities

- Co-Director, UIC ASCEND program, and NSF STEP grant to support students at the University of Illinois at Chicago in STEM majors. Includes networking on campus with major student support groups and programs to support students in early participation in research (Lon Kaufman, PI).
- Secretary and Councilor, Division of Chemical Education, American Chemical Society. Member of executive committee for 5000 member Division and also *ex officio* member and Secretary of the Board of Publication for the *Journal of Chemical Education*.
- Editorial Advisory Board, Education Division, American Chemical Society *Chemistry in the Community: 6th Edition*.

Former Advisors: Undergraduate: Prof. William Evans, University of California at Irvine; Graduate: Prof. N. John Cooper, University of Pittsburgh

Collaborators outside of UIC (2004–2009): Miami University: Stacey Lowery Bretz; William Rainey Harper College: Julie Ellefson Kuehn; Kennedy-King College, Sharonda Benson; Harold Washington College: Dana Perry, Mike Davis; College of DuPage: Susan Shih, Mary Newberg, Carolyn Dockus; Moraine Valley Community College: Ewa Fredette; Truman College: Yvonne Harris; Olive-Harvey College: David Zoller; New York University: Paramjit Arora, James Canary; Northeastern Illinois University: Veronica Curtis-Palmer, Ana Fraiman; IUPUI: Pratibha Varma-Nelson; Purdue University: Gabriela Weaver, Fred Lytle; Georgia State University: Jerry Smith; Chicago Public Schools: Michael Lach, John Loehr; University of West Georgia, Sharmistha Basu-Dutt, Gail Marshall; American Chemical Society, Angela Powers, Cynthia Mickevicus, Terri Taylor. Michigan State University: Diane Ebert-May.

Chairman LIPINSKI. Thank you, Dr. Wink.

Now we recognize Katherine Pickus.

STATEMENT OF MS. KATHERINE F. PICKUS, DIVISIONAL VICE PRESIDENT, GLOBAL CITIZENSHIP AND POLICY, ABBOTT; VICE PRESIDENT, ABBOTT FUND

Ms. PICKUS. Good morning, Chairman Lipinski, Ranking Member Ehlers and esteemed Members of the Committee. My name is Kathy Pickus and I am the Division Vice President of Global Citizenship and Policy at Abbott and I am also the Vice President of the Abbott Fund. As someone who works every day examining how Abbott and the Abbott Fund can make a difference in our communities, I so appreciate the opportunity to be here today to explore with the Subcommittee how to meet our country's increasing needs in science education.

Science and innovation, especially as they relate to human health, are key to addressing some of our greatest challenges. At the same time that our workforce needs science, engineering and technology skills, fewer U.S. students are choosing these studies, let alone professions. As a health care company, Abbott is dependent on an increasingly sophisticated workforce with strong skills in science, technology, engineering and math. We need to develop and encourage the next generation of innovators. Currently, Abbott employs approximately 7,000 scientists worldwide. 78 percent of these scientists are based here in the United States. The ability to fill these well-paying jobs with people from our communities would be highly beneficial.

As we all know, we are facing many challenges to achieve this goal including encouraging an interest in science given the parental levels. You know, I was struck recently when I was having a conversation with a student at Foreman High School. She said she loved science and wanted to be a pediatrician but she would never share that dream with her friends, not even her parents because she said, "No one will support me." We need to create a culture for students like the one I spoke of in which their interest in science is encouraged and validated. That means opportunities beyond the classroom, real-world experience, parents acting as advocates for their children's scientific aspirations and the scientific community actively engaged with their counterparts in education.

At Abbott, we took a look at what we could do to advance science education and determined that we wanted to develop educational programs that would be built around strong partnerships with existing educational organizations with proven records of success like After School Matters. They need to be strategic, systemic and sustainable and they need to be driven by scientific evidence, results and measurable outcomes but we also need them to serve as a catalyst calling others to action.

Our approach to this endeavor goes far beyond financial support. We provide expert consultants experienced in science and education program design, implementation and evaluation, and we believe that one of the most valuable contributions that we are making is providing access to our research and development facilities and our scientists who engage one-on-one with students.

The research we did indicated that programs that start early and that continue to touch students at various points in their K–12 education and involve parents have the greatest impact, so at Abbott we started reaching elementary students and their parents through Abbott Family Science. We also conduct this program in Spanish. And then from there we continue with Abbott Operation Discovery for middle school students and then to the high school students in Chicago. We have worked closely with After School Matters to create opportunities, again typically not available for public school students. Each of these programs brings students, teachers and scientists together for hands-on, exciting experiences. Building programs with strong community partnerships ensures a lasting impact over time. In Chicago, we are very proud of our partnership with one of the Nation's leading after-school initiatives, After School Matters. By investing in an exciting, highly successful program, Abbott has been able to develop a replicable model that provides innovative science education for Chicago-area youth. Again, we also want these investments to serve as a catalyst. Our programs are designed to increase the capacity of leading informal science educational institutions including museums. They will engage students, parents and our own employees and will also encourage other private sector corporations and companies to pitch in and join us as well.

Abbott science education initiatives, grounded in strategic alliances and best practices, are reaping measurable rewards. Maintenance of the lab that we have renovated at Foreman, we didn't do it alone. I want to offer our thanks to the Chicago Public Schools who heard we were renovating a lab and students were doing experiments in molecular biology with paper and pencil, they joined us to expand the project.

Abbott scientists and engineers are participating like never before. I recently met a Harvard-trained scientist who pointed out that this type of community involvement was crucial to his job satisfaction at Abbott. He said that scientists and engineers crave opportunities that allow them to apply their skills and knowledge in a way where they truly make a difference. I also met recently a young African-American woman, a Ph.D., working as a senior clinical research scientist, who told me that she can't wait for the next chance to get in front of young girls at under-served elementary schools to tell them that you can do it too. And we have seen other evidence that shows that these programs are having a positive impact on student attitudes toward science and science careers.

Chairman Lipinski, I agree with you. No single stakeholder can solve this crisis alone and only through all of us working together can we effectively address this challenge. As you develop policy and support of K–12 science education, we offer our experience as a benchmark but most importantly, we offer our ongoing commitment and support as you work to advance this important cause. Thank you very much.

[The prepared statement of Ms. Pickus follows:]

PREPARED STATEMENT OF KATHERINE F. PICKUS

Introduction

In this country, science and innovation, especially as they relate to human health, will be key to addressing some of our greatest challenges. Multiple trends and cumulative forces have contributed to a looming crisis in science and science education, impacting our ability to compete as an innovative global leader. At the same time, our workforce needs in science, engineering and technology are increasing at a time when fewer U.S. citizens are training for these professions.

Over the past 50 years, U.S. innovation has led global developments in science and technology, simultaneously improving our quality of life and fueling our economy. However, declining investments in science education, declining enrollments in science courses and professional training programs, and a declining level of encouragement from parents for their children to learn science and consider science and technology careers are putting us at increasingly greater risk.

In order to increase the perceived value of science learning in society, increase the level of scientific and technological literacy across that society, and increase the number of young people selecting science and technology career paths, we need to create more opportunities to actively engage the scientific community in education. Without immediate action, we risk losing our ability to find solutions to the challenging global problems that all humanity face in the areas of health, energy, security and the environment.

As a global, broad-based health care company, with scientific expertise and products that span the human life cycle and the continuum of care, Abbott is dependent on an increasingly sophisticated workforce with strong science, technology, engineering, math (STEM), and 21st century skills. Fifty-three percent of our U.S. workforce has a STEM background and are recruited from around the globe. While Abbott values their globally diverse workforce, it would be much to our advantage if we could recruit a higher percentage of these STEM skilled employees from our own research and development communities.

To this end, Abbott has taken the same scientific precision with which we execute our day-to-day research and operations and applied it to our approach to philanthropy and employee engagement in science education. We have taken a strategic approach to science education that capitalizes on Abbott's strengths in science and the strengths of a few strategic partners well-versed in science education. Our investments in science education can be characterized as:

1. **Strategic, Systemic, Sustainable—**working with students and their families throughout the K–12 spectrum
2. **Built Around Strong Partnerships—**working with existing successful organizations and education delivery models
3. **Serving as a Catalyst—**stimulating additional community investment and engagement.

Strategic, Systemic, Sustainable

Our focus on STEM education represents an investment along the full K–12 spectrum. This investment is part of Abbott's global science education platform serving students of all ages, with authentic, engaging and developmentally appropriate science learning experiences.

As a research-based company, we rely heavily on scientific evidence and measurable outcomes. Research shows that early investment in a child's education reaps tremendous rewards educationally, economically and socially. According to the National Science Teachers Association, research also indicates that when parents play an active role, children achieve greater success as students, regardless of socioeconomic status, ethnic/racial background, or the parents' own level of education (*NSTA Position Statement on Parent Involvement in Science Learning,* 2008). Couple these factors with programs that are systemic and sustainable and a model for success is created.

For this reason, Abbott has chosen to invest in programs that are strategic, systemic and sustainable. The programs start with young students and continue to provide opportunities through the K–12 educational spectrum.

To reach young children, and encourage greater participation from parents, Abbott has formed a partnership with the non-profit Family Science organization. Together we developed Abbott Family Science, a unique informal educational offering serving elementary school age children and their parents. Abbott Family Science events actively engage families typically under-served in the areas of science education. These programs bring kids, parents, teachers and scientists together for an exciting, hands-on experience focused on fundamental science and 21st century skills (observation, problem-solving, teamwork) and building confidence as life-long science learners. The program is designed to be replicable year after year, forming a strong, sustainable partnership between Abbott scientists and schools in their local community. To date, programs have been launched throughout the U.S. and internationally in Abbott research and development communities.

Abbott has also developed experiences that match the needs of older middle school students. At that age, interest in science often declines, especially in girls. Providing a rich, authentic, real world science experience is a way to introduce those students to the exciting world of scientific exploration and discovery. Abbott's Operation Discovery program is a guided experience at an Abbott facility in which Abbott scientists serve as mentors and role models to the students and facilitate hands-on experiments in small groups introducing the students to some of the very same tools and procedures that Abbott employees use everyday in their work.

At the high school level, Abbott is committed to enrichment experiences that complement in-school learning, thereby optimizing their investment with a systemic approach. By reaching students through after school science programs, both during the school year and the summer, Abbott meets a real need in the community and helps build bridges between formal and informal education. Working with the nationally acclaimed After School Matters (ASM) program, Abbott is actively engaged in increasing the opportunities in science for under-served students in the Chicago area.

In addition to their investment in After School Matters, Abbott supports other Chicago area K–12 enrichment experiences including FIRST Robotics and Project Exploration.

Built Around Strong Partnerships

Developing strong community partnerships ensures that programs evolve based on the interests and needs of the audiences being served, and that they are sustainable and have a lasting impact over time. At Abbott, we believe we can make valuable contributions to science education by providing scientific expertise and access to authentic STEM experiences. We also recognize that to have the strongest impact and make the most efficient use of our own resources, a more strategic approach to providing science education experiences is to partner with educational organizations. Informal science education organizations increasingly are being recognized for their crucial role in providing innovative STEM education (*Learning Science in Informal Environments: People, Places and Pursuits,* National Research Council, 2009).

In recent years, Abbott has increased their focus on partnering with established non-profits and informal STEM providers. In the case of Abbott Family Science, we developed our program in partnership with the Foundation for Family Science, an established non-profit with proven multilingual curriculum materials and program delivery models. We have adapted the program to include Abbott employees, scientists and engineers and are now delivering the program globally. The programs are designed to be sustainable and will continue to grow. To date, programs have been launched in the U.S. in Illinois, California, Ohio, Puerto Rico, as well as internationally in Ireland and Singapore.

In Chicago, we are very proud of our partnership with one of the Nation's leading after school initiatives, After School Matters (ASM), to design and launch a science-based after school program for Chicago area teens. Prior to 2007, ASM did not offer science enrichment to the nearly 22,000 teens it serves annually. By investing in an existing, successful informal education delivery model, Abbott has been working with ASM to retool that model to provide innovative science learning opportunities. After school and summer programs provide an opportunity to reach diverse and under-served students, thus potentially increasing both the size and diversity of our future science and engineering workforce.

The result is "science37", a new category of after school programming for Chicago-area youth, named after the original gallery37 arts program initiated by Chicago's First Lady, Maggie Daley. Abbott's investment is intended to serve as a catalyst to both increase the capacity of ASM and encourage further community engagement and investment in after school science programming.

The science37 program provides teens with hands-on opportunities that expose them to rewarding career opportunities and help them develop marketable job skills that have immediate value in the workplace. This innovative program also offers paid internships to high school students in some of Chicago's most under-served schools.

Abbott's support of this partnership goes far beyond direct program support. As part of Abbott's commitment to after school science, the company provides ASM with expert consultants experienced in innovative science and education program design, implementation and evaluation. To date, Abbott has contributed over $1.5 million to after school science programs in Chicago, which includes not only direct program support, but also program research, development, evaluation and scientific expertise.

Abbott scientists were directly involved in the design of the partnership and continue to play a major role in the implementation of two of science37's flagship courses in the Bio Sciences. Key components include hands-on laboratory experiments, interaction with guest scientists, visits to Abbott research and development sites, and a culminating project using important 21st Century skills in research, critical-thinking and communication.

Abbott continues to partner with ASM to design, expand and evaluate these innovative science enrichment experiences, and to provide strategic advice and educational expertise for further Science37 program development and implementation.

Understanding the impact of programs is key, and Abbott has implemented a formal evaluation process to measure the impact of the new science37 program. Early indications are that this program is having a positive impact on student attitudes toward science and science careers.

In the first full year of the program, students reported significant changes in their attitudes toward science and science careers:

- *Before taking a science37 course, only 33 percent of the students were interested in "pursuing a career in science." In post-course surveys, this number increased to 78 percent.*
- Students' sense of whether "It will be important for me to know about science for my daily life" increased from 47 percent to 89 percent.

Participants in the most recent session of science37 courses reported significantly increased interest in taking additional biology and chemistry courses in school.

While many after school programs have a strong interest in offering science programming, these programs require significant support in order to effectively implement high-quality science learning opportunities (*Coalition for Science After School Market Research Study,* December 2008). Private-public partnerships are critical for leveraging existing effective delivery models, and for providing expertise and innovative science content based on authentic science experiences, interaction with working scientists and exposure to STEM careers.

Serving as a Catalyst

In each of its programs, Abbott's investment is meant to serve as a catalyst. Our investments are designed to increase the capacity of leading informal science education institutions to deliver top-quality K–12 STEM programming; increase the engagement of people, including students, parents, teachers and our own employees in science education; support improvements in STEM education locally and globally; and increase the investment of other private sector corporations in this important effort.

Abbott's investments are generating meaningful progress on a number of fronts. Abbott's investment in ASM has resulted in increased interest and investment from the Chicago area informal science education community, formal education institutions and the corporate sector. ASM's science37 program workshop classes have increased in numbers from two to 24 in just three years. Informal science education institutions across the Chicago area have expressed strong interest in working with ASM to provide additional STEM programming and to incorporate authentic science experiences and practicing scientists into their programming.

Serving as a catalyst can sometimes result in unexpected and refreshingly positive outcomes. In developing an after school science program for Foreman High School in Chicago, we discovered that students were forced to do their lab experiments with just paper and pencil—the teacher was teaching molecular biology with no working laboratory sinks, electricity or gas. Abbott renovated the lab, providing an important resource for both after school students and science students in classes throughout the day. That investment resulted in an additional investment from Chicago Public Schools, making a full lab renovation possible. This summer the full lab renovation is underway, with a new, contemporary laboratory classroom space to be available to all Foreman students this fall.

As a second example of the catalytic effect, we are now working with Dr. Don Wink, who you will hear from shortly, at the University of Illinois Chicago to create additional authentic research experiences for the high school students enrolled in science37. UIC undergraduate and graduate students will be involved in the program, providing strong role models for the high school students.

In all of Abbott's K–12 science education programs, the company's investment has been a catalyst for increasing the involvement of Abbott volunteers in their community. The introduction of Abbott Family Science in communities has resulted in continuing close relationships between Abbott employees and local elementary schools. Existing volunteer programs at Abbott research and development sites have been reinvigorated by the introduction of Abbott Family Science and Abbott Operation Discovery programs in their communities.

This connection to the community for Abbott employees, scientists and engineers is not insignificant. Scientists crave opportunities that allow them to apply their skills and knowledge in a way that can truly make a difference.

Conclusion

In summary, we have learned a great deal from working with experienced science education professionals to provide science education opportunities to the community. Letting research guide our strategic decisions, investing the full K–12 spectrum, evaluating our impact and seeking continual improvement are all hallmarks of our ongoing platform in science education.

All of these factors have allowed us to be strategic, both internally and externally, in providing programs that are designed to have the greatest possible impact for program participants, our employees, and science education globally.

No single stakeholder can create the improvements we need to address our nation's crisis in STEM education. By serving as a catalyst, we have stimulated new program development and expanded existing programs beyond their initial impact.

As we challenge ourselves as a company every day, we challenge others to invest in those ideas, individuals and organizations that show the greatest promise. Taking a systems approach to improving K–12 STEM education requires that all facets of the system work together and contribute in significant ways. Abbott's science education initiatives are grounded in strategic alliances and best practices that are now reaping measurable rewards. In this spirit, we hope to inspire the next generation of scientists who will deliver the breakthrough, lifesaving medicines needed throughout the world today. We hope our testimony assists the Science Committee as you develop policy and program models in support of K–12 science education. Thank you for the opportunity to share the Abbott Fund's experiences with you today.

BIOGRAPHY FOR KATHERINE F. PICKUS

Kathy Pickus serves as Vice President of the Abbott Fund, the company's philanthropic foundation, managing and developing programs with not-for-profit organizations that address global needs in the area of access to health care and science and medical innovation. She also manages Abbott's disaster relief efforts and product donation program. In addition, Kathy serves as the Divisional Vice President of Global Citizenship and Policy for Abbott, overseeing the strategic direction of the company's global citizenship initiatives and reporting.

Prior to joining Abbott in 2004, Ms. Pickus served as the Director of Corporate Communications for Fruit of the Loom, Inc. Kathy joined Fruit of the Loom, Inc., after serving as the Special Assistant for National Security Affairs to the Vice President of the United States. Her primary responsibility was to advise the Vice President on all activities pertaining to U.S. foreign policy interests in sub-Saharan Africa.

Ms. Pickus began her career at the United States Information Agency, which at the time was a branch of the U.S. Department of State, where she worked with private sector organizations to develop and implement democratic institution building programs worldwide. In 1993, Kathy was selected by the United Nations to serve as an election monitor for the first-ever democratic elections held in the Republic of South Africa. She currently serves on the U.S. Afghan Women's Council, which is a cross-sectional working group dedicated to advancing the status of women in Afghanistan currently based at Georgetown University.

DISCUSSION

Chairman LIPINSKI. Thank you, Ms. Pickus.

I want to thank all our witnesses for their testimony, and now we will move on to the questions. I want to say, I am very pleased to see especially at this time, our last week, almost our last day before we are going to August recess to see so many Members who are here and I think it really shows the interest not only in STEM but it shows that Chicago just brings everybody out.

I am going to, as I usually do, use my prerogative as Chair; the Chair will ask the questions first but I want to pass it along. I will leave myself to the end so right now I recognize Ms. Fudge for five minutes.

Ms. FUDGE. Thank you, Mr. Chairman. I thank all of you for being here today. I have a couple of questions actually. I am going to begin with a question for Dr. Ward.

Dr. Ward, in his testimony, Dr. Wink emphasized that there is a need to bring school principles into any STEM efforts so that they can develop an appreciation for the importance of STEM learning in their schools and to provide their teachers with some support to implement reforms. Can you tell me what or if NSF is doing anything or addressing the need to bring principals and other administrators into your K–12 educational programs?

Dr. WARD. Thank you for your question, Congresswoman Fudge. I would say that we have a long history in fact in the engagement of principals in particular but also other administrators, as Dr. Wink described so well in his testimony. Even dating back to our formal systemic reform efforts, we recognized that it was critical for the progress, for the success and sustainability of education to engage fully administration, particularly principals, in the shared vision of what was going on, the shared implementation and the shared accountability of the reform undertaken. We found that this was successfully demonstrated in a number of what we called at that time process and outcome driver approach in our early systemic efforts and we encouraged administrative support for both process and outcome to look especially at coordination of sets of policies and resources for excellence in STEM education with facilitation and support of and commitment from a broad group of stakeholders which you are hearing fully from the experts here today that would include parents, industry and formal science institutions in collaboration with the administrators in the various systems. The role that the principals and other administrators play in helping demonstrating the criticality of high expectations for both the teachers and the students to enjoy and to demonstrate proficiency in STEM content and also the criticality of the support or acknowledging the support and importance of data to actually inform the decisions that the administrators would have to make and to track progress towards success. So yes, we have a history there and we agree with you, it is quite critical to have that component.

Ms. FUDGE. Thank you so much; and this is to any member of the panel. The test-score gap between minority and majority students is considered one of the most frustrating problems in public education. Experts say that such gaps result from various entrenched factors, often due to socioeconomic factors that can hinder them inside and outside the classroom. What is being done now to remove the achievement gap in STEM fields and how could we do a better job to eliminate some of these disparities?

Mr. LACH. That is a great question. It is an issue that I know is near and dear to the hearts of just about everyone who works for the Chicago Public Schools. In my experience, we have found that there are no silver bullets to closing the achievement gap. There is not a certain test or certain curriculum or certain kind of teacher that enables that. In fact, there are—it is a multitude of supports all working together that we can show will enable students to learn at high levels. In Chicago and around the country, there are existent proofs that show poor minority kids can and will learn at high levels when all those supports are put in place. Our challenge is to figure out how do we bring those existent proofs to scale, and so our work on creating systems to enable external partners to help us with the delivery of curriculum, our work to create the right kind of accountability tools and metrics to help schools know the right way to go and then connecting the social service and the families and communities in the school by extending the school day by more and more after-school and Saturday programs all seem to work but we know we have to have all of those levers be pulled in concert.

Ms. FUDGE. Thank you, Mr. Chairman. I know my time has expired, but I would certainly hope if there are other members of the panel who would wish to respond that they might do so to my office or in writing at some point. Thank you very much.

Chairman LIPINSKI. Thank you, Ms. Fudge. The Chair now recognizes Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman, and let me just quickly follow up, Mr. Lach, on your last response. What is your dropout rate in Chicago high schools, the overall dropout rate?

Mr. LACH. There are several different ways to measure it but it is around 50 percent, 55 percent.

Mr. EHLERS. 50 percent? Okay. That is not too bad compared to what we face in Detroit.

First of all, I just want to commend Ms. Pickus on what you are doing about getting scientists and engineers in the schools. Every time I speak to a group of scientists and engineers, I encourage them to go to their nearest school or their children's school and offer to speak and perhaps offer to take the students on a field trip to their labs, or if they are engineers, take them out in the field and show them how bridges are built. A lot of them are excited about that. The unfortunate feedback I get at times is that the schools don't want to do it, and that is where I think you play a key role at persuading the schools and doing a lot of the legwork. They don't want to do field trips. There is too much time, too much trouble. There is liability and there is expense and you cannot allow someone in the school without knowing long ahead of time what they are going to say. A lot of them are afraid of that. So thank you and to Abbott for what you are doing because I can assure you, based on my conversations, it is desperately needed to have someone there to make the arrangements and break the ice.

Also, Ms. Daley, a comment about your statement that most scientists are led to science by an early experience. That is also my situation. I don't know whether I would have become a scientist without that. But my sister, when she was in high school and was taking high school chemistry, *Popular Science* magazine gave free magazines to every student in high school physics or chemistry. She took them home. I read them. I remember doing home experiments and I was just astounded that a little boy in a town of 800 people who had never met a scientist and never expected to meet any could sit there and make carbon dioxide and channel it down to a candle flame and make it go out. I didn't realize it was contributing to global climate change by doing that. But nevertheless, it was an "aha" moment for me, and I think it is very important to generate and encourage those "aha" moments.

Dr. Wink, a quick question. For your MSP program, how are the teachers selected and where does your support come from outside of NSF?

Dr. WINK. So as to the selection process, and this goes back to the question of principals, we are actually going to be working with schools, and one of things we will be doing this fall is working in developing some examples but then also in dialogue with the schools to produce an application process where it is teams of teachers but also the school administration comes into the program. So we are not looking to work with individual teachers. We will expect that the teachers that are in the team will have a shared commitment but they will also have initial training appropriate for being a science teacher in the high schools and then we will be looking at what their particular needs are in terms of which of the cohorts that we bring them into. So we really need teachers who are ready to engage and have initial proper training because they are going to be in graduate courses that will go considerably farther but it is not going to be as individuals. It will be teams that show that the leadership components of the program actually will have some traction within the schools.

Mr. EHLERS. Very good. I have been in institutes before in my prior life and that is a key factor, getting the right people involved, and it sounds like you have a very good approach.

Back to you, Mr. Lach. you've emphasized several times the rich resources you have available in Chicago and the use you make of them. How would you advise or what would you advise schools in smaller school districts further from urban centers? Is there any way you would see that they would be able to substitute for experience that you are making such good use of?

Mr. LACH. A couple comments on that. I think there is a lot of local resources in every community. It doesn't have to be something like the Adler Planetarium or the University of Illinois at Chicago. I am sure there is an awful lot of science that happens in local businesses and the agricultural industries and what not in rural areas that could be leveraged in those sorts of ways. That said, I think there is also the issue of driving capacity in rural areas is a really difficult problem to solve because we depend on our partners in Chicago a great deal. I think something I would encourage local administrators to consider is ways to leverage some of the national work around curriculum design, around teacher training institutes, around online learning that might be available to their locations. For instance, there are tremendous computer-based programs. We use some of them to do our high school mathematics, which don't have to be invented locally but can be purchased. Most of them were developed with NSF resources at that point and that can be used to really drive that kind of work.

Mr. EHLERS. I see my time is expired, so I thank each and every one of you.

Chairman LIPINSKI. Thank you, Dr. Ehlers, and I will recognize Mr. Carnahan.

Mr. CARNAHAN. Thank you, Mr. Chairman, and I thank the panel for being here on this subject. It is one of great interest to me, and I guess I want to start by asking a question that has really been prominent in my hometown in St. Louis. Like a lot of urban school systems, we have had problems, and at the same time, you know, we have had a State board come take over from our elected school board as they try to grapple with changes in the system. There has been a big disconnect, a disconnect between what our really world-class institutions and resources around the area from universities, corporations, institutions like the St. Louis Science Center, the Missouri Botanical Gardens, the Danforth Science Center. The list goes on. So we have this amazing infrastructure of institutions but there is this disconnect with the public school system and those resources in those towns and being able to be involved and support the public schools and especially STEM education programs, and they have some stake in seeing the best and brightest kids get into those fields so they can be a part of those institutions, and I guess I am very—this is a fundamental question for our community but I think for a lot around the country, but I guess I am asking, how do you bridge that gap? Are there Chicago or other cities that have done this well, and we really are interested to learn from them in terms how best to make those connections and support the schools generally but also with regard to STEM education.

Mr. LACH. I can offer some examples of what we have learned in Chicago. We have made plenty of mistakes on the way to do that but I can tell you what we have learned. First, we found it was really important to have very clear requests from all of our partners. We are the Chicago public schools. We need as much help as we can get. I am not really in a position to tell anybody their help isn't welcome. That said, if I can go to a university and say you know, I need more help in middle school science than I do K–5 math because U of C is covering K–5 math, that is really helpful. So the first thing we did was with our strategy sort of carved out the pieces and made sure each of our players and partners had some ownership over those pieces.

The second thing that we have done is, we had enough political capital to move things in that direction. This came from several places. The mayor has always been very, very interested in science and mathematics education. In fact, he convenes every year a carnival. We call it Science in the City. It celebrates Chicago as a city of science and organizes all the people who do science and science-related activities together. That helps bring people along. We have a plan that is the center of that and that pulls things in place. Having resources from external sources is also very, very helpful. At the high school level, we leaned on the Bill and Melinda Gates Foundation. For middle school, we have really focused on resources from the Chicago Community Trust, the largest local foundation. For much of the work around organizing universities, that has come from the National Science Foundation. If there isn't a political will to get the university presidents and deans of education and museum presidents all in the same room, having external resources to sort of grease the skids and make that happen has been really, really useful.

Mr. CARNAHAN. Thank you.

Dr. WARD. I would add and fully agree with what Dr. Lach has pointed out, the political will is quite critical. Making the case of the economic competitiveness that a city or a state or a rural area stands to benefit from this kind of coherence and seamlessness throughout the learning continuum have served in a number of places as a powerful incentive. You may be familiar, several years ago the Council on Competitiveness initiated an innovation initiative and talked about clusters of competitiveness and clusters of innovation and, you know, the saying it takes a village to raise a child, for that child to come through and become a productive citizen either of that hometown area or elsewhere, all of the components that Dr. Lach talked about are quite, quite critical. From the federal level, particularly at the NSF level, the math and science partnership, for example, there is an explicit emphasis on that partnership notion. The awards are made to colleges and universities but there have to be strong partnerships with that K–12 system and all other relevant stakeholders in those respective communities, and so the notion of synergy, connectivity, integration of the critical components not only within the system but I would argue within the entire community that is being served is quite, quite critical.

In terms of tools through that program, there is something called Math and Science Partnership Network, MSP Net, and it is designed expressly to be an accessible tool not only to MSP PIs but anyone interested in both the research and implementation that is taking place within a network of MSP activities. And then finally, I would simply add back to the Congresswoman's statement about the achievement gap, I would recommend the MSP Net and will make provisions to get copies available to interested Members. Just last fall, the *Peabody Journal of Education* did a special journal issue on the MSP project itself and it details explicitly all of the data about the achievement gaps that were reduced across the several MSP Net sites, and we will provide that to you before recess. Thank you.

Mr. CARNAHAN. Thank you.

Ms. FUDGE. You know that is tomorrow, right?

Dr. WARD. Yes.

Chairman LIPINSKI. I was hoping it was today.

Mr. CARNAHAN. Thank you, Mr. Chairman.

Chairman LIPINSKI. Thank you, Mr. Carnahan.

Dr. WINK. Mr. Chairman, if I may just——

Chairman LIPINSKI. Yes.

Dr. WINK.—an additional point from the university perspective. The colleges and universities are doing something already that is vital to K–12 and it needs to be linked more tightly to what goes on in STEM education reform and that is teacher preparation. In my own background it was actually in the area of teacher preparation that I first started to engage in these questions, and that has to be something that is shared on the campuses between the colleges of education and the departments of mathematics and science. It is an important requirement of NSF funding but it is also something to pay careful attention to. The universities are creating the teachers and enroll in this process to do it well and to make sure those teachers know not only the STEM content but also some of the issues associated with educating the children in these particular contexts is absolutely vital.

Chairman LIPINSKI. Thank you, Dr. Wink, and I will recognize Mr. Neugebauer.

Mr. NEUGEBAUER. Thank you, Mr. Chairman. Before we get started, I think Mr. Lach probably pointed out a much bigger problem than STEM education and that is the dropout rate in America, and it is almost embarrassing that one of the most prosperous countries in the world has some of the highest dropout rates and the highest incarceration rates, but that is not the subject of this hearing but certainly should be something that we should be very concerned about.

You know, I hear a lot of folks talk about, you know, in the school districts around the country difficulty of retaining math and science teachers. There is not—in many school districts there is not enough math and science teachers, and certainly that is an issue that needs to be addressed. I am from the business world, and when we used to have a deficiency in our team, we would go out and recruit the talent that we needed to complete our team, and sometimes that talent would cost more to acquire than other skill sets. Has there been discussion in the academic world K–12 about if we need more math and science teachers that we would pay a higher rate to attract and retain a sufficient number of math and science teachers to make sure that we have those folks on board? I will throw that out to the panel.

Mr. LACH. I have long been an advocate for paying mathematics and science teachers more. It was not an issue that we could successfully include in the most recent contract negotiations in Chicago but it is something that I think is particularly important. I do believe that our current Secretary of Education supports that idea as well.

Mr. NEUGEBAUER. Does anybody else want to comment? Dr. Ward?

Dr. WARD. Yes. Certainly we appreciate the importance of an adequate salary for teachers doing some of the most important work that takes place in the Nation. One particular instance is through our recent Noyce program. There are explicit provisions made such that during this teacher preparation time existing teachers are paid a stipend, if you will, for the period of time that they are undergoing the training through this program but the issue that you speak to is far greater than stipends for preparation itself and it is one that continues to loom large on the national horizon.

Mr. NEUGEBAUER. So is your opinion yes or no, you think we ought to pay more for——

Dr. WARD. Yes, I think so.

Dr. WINK. Sir, if I may add something, please?

Mr. NEUGEBAUER. Yes.

Dr. WINK. It is also a question of understanding the opportunities, as Michael said earlier, that really do come from being in an urban setting so there are pay differentials between CPS and some suburban districts which hamper the ability of CPS to retain teachers, and that is across the board, but in particular in math and science, and yet it is in my experience the case that on the same pay, a teacher will want to teach in Chicago in almost every case, and the reason is because of the excitement and the opportunities that are there. So we need to address that gap. But the other thing that we need is for the teachers to recognize that those opportunities exist, so we commonly work with individuals who may be from a background that is not in the city and giving them the opportunity to see what really good teaching goes on in the CPS schools and in very many cases really turns them on to that opportunity. So including urban education experiences within the training of teachers is an important part to bringing teachers into these higher-need environments. They are not going to just come in when they get their bachelor's degree. They need to be trained in those environments as well.

Mr. EHLERS. Would the gentleman yield?

Mr. NEUGEBAUER. I would yield, yes.

Mr. EHLERS. Thank you very much. I have been an advocate of pay differential for many years and generally it has ended up being, as Mr. Lach said, when you get to union negotiating, there are very few science and math teachers and so that negotiators worry much more about the broad body than they do about specific disciplines. I think this is something that has to be addressed in some other way, perhaps through additional stipends from other organizations which some school districts use but you are right on. My colleague is right on on this point. We live in a country that believes in a free enterprise system. The amount you get paid in your particular job depends on what could earn elsewhere, and I don't care whether it is teaching or working in an office or something, and it is clear that a typical high school science teacher can get at least $20,000 or $30,000 a year more by going into industry. Why shouldn't the schools meet the competition? I don't think it should be a matter of union contracts. I think it should just be a matter of competition. With that, I yield back.

Chairman LIPINSKI. Thank you. I wanted to hopefully in my questions here sort of try to bring a lot of this together since we are talking about a systems approach, and being the engineer I am, I am sitting here drawing a diagram. But we have NSF, a representative of someone that runs an information education institute. We have K–12 represented here, and university. We have industry here. But beyond that, you know, we have talked a little bit about we also have out there foundations, retired professionals. We have had a hearing earlier this year about including informal educational institutions, museums. We talked here about the aquarium and planetarium. We also have in the Chicago area and some other places that are fortunate across the country national labs, and I am probably leaving out some others, but the question is, what—I am looking for what recommendations that you would give. If you were going somewhere else to another area that had a lot of these similar potential for bringing together so many different pieces, so many different stakeholders, what would your recommendations be as to how to best try to coordinate? Because we heard stories from each of you about a little bit of the coordination that you have done, especially Mrs. Daley worked with Abbott for some coordination. We have heard some other examples of how that is done. Mr. Lach talked about how Mayor Daley has been important in emphasizing Chicago in science and technology. But how else—how would you recommend going about making these connections or telling someone else, telling another city how do you make these connections and make them work to really have a systemic approach to STEM education to really better educate our children in STEM education? I am just trying to throw that out there and give you a chance to think about, give some recommendations for what you would do and what you would recommend. Ms. Pickus.

Ms. PICKUS. Yes, I would just like to also say that there is some great leadership that has been demonstrated by Mayor and Ms. Daley. It is unique for the city of Chicago. They have reached out to unusual, atypical partners and they have brought people together to approach a challenge in a uniform manner, and I think that if we are to take the model that is taking place in Chicago and find what makes it work, we can share it with other communities. You know, Abbott has facilities all across the United States, all across the world, and what we are trying to do is piece this together. You know, clearly the leadership that they have provided has given us, you know, great vision to establish the kind of partnerships that we could have in Columbus, Ohio, for example, where we have a very large presence, and we found that by looking at what is going on in Columbus, small siloed activities were already taking place. Our nutrition scientists who are based there were reaching out to their counterparts at the Ohio State University and they were together going to elementary schools or they were going to a museum. It is about looking at bringing others in and establishing some order and getting others to as a group provide leadership for a long-term vision in this area. So I suggest we look at Chicago and share the model with St. Louis, Columbus, other places around the country.

Chairman LIPINSKI. Ms. Daley.

Ms. DALEY. I would say that I agree with you, Kathy. I think that—when I do talk to other cities and mayors, I will say really in this case it is really important for the Mayor to be dedicated to these things, and it will fall into place. You know, if a Mayor gathers all these people around the table and says we are going to make this work, I mean, it is really a great step in the right direction. So in a way it is executive driven, I think, but then once you get these people together, then the partnerships develop and everyone I think feels committed to trying to, you know, enhance the whole idea of advancing STEM education, and you know, one of the reasons that business is that businesses can also see how it will affect the economy of the city, and I think that it really is relatively easy to do. Once you gather the people together, the partnerships become, you know, like motivated friends actually, to make it happen.

Chairman LIPINSKI. Dr. Ward.

Dr. WARD. I think the role of dissemination of actually what works and to be candid, what has not worked, so that one can learn from lessons of previous existence proofs, if you will. We learned quite a lot during the urban systemic program, for example, but there was also the rural systemic program. We now have math and science partnerships documenting very carefully and rigorously in terms of accountability of all the critical components that are necessary to make a systems approach in the effectiveness of STEM education—it can't be understated. These networks that we are talking about, the use of technology, for example, so that people have ready access while they are in the process of trying to mount these kinds of activities. From the federal level, we do whatever we can in terms of outreach and making available those best practices and dissemination. We are talking with the Department of Education now as they are about to distribute quite a lot of ARRA money to work together, such that best practices that NSF has supported over the past several decades can be immediately made available to communities, and that discussion is going quite well. We have a workshop coming up I think within a month's time, for example, for those kinds of things. But recalling what Dr. Wink had said in his written testimony, I was very struck by it. This is not easy. It is not quite as easy. It takes a long-term mounting of trust and relationships among the critical players, the appreciation of rigor and high expectations, the needed infrastructure in place, not only just the physical infrastructure but financial resources in place, the necessary policies being aligned well, standards, standards-based instruction being aligned well so that you can see the necessary student attainment in the STEM fields that are so desired.

Chairman LIPINSKI. Thank you. Any other comments?

Ms. DALEY. Yes, I would like to comment. We are talking about two very important things, and one is changing and enhancing what is happening during the school day, but I would also, because of course I am involved in out-of-school activities, I think at the same time we have to consider the importance of that just as Dr. Ehlers was saying where often is that spark. We want to have more scientists and engineers in the future of our country, and if in fact it does seem that quite a few of them develop that interest in and out-of-school, I think that that is something that we should pursue and think about because it is actually easier to do. It is important to work on the system and continue to do that but to make impact out of school is relatively easy to do and also is very cost-effective. It is not nearly as expensive as the traditional school day. So I just think that that should definitely be a priority as well.

Chairman LIPINSKI. I yield to Dr. Ehlers.

Mr. EHLERS. I thank the gentleman for yielding. I just wanted to comment on an experience I had in the past few weeks. I learned to fly many years ago and then gave it up because of a number of reasons and got back into it recently, but I met a teacher in Grand Rapids. He was a high school teacher, and he had learned to fly at one point. He was hoping to become an airline pilot and return to the Bahamas where he was from and run tours. He never quite managed to do that, but he decided that a good way to get the kids excited, elementary school kids, excited about math and science was to have them study aviation, and so he volunteered to teach them after school and has them build model airplanes. I met him at an event where a chapter of the Experimental Aviation Association, of which I am a member, was meeting. We invited him in, gave the kids rides in real airplanes. It is amazing. I would predict that more of those kids would go into math and science as a result of that simple experience than would have almost any other experience he could have given them in the school. They love airplanes. They love to build their own now and so forth. So I think there are endless opportunities to use that after-school time to really develop kids' interest in math and science and careers in those fields other than just the standard things that we have been doing in the past. Thank you.

Chairman LIPINSKI. Does anyone else on the panel want to add anything here?

Ms. PICKUS. One last quick comment. You are talking about during school education and then after school and how they relate, but one of the things that we saw with After School Matters was the investment that we have made in the facility at one high school actually impacted the course, the science courses for during school and leveraging those investments and also with regard to attracting teachers, and I think the teachers we are working with at Foreman High School, you know, their opportunity to reach and do more work in an after-school environment I think also encourages them to become more engaged in the Chicago public school system and also engages them with the students long-term.

Chairman LIPINSKI. I certainly think, and we all know, everything feeds off each other in all these and I certainly know that that was the case in my life, in my education and growing up and it was very significant to be in Chicago and have the opportunities that I had, you know, and I have talked about this many times, going to the Museum of Science and Industry, the aquarium, Adler Planetarium, Brookfield Zoo and all those things, you know, especially that really played into and got me more and more interested in eventually getting a degree in engineering. But I want to thank you for all your work. Ms. Daley.

Ms. DALEY. I actually have one little anecdote that I would like to share. One time when we were doing a robotics program in school that was having difficulties, and it wasn't one of our more successful high schools but it was, you know, always these teenagers are wonderful, and I was observing a Tech 37 program which was dealing with robotics, and what happened is, I noticed a gentleman was there observing these kids and he came over to me and he said, you know, Mrs. Daley—you saw 25 teenagers very much engaged in robotics, they actually were walking on the tables and on the floor and they were all having a wonderful, joyous experience in this learning experience, and he came over to me and he said, you know, he said, I have to tell you this, I have been teaching in this school for 25 years, I am a math teacher, and he said sometimes I would get a little down thinking that these young people really just don't care, they are not interested, and he said after watching this this afternoon, he said I realize that I need to change the way I teach. So that was an "aha" moment for him, I think, and so I think that working together out of school and in school and getting all of us, you know, to realize the potential of our teenagers. Even in the schools that are failing, the potential is great. So we have to create these activities that allow these youngsters to show their possibilities.

Chairman LIPINSKI. And it is not just the students who learn. We all learn as we go along and learn how to do this better and get some reinforcement out of doing these things with these kids, and I just want to thank you for the work that you do. I want to thank all of our witnesses today for their testimony. 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.

With that, the witnesses are excused and the hearing is now adjourned.

[Whereupon, at 11:32 a.m., the Subcommittee was adjourned.]

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