WHAT MAKES FOR SUCCESSFUL K–12 STEM EDUCATION: A CLOSER LOOK AT EFFECTIVE STEM EDUCATION APPROACHES

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

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WEDNESDAY, OCTOBER 12, 2011

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Wednesday, October 12, 2011

WHAT MAKES FOR SUCCESSFUL K–12 STEM EDUCATION: A CLOSER LOOK AT EFFECTIVE STEM EDUCATION APPROACHES

WEDNESDAY, OCTOBER 12, 2011

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

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Mo Brooks [Chairman of the Subcommittee] presiding.

RALPH M. HALL, TEXAS
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EDDIE BERNICE JOHNSON, TEXAS
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U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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Subcommittee on Research and Science Education

What Makes for Successful K-12 STEM Education: A Closer Look at Effective STEM Education Approaches

Wednesday, October 12, 2011

10:00 a.m. to 12:00 p.m.

2318 Rayburn House Office Building

Witnesses

Dr. Adam Gamoran, Director, Wisconsin Center for Education Research, University of Wisconsin

Mr. Mark Heffron, Director, Denver School for Science and Technology: Stapleton High School

Dr. Suzanne Wilson, Chair, Department of Teacher Education, Division of Science and Math, Education, Michigan State University

Dr. Elaine Allensworth, Senior Director and Chief Research Officer, Consortium on Chicago School Research, University of Chicago

Dr. Barbara Means, Director, Center for Technology in Learning, SRI International

HEARING CHARTER

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

What Makes for Successful K–12 STEM Education: A Closer Look at Effective STEM Education Approaches

WEDNESDAY, OCTOBER 12, 2011
10:00 A.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, October 12, 2011, at 10:00 a.m., the Subcommittee on Research and Science Education will hold a hearing to review and examine the findings of the National Research Council Report, Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics, as requested by Congress in 2009 to identify highly successful K–12 schools and programs in STEM.

2. Witnesses

- *Dr. Adam Gamoran,* Director, Wisconsin Center for Education Research, University of Wisconsin
- *Mr. Mark Heffron,* Director, Denver School for Science and Technology: Stapleton High School
- *Dr. Suzanne Wilson,* Chair, Department of Teacher Education, Division of Science and Math, Education, Michigan State University
- *Dr. Elaine Allensworth,* Senior Director and Chief Research Officer, Consortium on Chicago School Research, University of Chicago
- *Dr. Barbara Means,* Director, Center for Technology in Learning, SRI International

3. Overview

- In the U.S, student mastery of STEM subjects is essential to thrive in the 21st century economy. As other nations continue to gain ground in preparing their students in these critical fields, the U.S. must continue to explore a variety of ways to inspire future generations.
- The 2007 *Rising Above the Gathering Storm* report called for an increased emphasis on recruiting, educating, training, and increasing the skills of K–12 STEM education teachers and increasing the pipeline of American students who are prepared to enter college and graduate with a degree in STEM.
- In 2009, Congress directed the National Science Foundation (NSF) to survey highly successful K–12 STEM schools and "report recommendations on how their STEM practices might be more broadly replicated in the U.S. public school system." [1]
- In June 2011, the National Research Council released the NSF-sponsored report, *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics.*

[1] Report to Accompany the Commerce, Justice, Science and Related Agencies Appropriations Act for FY 2010 (House Report 111–149).

4. Background

STEM Education and the Federal Government

A consensus exists that improving STEM education throughout the Nation is a necessary 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 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 House Science, Space, and Technology Committee following the issuance of the report and was included in the 2007 *America COMPETES Act*. The 2010 *America COMPETES Reauthorization Act* continues this priority.

Beyond activities authorized in *America COMPETES*, President Obama has called for a new effort to prepare 100,000 science, technology, engineering, and math (STEM) teachers with strong teaching skills and deep content knowledge over the next decade. As a component of achieving this goal, the FY 12 Budget Request proposes an investment of $100 million through the Department of Education and the National Science Foundation (NSF) to prepare effective STEM teachers for classrooms across America. This proposal also responds to a recommendation by the President's Council of Advisors on Science and Technology (PCAST) to prepare and inspire America's students in science, technology, engineering, and mathematics. [2]

In addition, the FY12 Budget Request proposes $90 million for the creation of an Advanced Research Projects Agency—Education (ARPA–ED) with the mission of driving transformational improvements in education technology. [3]

The President's new "Educate to Innovate" campaign leverages federal resources with over $700 million in private-sector resources. The goals of the program are to increase STEM literacy so that all students can learn deeply and think critically in science, math, engineering, and technology; move American students from the middle of the pack to top in the next decade; and expand STEM education and career opportunities for underrepresented groups, including women and girls.

With specific regard to K–12 STEM education funding beyond what has already been identified, the FY 12 Budget Request calls for $206 million for the Department of Education's proposed Effective Teaching and Learning in STEM program; a $60 million (28 percent) increase for NASA's K–12 education programs; $300 million for an "Investing in Innovation" program (expansion of a Department of Education American Reinvestment and Recovery Act program); and $185 million for a new Presidential Teaching Fellowship program.

In total, the FY 12 Budget Request devotes $3.4 billion to STEM education programs across the Federal government. [4] The 2010 America COMPETES Reauthorization Act called for the creation of a National Science Technology Council (NSTC) Committee on STEM Education to coordinate federal STEM investments. The first-year tasks of the Committee are to create an inventory of federal STEM education activities and develop a five-year strategic Federal STEM education plan. The inventory, as well as a similar Government Accountability Office (GAO) survey requested by the Committee on Education and Workforce, is currently underway and results are expected in early 2012.

In the 112th Congress, the Science, Space, and Technology Committee will continue to hold oversight hearings and briefings on STEM education activities across the federal government and will closely monitor the scope and findings of both the NSTC and the GAO federal STEM education inventories.

The "Successful K–12 STEM Education" Report

In 2009, Congress directed the National Science Foundation (NSF) to survey highly successful K–12 STEM schools and "report recommendations on how their STEM practices might be more broadly replicated in the U.S. public school system." [5]

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[2] White House Office of Science and Technology Policy, *Winning the Race to Educate Our Children*, STEM Education in the 2012 Budget, p.1

[3] White House Office of Science and Technology Policy, *Winning the Race to Educate Our Children*, STEM Education in the 2012 Budget, p.1

[4] White House Office of Science and Technology Policy, Innovation, Education, and Infrastructure: *Science, Technology, STEM Education, and 21st Century Infrastructure in the 2012 Budget,* p. 2.

[5] Report to Accompany the Commerce, Justice, Science and Related Agencies Appropriations Act for FY 2010 (House Report 111–149).

In October 2010, the National Research Council brought together a group of experts to explore the issue. This Committee of experts was charged with "outlining criteria for identifying effective STEM schools and programs and identifying which of those criteria could be addressed with available data and research, and those where further work is needed to develop appropriate data sources."[6] In addition, a public workshop was held in May 2011 to "refine criteria for success, explore models of 'best practice,' and analyze factors that evidence indicates lead to success" in highly successful K–12 schools. In late June 2011, they released the NSF-sponsored report, *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics.*

The report identifies three goals for successful STEM education in the United States[7]:

1. **Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.** A number of reports directly link the Nation's economic competitiveness to the ability of K–12 STEM education to produce the next generation of scientists, engineers, and innovators. Given changing demographics in the U.S. and the need to produce more STEM-career prepared students, increasing the participation of underrepresented groups in the sciences is important.
2. **Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.** In addition to preparing those students for advanced degrees, it is also necessary to prepare students for STEM-related careers, such as medical assistants and computer technicians. "Sixteen of the 20 occupations with the largest projected growth in the next decade are STEM related, but only four of them require an advanced degree."[8] Typically, these careers require vocational certification, an associate's degree, or a bachelor's degree.
3. **Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.** The challenges of the science- and technology-driven 21st century increasingly dictates that everyone have knowledge and understanding of STEM concepts for personal decision making, participation in civic and cultural affairs, and economic productivity.

In order to identify what makes a successful school able to achieve one or all of the broad goals, the report establishes three criteria for success[9]:

1. **Student STEM Outcomes.** Since achievement test data are widely available and used for accountability purposes, they are most commonly used to gauge student and school success, but test scores do not always tell the whole story. It is difficult to measure interest, motivation, and creativity, all important for success in STEM. Likewise, utilizing STEM content knowledge is required in numerous settings other than tests, like navigating financial aid forms or working in teams, but currently these are not measures of success. The same can be said for participating in after school programs or internships, as they could indicate a student's engagement in a STEM activity, but they are not factored in as a measurement of success. Research gaps exist on student outcomes.
2. **STEM–Focused School Types.** The report acknowledges the difficulty in identifying schools and programs that are the most successful in STEM because "success is defined in many ways and can occur in many different types of schools and settings, with many different populations of students."[10] As such, three broad categories of STEM-focused schools are identified that have the potential to meet the overarching goals for U.S. STEM education: selective schools, inclusive schools, and schools with STEM-focused career and technical education (CTE).

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[6] *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*, National Research Council, 2011. (http://www.nap.edu/catalog.php?record_id=13158) p. 1.
[7] Ibid, p. 4.
[8] Ibid, p. 5.
[9] Ibid, p. 6.
[10] Ibid. p. 8.

Selective STEM schools tend to be focused around one or more STEM disciplines and have selective admissions criteria with highly talented and motivated students, expert teachers, and advanced curricula. They can be state residential schools, stand-alone schools, schools-within-a-school or regional centers with half-day courses. Research gaps exist on the contributions of these schools over regular schools.

Inclusive STEM schools are similar to selective STEM schools but have no selective admissions criteria, thereby serving a broader population. Many work under the auspices that "math and science competencies can be developed, and that students from traditionally underrepresented subpopulations need access to opportunities to develop these competencies to become full participants in areas of economic growth and prosperity." [11]

Schools and programs with STEM-focused CTE allow students to explore STEM-related career options by learning practical applications of STEM subject areas and are intended "to prepare students for STEM-related careers, often with the broader goal of increasing engagement to prevent students from dropping out of school." [12] Many CTE programs and schools are highly regarded, but research gaps exist on their effectiveness.

The report recognizes the contribution of comprehensive schools in STEM education as well, as "much of the available research knowledge of effective practices comes from comprehensive schools, which educate the vast majority of the nation's students—including many talented and aspiring scientists mathematicians, and engineers who might not have access to selective or inclusive STEM-focused schools." [13] hese schools are not focused specifically on STEM, but cover all disciplines. Advanced Placement (AP) and International Baccalaureate (IB) programs provide advanced STEM programs in these schools.

3. **STEM Instruction and School Practices.** Looking at outcomes and focusing on practices provide schools with guidance on improving STEM instruction. Two themes tend to be found in successful schools, "instruction that captures students' interest and involves them in STEM practices and school conditions that support effective STEM instruction." [14] Imperative to instruction are a coherent set of standards and curriculum, teachers with high capacity to teach in their discipline, a supportive system of assessment and accountability, adequate instruction time, and equal access to high-quality STEM learning opportunities. [15]

At the same time, while teacher qualifications are important, school conditions and cultures that support learning are just as, if not more, important. Specifically, a successful school should have: 1) school leadership as the driver for change, a strategic, focused principal; 2) professional capacity, with quality professional development and an ability for faculty to work together; 3) active parent-community ties, to engage parents in supporting their children's success; 4) student-centered learning climate that is safe, welcoming, stimulating, and nurturing; and 5) instructional guidance when it comes to curriculum organization and instructional materials.

A number of research gaps are identified throughout the report. Much research is underway, but not yet conclusive. Broadening research on measuring success beyond student test scores, graduation rates, and data on effective STEM practices could allow for a more comprehensive analysis of schools and K–12 STEM education. [16]

The report concludes with recommendations for what schools and districts and state and national policy makers can do to support effective K–12 education [17]:

Schools and Districts:

- Consider all three models of STEM-focused schools if seeking to improve STEM outcomes beyond comprehensive schools;
- Devote adequate instructional time and resources to science in grades K–5;

[11] Ibid, p. 11.
[12] Ibid, p. 13.
[13] Ibid, p. 15.
[14] Ibid. p. 18.
[15] Ibid. p. 19–22.
[16] Ibid, p. 26.
[17] Ibid, p. 27.

- Ensure STEM curricula are focused on the most important topics in each discipline, are rigorous, and are articulated as a sequence of topics and performances;
- Enhance the capacity of K–12 teachers; and
- Provide instructional leaders with professional development that helps to create the school conditions that appear to support student achievement.

State and Local Policy Makers

- Elevate science to the same level of importance as reading and mathematics and develop effective systems of assessment;
- Invest in a coherent, focused, and sustained set of support for STEM teachers; and
- Support key areas for future research.

Chairman BROOKS. The Subcommittee on Research and Science Education will come to order.

Good morning. Welcome to today's hearing entitled, "What Makes for Successful K–12 STEM Education: A Closer Look at Effective STEM Education Approaches. The purpose of today's hearing is to review and examine the findings of the National Academies' report, "Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics," as requested in 2009 by then Commerce, Justice, and Science Appropriations Subcommittee Ranking Member Frank Wolf to identify highly successful K–12 schools and programs in STEM. He is now the Chairman, and I am pleased to have him join us today and look forward to working with him on STEM education and other areas of the federal science budget that our Subcommittees share.

At this point I would move for unanimous consent for Chairman Wolf to sit and participate. Having heard no objection, Chairman Wolf, you are permitted to sit and participate.

At this point, the Chairman will give his opening statement. I plan to yield some of my opening statement time to Chairman Wolf, but before I do, let me reiterate a point from today's charter. Student mastery of STEM subjects is essential to thrive in the 21st century economy. As other nations continue to gain ground in preparing their students in these critical fields, the United States must continue to explore a variety of ways to inspire future generations. This report explores some of those ways.

I believe the findings of this report reveal many things that we already know about what it takes to have a successful K–12 STEM school. And while research gaps continue to exist, getting this helpful information into the hands of state education departments and local school districts is important, because that is where real change takes place. Whether we are preparing students for advanced degrees in STEM or ensuring that young adults have the scientific and mathematic literacy to strive and thrive in a 21st century technology-based economy, the foundation for both of these begins in our K–12 schools.

I look forward to hearing from all of our witnesses today about their contributions to this report as well as their contributions for improving K–12 STEM education in the United States.

With that, I yield the remainder of my time to Chairman Wolf.

[The prepared statement of Mr. Brooks follows:]

PREPARED STATEMENT OF CHAIRMAN MO BROOKS

Good morning, and welcome to each of our witnesses. The purpose of today's hearing is to review and examine the findings of the National Academies report, Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics, as requested in 2009 by then Commerce, Justice, and Science Appropriations Subcommittee Ranking Member Frank Wolf to identify highly successful K–12 schools and programs in STEM. He is now the Chairman, and I am pleased to have him join us today and look forward to working with him on STEM education and other areas of the federal science budget that our Subcommittees share.

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With that, I yield the remainder of my time to Chairman Wolf.

Mr. WOLF. I thank you, Mr. Chairman. I appreciate that. I will be very, very brief, and I will just be here briefly to listen to the panel as much as I can.

This is important. A couple of years ago I became very concerned as to why young people at age fifth grade were going in law or whatever and not into sciences. So we put this in directing the National Science Foundation to do this. It really is an issue of the future of the country and also jobs. To give you some example, for instance, if you were to go outside this room and ask the average person what country is number one in space, most people would say America. But the reality is that China is catching up. And China has 200,000 people working on their space program, and we in the United States only have about 90 or 95,000 counting NASA employees and outside.

And we are falling behind so dramatically, and I think if you can get more young people to be involved in math and science and physics and chemistry and biology—and if you all take a look at the rising storm of Norm Augustine, the report that we work with him—you can see that it literally is jobs, it is will the 21st century be the American century or will the 21st century be the Chinese century? If it is the Chinese century—and keep in mind, the People's Liberation Army that runs the Chinese space program is the same group in China that executes people for their organs and sells them for 50 to $55,000 for a kidney, you can see—if you want to see what the world would be like if China is number one, the number one supporter of the genocide in Darfur—genocide is taking place in Darfur. I was the first Member to go to Darfur with Sam Brownback. The number one supporter is China. China is pushing, helping the Khartoum government with regard to genocide.

So in order for this to be the 21st century, the American century, the more we have the math and science and physics and chemistry and biology in the STEM is very important.

The last issue—and I would urge the Chairman and Mr. Lipinski to take a look at this—when the FBI comes before my Committee, we have gone out—and I would urge both of you to do it, too, to look at the briefings to see the Chinese are stealing so much technology. In fact, as—I think it was Mike Rogers the other day said there are only two kind of companies in America: those who have been hit with cyber attacks by the Chinese where they are stealing of technology, stealing jobs—and the American companies who have been hit by the Chinese who don't know that they have been hit.

And so as we are putting all of this in the top of the basket to create jobs and economic opportunity and math and science and physics and chemistry, we also have to look at how they are stealing from us below and taking away much of their gains in science have come because not—their scientific efforts. They are making them, but also what they have taken. They are hitting the Patent and Trademark Office websites. They are doing different things. So I would urge the Committee—I appreciate you doing this hearing. I would hope maybe both of you could take a look at this briefing where the FBI can show you the companies that they are hitting and that we can then stop this stealing by the Chinese and do what we can to make sure the 21st century is not the Chinese century but it is the American Century.

But thank you for having these hearings.

Chairman BROOKS. Thank you, Chairman Wolf.

At this point, the Chair recognizes Mr. Lipinski of Illinois for an opening statement.

Mr. LIPINSKI. Thank you, Chairman Brooks. I want to thank you for holding this hearing, thank our witnesses for being here today, and especially thank Chairman Wolf for requesting this report. I've worked with Chairman Wolf on a number of issues. I share his great concern about what is happening in America with STEM education and echo many of his concerns about what China is doing right now in threatening the United States and our economy.

As an engineer and an educator, STEM education is of particular importance and interest to me and it is one of the reasons I was eager to join this Committee and Subcommittee. As a college professor, I saw firsthand how poorly some of our students are prepared, especially in math. I also know how my own career was shaped by my early exposure to engineering concepts and how much I benefitted from the emphasis put on math and science by my teachers and parents.

I am also focused on improving STEM education because I am keenly aware that our future economic competitiveness and prosperity depend on it. Time and again we hear about how poorly our students are doing on math and science tests. On the last National Assessment of Educational Progress, the so-called Nation's Report Card, nearly 80 percent of 12th graders fell short on science proficiency. The World Economic Forum ranked the U.S. 48th in math and science. Not surprisingly, this poor performance has resulted in fewer scientists and engineers. Only one-third of the undergraduate degrees earned by American students are in a STEM field, compared with 63 percent in Japan and 53 percent in China. In a global economy where so many jobs are based on math, science, and technology, these numbers are frightening.

But there are many examples of schools and programs that are having great success increasing student interest and performance in STEM. That is why I am excited about this hearing and the recent NRC report on K through 12 STEM education. There are exemplary STEM schools like the Illinois Math and Science Academy and I want to learn why and how they work and what aspects of their success can be replicated broadly.

I hope to hear from our witnesses about what we can do better to give students from all backgrounds access to high-quality education and the opportunities that come with it. One of the most important lessons I have learned about STEM education policy is that one successful model is not enough to achieve systemic change. For one, there still remains a lot we don't know about what components of successful schools or programs have been most critical to their success. We also know from experience that simply copying successful schools doesn't work. We live in a large and diverse country and our approach needs to reflect that.

I also think that is why it remains critical that we continue investing in education research that accounts for tremendous diversity of environments, infrastructure, cultures, laws, student populations, family situations, and other factors that together describe a community and a school. As I mentioned, one of the most important factors in my educational success was the involvement of my parents, especially my mother, so I was glad to hear that this report looked beyond the classroom.

I hope to hear from our witnesses about the current state of research in education and about where gaps remain. The National Science Foundation is not represented on the panel today, but as some of the witnesses pointed out in their testimony, NSF is the premier STEM education research organization in the country. Along with the Institute of Education Sciences at the Department of Education, the NSF has been a leader in improving our collective understanding of how students learn.

In her testimony, Dr. Means very convincingly describes why this is a unique federal role and she is not the only one to make this point. It is important that we continue to support this research, especially projects that focus on sustainability and large-scale implementation of successful education programs.

Especially in these tight budget times, it is critical that we are spending our tax dollars on programs that work, and only through investing in education research will we know what works, what doesn't, and where we should target our limited resources. We know there is no silver bullet when it comes to addressing the STEM education challenge we face in our country. At the same time, with so many examples of successful models and programs, we have much we can look to for guidance.

I want to thank the witnesses for being here this morning and I look forward to your testimony.

[The prepared statement of Mr. Lipinski follows:]

PREPARED STATEMENT OF RANKING MEMBER DANIEL LIPINSKI

Thank you Chairman Brooks for holding this hearing, and our witnesses for being here today. STEM education is of particular importance and interest to me, and is one of the reasons I was eager to join this Committee and Subcommittee. As a former college professor I saw first-hand how poorly some of our students are prepared, especially in math. I also know how my own career was shaped by my early exposure to concepts like engineering and how much I benefited from the emphasis put on math and science by my parents and teachers.But I am also focused on improving STEM education because I am keenly aware that our future economic competitiveness and prosperity depend on it.

Time and time again we hear about how poorly our students are doing on math and science tests. On the last National Assessment of Educational Progress, the so-called "nation's report card," nearly 80 percent of 12th graders fell short of science proficiency. The World Economic Forum ranks the U.S. 48th in math and science. Not surprisingly, this poor performance has resulted in fewer scientists and engineers. Only one third of the undergraduate degrees earned by American students are in a STEM field, compared with 63 percent in Japan and 53 percent in China. In a global economy where nearly everything we do is based on math, science, and technology, these numbers are frightening.

But there are many examples of schools and programs that are having great success increasing student interest and performance in STEM. That's why I'm excited about this hearing and the recent NRC report on K–12 STEM Education. There are exemplary STEM schools, like the Illinois Math and Science Academy, and I want to learn why and how they work and what aspects of their success can be replicated broadly. I hope to hear from our witnesses about what we can do better to give students from all backgrounds access to a high-quality education and the opportunities that come with it.

One of the most important lessons I've learned about STEM education policy is that one successful model is not enough to achieve systemic change. For one, there still remains a lot we don't know about what components of successful schools or programs have been most critical to their success. We also know from experience that simply copying successful schools doesn't always work. We live in a large and diverse country, and our approach needs to reflect that.

I also think that is why it remains critical that we continue investing in education research that accounts for the tremendous diversity of environments, infrastructure, cultures, laws, student populations, and other factors that together describe a community and a school. As I mentioned, one of the most important factors in my educational success was the involvement of my parents, especially my mother, so I was glad to hear that this report looked beyond the classroom. I hope to hear from our witnesses about the current state of research in education, and about where gaps remain.

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We know there is no silver bullet when it comes to addressing the STEM education challenge we face in our country. At the same time, with so many examples of successful models and programs, we have much we can look to for guidance. I want to thank the witnesses for being here this morning and I look forward to your testimony.

Chairman BROOKS. Thank you, Mr. Lipinski.

If there are members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time, I would like to introduce our witnesses for today's hearing.

Dr. Adam Gamoran is the Director of the Wisconsin Center for Education Research at the University of Wisconsin- Madison. Dr. Gamoran chaired the National Research Council's Committee on Highly Successful Schools or Programs in K through 12 STEM Education, which produced the report we are considering today.

Next, we have Mr. Mark Heffron. He is the Director of Stapleton High School at the Denver School for Science and Technology and includes the school featured in the report. After working as a structural engineer, Mr. Heffron left engineering to pursue a career as a math teacher. In 2010, Mr. Heffron became the High School Director of DSST, Stapleton Campus, and he is currently the Stapleton Campus Director leading Culture, Instruction, and Assessment of the high school and overseeing the operations of six through eight, Stapleton Middle School.

Dr. Suzanne Wilson serves as Chair and Professor in the Department of Teacher Education at Michigan State University. Prior to joining the faculty at MSU, Dr. Wilson was the first Director of the

Teacher Assessment Project. Dr. Wilson has served on several National Research Council Committees, including the Teacher Preparation Study and participated in the workshop for the report we are reviewing today.

Next, we have Dr. Elaine Allensworth. She is Senior Director and Chief Research Officer at the Consortium on Chicago School Research at the University of Chicago. She has served on a number of committees for the National Academies, is a standing member of the Scientific Review Panel of the United States Department of Education, and was on the Board of the Illinois Education Research Council. She, too, participated in the workshop for this report.

And then finally, we will have Dr. Barbara Means. She is the Director for the Center for Technology in Learning at SRI International, a Fellow of the American Educational Research Association. Dr. Means serves on the National Academy of Engineering, National Research Council Committee on Integrated STEM Education, and on the National Research Council's working Committee on Highly Successful Schools or Programs for K through 12 STEM Education.

As all of our witnesses should know, spoken testimony is limited to five minutes each, after which the members of the committee will have five minutes each to ask questions.

I now recognize our first witness, Dr. Adam Gamoran. Dr. Gamoran, you are recognized for five minutes.

STATEMENT OF DR. ADAM GAMORAN, DIRECTOR, WISCONSIN CENTER FOR EDUCATION RESEARCH, UNIVERSITY OF WISCONSIN

Dr. GAMORAN. Chairman Brooks, Ranking Member Lipinski, Chairman Wolf, and other Members of the Subcommittee, thank you for the opportunity to discuss this report. As you indicated, my name is Adam Gamoran, and I chaired the committee that produced this report. Although I am speaking on my own behalf, my written statement has been endorsed by the other members of the committee. I am here to discuss the report and its implications for the federal role in K–12 STEM education.

Both Chairman Brooks and Chairman Wolf, as well as Ranking Member Lipinski have already stated more eloquently than I could the importance of the federal role in leveraging excellence and fostering equity in K–12 STEM education.

Our committee faced two major challenges. First, there has been little research about engineering and technology education. As a result, the report's findings and recommendations about K–12 STEM education are largely based on research on mathematics and science education. Second, only a small portion of the research addresses impact questions. Because students and teachers are rarely assigned at random, what appears to be a successful program may be one that started with students who were already advanced. The Committee took such suggestive evidence into account but took as evidence of success only that which distinguished between program effects and effects of participant selection.

The Committee identified three goals: expanding and broadening participation in STEM careers, expanding and broadening participation in a STEM-capable workforce, and increasing STEM literacy for all students. We examined success in three areas: student outcomes, specialized STEM-focused schools, and the quality of STEM teaching. We found that while achievement tests are the most common indicator of student outcomes, they do not tell the whole story.

We found that high-quality teaching and learning can occur in all types of schools, including specialized STEM schools and regular public schools. However, most research addresses classroom instruction. Here, there is more to say. STEM learning gets a boost from a coherent, focused, and rigorous curriculum, from teachers who are knowledgeable in their fields, from supportive systems of assessment, from adequate time for learning, and from equal access to learning opportunities. School conditions such as teacher learning communities and leadership focused on learning help support effective instruction.

The Committee identified four areas that urgently require new research—research that links organizational and instructional practices to longitudinal data on student outcomes; research on student outcomes other than achievement; research on STEM programs that distinguishes program effects from selection effects, that identifies distinctive aspects of educational practices, and that measures long-term effectiveness; and research on effects of professional development for STEM teachers on student learning.

No other entity can fill the Federal Government's role in supporting research on STEM education. Much of the research reviewed in this successful STEM report was supported by federal funding, mainly through the National Science Foundation and the U.S. Department of Education's Institute of Education Sciences. Funding for STEM education research should remain a priority despite the fiscal challenges of our times.

Like the authors of another NRC report, "Rising Above the Gathering Storm," I believe our Nation cannot afford to back away from investments in STEM education. New investments in research are needed to help fill critical gaps. As the primary sponsors of K–12 STEM education research, NSF and IES are staffed by professionals who rely on scientific peer review for funding decisions, so they are well placed for this role. Interagency collaboration can help ensure that ongoing research covers the continuum from basic insights about STEM teaching, learning, and leading to rigorous research on applications as they are tested, replicated, and implemented at scale.

In addition to NSF and IES, numerous federal agencies have small roles in education research and programming. This scattershot approach should be reconsidered as the more concentrated investments at agencies where education research is the primary mission are likely to have higher yield.

The Committee identified two negative consequences of the No Child Left Behind Act that could be addressed in new federal legislation. First, assessments used for accountability tend to be inadequate to promote deep understanding in the STEM domains. A system of assessments that spans the range from basic concepts to deep understanding could be equally well tied to standards and more supportive of instruction. Efforts to develop better math and reading assessments are currently underway. Similar efforts are needed in science.

Second, NCLB's emphasis on reading and mathematics is squeezing out time for science instruction. Particularly at the elementary level, studies show that less time is being devoted to science perhaps because schools are not held accountable for science learning. Yet other research points to the importance of capturing students' interest at an early age. This may be particularly important for disadvantaged youth who have few opportunities for science learning in their homes and neighborhoods. The Committee thus recommended that science should be elevated to the same level of importance as mathematics and reading in state and federal accountability systems.

Thank you.

[The prepared statement of Dr. Gamoran follows:]

PREPARED STATEMENT OF DR. ADAM GAMORAN, WISCONSIN CENTER FOR EDUCATION RESEARCH, UNIVERSITY OF WISCONSIN-MADISON

Chairman Brooks, Ranking Member Lipinski, and other Members of the Subcommittee, thank you for the opportunity to discuss with you the findings of the recent National Research Council (NRC) report on *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics.*[1] My name is Adam Gamoran, and I chaired the committee that produced this report. Although I am speaking on my own behalf, my written statement has been endorsed by the other members of the committee. My goals today are to recount and respond to questions about the findings of the report and the research that lies behind it, to identify gaps in our knowledge that limited the findings, and to discuss implications for enhancing the federal role in K–12 STEM (science, technology, engineering, and mathematics) education.

My testimony is based not only on my role as chair of this committee, but also on my experience in education research over a career of 27 years at the University of Wisconsin-Madison, in which I have focused on efforts to improve performance and reduce learning gaps in U.S. schools from early education to the postsecondary level. I have served on a variety of national panels and am currently a member of the NRC Board on Science Education. I also chair the Independent Advisory Panel of the National Assessment of Career and Technical Education for the U.S. Department of Education, and I am an appointed member of the National Board for Education Sciences.

Although education in the U.S. is primarily a state and local responsibility, the quality of K–12 STEM education is a matter of pressing national interest; indeed it is a national security issue, as expressed a decade ago by the U.S. Commission on National Security in the 21st Century.[2] Consequently it is both appropriate and necessary that the federal government play a role in leveraging excellence and fostering equity in K–12 STEM education across the country.

Challenges Faced by the Committee

The Committee on Highly Successful Schools or Programs for K–12 STEM Education faced two major challenges as we pursued our work over a very short and intensive time frame (October 2010 to June 2011). First, we quickly learned that knowledge about successful K–12 STEM education is unevenly distributed across the STEM domains: research on mathematics education is more extensive than that on science education, particularly when addressing the effects of particular schools and programs, and there has simply been very little research about K–12 education in engineering and technology, because these subjects are less often taught at the K–12 level. Regarding the effects of K–12 engineering education on learning, another NRC panel concluded in 2009 that "the limited amount of reliable data does

[1] National Research Council. (2011). Successful K–12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics. Committee on Highly Successful Science Schools or Programs for K–12 STEM Education. Washington, DC: National Academies Press. Available at: http://www.nap.edu/catalog.php?record_id=13158

[2] United States Commission on National Security in the 21st Century. (2001). Road map for national security: Imperative for change. Washington, DC: U.S. Commission on National Security in the 21st Century. Available at: http://govinfo.library.unt.edu/nssg/PhaseIIIFR.pdf

not provide a basis for unqualified claims of impact."[3] That is still the case. As a result, our Committee's findings and recommendations about K–12 STEM education are largely based on research on mathematics and science education. Moreover, as I will note below, the research on school and program success focuses mainly on a narrow set of achievement outcomes and yields little evidence on other types of outcomes such as interest, motivation, and participation. This, too, constrained the ability of the Committee to identify areas of success.

The second major challenge was that a relatively small portion of the research on K–12 STEM education addresses questions about the impact of STEM-focused schools and programs. Commonly, studies do not use designs that allow them to distinguish the effects of schools or programs from the effects of who participates and who does not. Because students and teachers are rarely assigned at random, what appears to be a successful program may be one that started with students who were already advanced before they enrolled. (Similarly, if a program appears ineffective, the lack of apparent effects may also reflect selection patterns.) This is the fundamental challenge of all research on school, program, and teacher effects. Research designs to address this challenge are available—experimental or rigorous quasi-experimental designs—but they have only recently begun to be widely employed. Using an experimental design in some of my own research, I recently identified a professional development program in elementary science education that was unsuccessful at raising student achievement.[4] Without a rigorous design, we might have been misled about the effects of the program. While negative findings are hardly glamorous, they are a crucial part of advancing knowledge.

Because of this challenge, the Committee considered evidence to be merely suggestive if it pointed to conditions associated with success, but did not reveal whether success resulted from the qualities of the program or the characteristics of participants. We took as evidence of success only findings that "resulted from research studies that were designed to support causal conclusions by distinguishing the effectiveness of schools from the characteristics of students attending them" (p.1).

Background to Findings of the Successful STEM Report: Goals of K–12 STEM Education

Our Committee was charged with "outlining criteria for identifying effective STEM schools and programs and identifying which of those criteria could be addressed with available data and research, and those where further work is needed to develop appropriate data sources" (p.1). It was immediately clear that the charge could be met only if we first answered the question, "Effective for what?" Before answering questions about criteria of success, we first needed to identify the goals against which success could be measured. We focused on three goals:

- **Goal 1:** Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields, and broaden the participation of women and minorities in those fields.

This goal is about nurturing our top talent to advance scientific discovery and leadership. It is also about ensuring that persons from underrepresented groups have the opportunity to take advantage of their talents to make scientific contributions.

- **Goal 2:** Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.

A growing number of jobs—not just those in professional science—require knowledge of STEM fields. Schools and programs are needed that prepare young people for a wide range of careers that benefit from such expertise.

- **Goal 3:** Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

As a nation, our goals extend beyond having a capable and competitive work force. We also need to help all students become scientifically literate. Our citizens are increasingly facing decisions related to science and technology, from understanding a medical diagnosis to weighing competing claims about the environment, and successful STEM education must address this aim as well.

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[3] Katehi, L., Pearson, G., & Feder, M., Editors. (2009). Engineering in K–12 education: Understanding the status and improving the prospects. Committee on K–12 Engineering Education. Washington, DC: National Academies Press, p. 154.

[4] Borman, G. D., Gamoran, A., & Bowdon, J. (2008). A randomized trial of teacher development in elementary science: First-year effects. Journal of Research on Educational Effectiveness, 1, 237–264.

With these goals in mind, the Committee examined success in three areas: (1) student outcomes; (2) specialized STEM schools and programs; and (3) effective classroom instruction in STEM fields. We also assessed the research on school conditions that support effective instruction.

Findings about Student Outcomes

Student achievement test scores are the measures most commonly used to gauge success, regardless of the goals of a particular school or program. But test scores do not reveal all we need to know about success. For example, the Committee learned about the Thomas Jefferson High School of Science and Technology, a highly selective magnet school in Alexandria, VA. This school's mission is to "provide students a challenging learning environment focused on math, science, and technology, to inspire joy at the prospect of discovery, and to foster a culture of innovation based on ethical behavior and the shared interests of humanity" (p. 6). A narrow focus on test scores does not begin to tell the story of whether such schools are successful.

Assessing a school's success relative to its full set of goals requires using additional criteria. For example, entry into STEM-related majors and careers and making good choices as citizens and consumers also require applying and using STEM content knowledge. Other indicators of student engagement include participation in formal STEM courses in middle and high school, and other kinds of STEM educational activities such as visits to museums, participation in after-school clubs or programs, internships, and research experiences.

Findings about Specialized STEM Schools and Programs

A major question for the Committee was whether certain types of specialized STEM-focused schools are especially successful at advancing the goals of U.S. STEM education. We identified three type of STEM-focused schools: selective STEM schools, inclusive STEM schools, and schools with STEM-focused career and technical education (CTE). Each type of school has strengths and weaknesses and poses a unique set of challenges associated with implementation.

As I explained at the outset, identifying schools and programs that are most successful in the STEM disciplines is not a simple matter, because it is difficult to determine the extent to which a school's success results from any actions the school takes, or the extent to which it is related to which students are enrolled in the school. Moreover, specialized models of STEM schools are difficult to replicate on a larger scale. That's because the context in which a school is located may facilitate or constrain its success. Specialized STEM schools often benefit from a high level of resources, a highly motivated student body, and freedom from state testing requirements.

Selective STEM schools are organized around one or more of the STEM disciplines and have selective admissions criteria. Typically, these are high schools that enroll relatively small numbers of highly talented and motivated students with a demonstrated interest in and aptitude for STEM. The Committee identified four types of selective STEM schools: state residential schools; stand-alone schools; schools-within-schools; and regional centers with specialized half-day courses. All of these selective STEM schools seek to provide a high-quality education that prepares students to earn STEM degrees and succeed in professional STEM careers.

There are approximately 90 selective STEM specialty high schools in the United States. Examples include Thomas Jefferson High School of Science and Technology, a stand-alone school in Virginia; the North Carolina School of Science and Mathematics, a residential school for grades 11–12; the Illinois Mathematics and Science Academy, a residential high school; and Brooklyn Technical High School, a stand-alone school. At the time of the report, no completed study provided a rigorous analysis of the contributions that selective schools make over and above regular schools. The Committee identified one such study that was, and still is, under way.[5] Preliminary results from that study show that when compared with national samples of high school graduates with ability and interest in STEM subjects, the research experiences of students who graduate from selective schools appear to be associated with their choice to pursue and complete a STEM major.

Since the Successful STEM report was completed, another research study has used a rigorous quasi-experimental design to assess the impact of three selective

[5] Subotnik, R. F., & Tai, R. H. (2011). Successful education in the STEM disciplines: An examination of selective specialized science, mathematics, and technology-focused high schools. Background paper presented at the NRC Workshop on Successful STEM Education in K–12 Schools. Washington, DC: National Research Council.

STEM-focused schools in New York City.[6] Students enrolled in the selective STEM schools took more advanced courses and were more likely to graduate from high school. One of the three schools produced higher SAT mathematics scores compared to non-specialized, non-selective high schools, but the other two did not, and there were no benefits for rates of college enrollment or graduation. It should be clear that research on this topic is just beginning to emerge with designs that allow one to distinguish the effects of selective STEM-focused schools from the effects of who attends such schools.

Inclusive STEM schools emphasize one or more of the STEM disciplines but do not have selective admissions criteria. These schools seek to provide experiences that are similar to those at selective STEM schools, while serving a broader population. Examples include High Tech High, a set of schools in southern California; Manor New Technology High School in Texas; the Denver School for Science and Technology in Colorado for grades 6–12; and Oakcliff Elementary School in Georgia.

Insights from inclusive STEM schools come from an ongoing study of high school reform in Texas.[7] Early findings suggest that students in that state's 51 inclusive STEM schools score slightly higher on the state mathematics and science achievement tests, are less likely to be absent from school, and take more advanced courses than their peers in comparison schools. The schools in the Texas study are new, having opened in 2006–2007 or later. They have achieved these gains within their first three years of operation. Five factors that appear to have helped the schools include (1) a STEM school blueprint that helps to guide school planning and implementation, (2) a college preparatory curriculum and an explicit focus on college readiness for all students, (3) strong academic supports, (4) small school size, and (5) strong support from their district or charter management organization.

STEM-related career and technical education (CTE) serves mainly high school students. It can take place in regional centers, CTE-focused high schools, programs in comprehensive high schools, and career academies. An important goal of STEM-focused CTE is to prepare students for STEM-related careers, often with the broader goal of increasing engagement to prevent students from dropping out of school. Students explore STEM-related career options and learn the practical applications of STEM subjects through the wide range of CTE delivery mechanisms. Examples include Loudoun Governor's Career and Technical Academy, a high school in Virginia; Sussex Technical High School in Delaware; and Los Altos Academy of Engineering, a high school in California. There are many examples of highly regarded CTE schools and programs, but there is little research that would support conclusions about the effectiveness of the programs. One rigorous study of instruction that integrated mathematics content into CTE found benefits for student mathematics achievement, suggesting that CTE and academic achievement need not be in conflict.[8] A similar study is under way to examine the integration of science content into CTE.

The limited research base on these three school types hampered the Committee's ability to compare their effectiveness relative to each other, and for different student populations, or to identify the value these schools add, over and above non-STEM focused schools. However, the available studies suggest some potentially promising—if preliminary and qualified—findings associated for each school type.

The Committee further noted that high levels of STEM learning can also occur in non-STEM focused schools. Much of what we know from research about effective practices comes from comprehensive public schools, which educate the vast majority of our students including many talented students aspiring to STEM careers. At the high school level, Advanced Placement and International Baccalaureate are the most widely recognized programs of advanced study in science and mathematics.

Findings about Effective Classroom Instruction in STEM Fields

One way to think about the Committee's charge is that a successful school is one in which effective instructional practices are implemented widely throughout the school. An advantage to a focus on practices is that it provides schools with concrete

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[6] Dobbie, W., & Fryer, W. G. (2011). Exam high schools and academic achievement: Evidence from New York City. NBER Working Paper 17286. Cambridge, MA: National Bureau of Economic Research.

[7] Young, V. M., House, A., Wang, H., Singleton, C., & Klopfenstein, K. (2011). Inclusive STEM schools: Early promise in Texas and unanswered questions. Background paper presented at the NRC Workshop on Successful STEM Education in K–12 Schools. Washington, DC: National Research Council.

[8] Stone, J. R., III, Alfeld, C., & Pearson, D. (2008). Rigor and relevance: Testing a model of enhanced math learning in career and technical education. American Educational Research Journal, 45, 767–795.

guidance for improving the quality of STEM instruction and, presumably, of STEM learning. Another reason for reporting on instruction is that the evidence on effective practices tends to be stronger than the evidence on school types. The Committee examined two key aspects of practice that are likely to be found in successful schools: instruction that captures students' interest and involves them in STEM activities, and school conditions that support effective STEM instruction.

Effective STEM instruction capitalizes on students' early interest and experiences, identifies and builds on what students already know, and provides students with experiences to engage them in the practices of science and sustain their interest. Effective teachers use what they know about students' understanding to help students apply these practices. In this way, students successively deepen their understanding both of core ideas in the STEM fields and of concepts that are shared across areas of science, mathematics, and engineering. Students also engage with fundamental questions about the material and natural worlds and gain experience in the ways in which scientists have investigated and found answers to those questions.

For this type of K–12 STEM instruction to become the norm, further transformation is needed at the national, state, and local levels. The Committee identified five key elements that may guide educators and policy makers in that direction.

Key element 1: A coherent set of standards and curriculum. The research shows a clear link between what students are expected to learn and mathematics achievement: At a given grade level, greater achievement is associated with covering fewer topics in greater depth. Some evidence suggests that adopting rigorous standards and aligning curriculum and assessments to those standards can lead to gains in student achievement.

The data support the hypothesis that there is a relationship between standards and achievement— that content coverage led by coherent, focused, and rigorous standards, and properly implemented by teachers, can improve student outcomes in mathematics. My own research has supported this claim in the area of mathematics instruction. [9]

Key element 2: Teachers with high capacity to teach in their discipline. To be effective, teachers need content knowledge and they need expertise in teaching that content. But the research suggests that many science and mathematics teachers are underprepared for these demands. For example, in both middle and high schools, many teachers who teach science and mathematics courses are not certified in those subjects and did not major in a related field in college. Estimates of the number of out-of-field science and mathematics teachers in secondary school are between 10 and 20 percent. Moreover, a recent survey of university teacher preparation programs found that future elementary teachers were required to take, on average, only two mathematics courses.

Professional development for teachers in STEM is often short, fragmented, ineffective, and not designed to address the specific need of individual teachers. Instead, teacher development should occur across a continuum that ranges from initial preparation to induction into the practice of teaching, and then to systematic, needs-based professional development, including on-site professional support that allows for interaction and collaboration with colleagues.

Key element 3: A supportive system of assessment and accountability. Current assessments limit teachers' ability to teach in ways that are known to promote learning of scientific and mathematical content and practices. For example, since implementation of the No Child Left Behind (NCLB) Act, surveys of teachers indicate a shift in mathematics instruction away from complex performance assessments toward multiple-choice items, and researchers have argued that this shift leads teachers to teach a narrow curriculum focused on basic skills.

In a supportive system of standards-based science assessment, curriculum, instruction, and assessment are aligned with the standards, target the same goals for learning, and work together to support students' developing science literacy. The classroom, school, school district, and state all share a vision of the goals for science education, the purposes and uses of assessment, and of what constitutes competent performance. The system takes into account how students' science understanding

[9] Gamoran, A., Porter, A. C., Smithson, J., & White, P. A. (1997). Upgrading high school mathematics instruction: Improving learning opportunities for low-income, low-achieving youth. *Educational Evaluation and Policy Analysis*, 19, 325–338; Gamoran, A. (2001). Beyond curriculum wars: Content and understanding in mathematics. Pp. 134–162 in T. Loveless (Ed.), *The great curriculum debate: How should we teach reading and math?* Washington, DC: Brookings Institution Press.

develops over time and the scientific content knowledge, abilities, and understanding that are needed for learning to progress at each stage of the process.[10]

A supportive accountability system focuses on teacher practices as well as on student outcomes. For example at the Illinois Mathematics and Science Academy, teachers' use of science inquiry practices are monitored with student surveys, classroom observations, and external reviews.

Key element 4: Adequate instructional time. The NCLB Act has also changed the time allotted for science, technology, engineering, and mathematics instruction in the K–12 curriculum. Particularly in elementary school, instruction emphasizes mathematics and English language arts because those subjects are tested annually under the current accountability system. Meanwhile, surveys of districts, schools, and teachers are reporting diminished instructional time for science in elementary schools. The decrease in time for science education is a particular concern because some research suggests that interest in science careers may develop in the elementary school years.

Key element 5: Equal access to high-quality STEM learning opportunities. Many factors contribute to students having unequal access, including poverty, but we focused on structural inequalities that states, schools, and districts have the potential to address. For example, disparities in teacher expectations and other school and classroom-level factors, such as access to adequate laboratory facilities, resources, and supplies, contribute to gaps in science achievement for underrepresented groups. Similar structural inequities hinder the mathematics learning of underrepresented minorities and low-income students, such as disparities in access to well-trained or credentialed teachers, less rigorous educational courses, and ability tracking in the early grades. In mathematics, these inequalities can have cumulative effects as students progress through grades K–12 because mathematics is a gatekeeper to academic opportunity. Policies to ensure that well-prepared teachers are placed in all classrooms can redress the imbalance in students' access to qualified teachers.

Findings about School Conditions that Support Effective Instruction

Strong teachers and focused, rigorous, and coherent curricula are certainly important factors to improve student learning in STEM. However, school and community conditions also affect what is taught, how it is taught, and with which results. A variety of studies highlight the value of teacher learning communities as a source of improvement in teacher and student learning. In a study of 200 low-performing elementary schools in Chicago, no schools with a poor learning climate and weak professional community substantially improved math or reading scores. However, about half of schools with a well-aligned curriculum and a strong professional community among teachers substantially improved math and reading achievement.[11] The elementary schools that improved student learning in mathematics and reading shared five common elements, as summarized in the *Successful STEM* report (p.24):

1. School leadership as the driver for change. Principals must be strategic, focused on instruction, and inclusive of others in the leadership work.
2. Professional capacity, or the quality of the faculty and staff recruited to the school, their base beliefs and values about change, the quality of ongoing professional development, and the capacity of a staff to work together.
3. Parent-community ties that involve active outreach to make school a welcoming place for parents, engage them in supporting their children's academic success, and strengthen connections to other local institutions.
4. Student-centered learning climate. Such a climate is safe, welcoming, stimulating and nurturing environment focused on learning for all students.
5. Instructional guidance that is focused on the organization of the curriculum, the nature of academic demand or challenges it poses, and the tools teachers have to advance learning (such as instructional materials).

The strength of these supports varied within and across elementary schools in Chicago: Some schools were strong along all dimensions, and some were stronger in some dimensions than in others. Although not all of these supports need to be

[10] For more on this vision of science assessment, see: National Research Council. (2006). *Systems for state science assessment.* Washington, DC: National Academies Press.

[11] Bryk, A. S., Sebring, P. B., Allensworth, E., Luppescu, S., & Easton, J. (2010). *Organizing schools for improvement: Lessons from Chicago.* Chicago: University of Chicago Press.

strong for schools to succeed, schools that were weak on all of these dimensions showed no gains in achievement.

Gaps in Our Knowledge about Successful K–12 STEM Education

Careful assessment of existing research is valuable not only because of the findings it reveals, but also because it helps identify gaps in our knowledge that need to be filled before we can fully answer questions about highly successful STEM schools and programs. The Committee identified four major areas that urgently require new research.

- Research that links organizational and instructional practices to longitudinal data on student outcomes.

State longitudinal data systems now permit researchers and policy makers to monitor student achievement trends over times and across schools and classrooms. Yet too little is known about the conditions under which achievement differences are produced. We need more research like the Chicago study that linked school conditions and instructional practices to student outcomes. Work of this sort is currently under way at the National Center for Scaling Up Effective Schools at Vanderbilt University. This type of work is especially critical because successful implementation of STEM programs may depend on contextual factors such as leadership and professional supports.

- Research on student outcomes other than achievement

While we know too little about conditions that elevate achievement and reduce achievement gaps, we know even less about other outcomes of STEM education. A successful school or program is one that not only promotes cognitive growth but also stimulates interest, entices students with the allure of scientific discovery, provides opportunities for inquiry and research, and motivates students to engage in scientific pursuits. Few studies investigate these outcomes using designs that permit one to discern school or program effects.

- Research on STEM programs and schools that allows one to distinguish school effects from effects of student characteristics; that identifies distinctive aspects of educational practices; and that measures long-term effectiveness relative to goals.

As noted earlier, a shortage of studies that permit conclusions about cause and effect was one of the major challenges faced by the Committee. More such studies are needed to allow firm conclusions about successful schools and programs. At the same time, studies that adopt experimental designs often take a "black box" approach by not investigating what is occurring inside the school or classroom, and this limits the information one can draw, especially if the program is not as effective as expected. Studies are needed that not only identify program effects, but reveal how those effects emerge. Moreover, research grant funding cycles mean there is an unfortunate tendency to focus on short-term outcomes of a year or two (or even less). Effective programs, however, often take five years to reach a high level of success. Many programs deemed ineffective may not have been sustained or studied for long enough to have the chance to succeed. Consequently, research with a longer horizon is also needed.

- Research on effects of professional development for STEM teachers and of school culture for student learning

The Committee noted that an emerging consensus among researchers has identified characteristics of effective professional development. Yet these characteristics have yet to be confirmed with research designed to measure impact. This is regarded as an extremely important area of research because teacher quality is a major source of variation in student achievement. Professional development that elevates the quality of teaching is one potential strategy to enhance STEM learning and reduce learning gaps. Research is also urgently needed on which aspects of school culture contribute to STEM learning, especially in schools that serve high proportions of students who are underrepresented in the STEM fields, such as low-income and minority students.

Implications of the Successful STEM Report for the Federal Role in K–12 STEM Education

In my judgment, the federal government plays two essential roles in K–12 STEM education: leveraging excellence and fostering equity. Leverage for excellence occurs when the government sponsors research that yields new understandings of how children learn in the STEM domains, how teachers can teach more effectively, and how schools and districts can better support effective teaching. It also occurs when the federal government sponsors programs to train outstanding new teachers and leaders for U.S. schools. These programs also foster equity when they focus on improving conditions for students from disadvantaged backgrounds. The federal government also helps foster equity by holding states, schools, and districts accountable for providing equal educational opportunities for students of all backgrounds.

Federal Support for STEM Education Research

No other entity can fill the federal government's key role in supporting research on STEM education. Much of the research reviewed in the Successful STEM report was supported by federal funding, mainly through the National Science Foundation (NSF) and the U.S. Department of Education's Institute of Education Sciences. The Successful STEM report shows that while much has been learned, the gaps in our knowledge remain wide.

Funding for STEM education research should remain a priority despite the fiscal challenges of our times. Like the authors of another NRC report, Rising Above the Gathering Storm, I believe our nation cannot afford to back away from investments in STEM education that are crucial for our long-term economic and social prosperity. The Education and Human Resources Directorate (EHR) at NSF and the Institute of Education Sciences at the Department of Education are the primary sponsors of STEM education research; the professional expertise of their staffs and their engagement with the research community including reliance on scientific peer review for funding decisions have positioned them well for this role.

A challenge for NSF funding of STEM education research is that recent laudable funding for developing STEM teachers and leaders has come at the expense of funding for research. Both are important, and indeed the Successful STEM report encourages federal investment in "a coherent, focused, and sustained set of supports for STEM teachers" (p.28). Yet these supports should complement rather than compete with funding for research-based innovations that can have wide and long-lasting implications. Moreover, the Committee urged that "federal funding for STEM-focused schools should be tied to a robust, strategic research agenda" (p.28), so that the questions put to the Committee can be fully addressed in the future.

The Committee recommended federal support for "research that disentangles the effects of school practice from student selection, recognizes the importance of contextual variables, and allows for longitudinal assessment of student outcomes" (p.28). It is important that NSF continue to fund basic as well as applied research in STEM education. While rigorous impact studies are essential, they cannot be the only focus of education research because there is still much to learn about basic questions such as how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers. Particularly in light of the applied research mission of the Institute of Education Sciences (IES), it is important that NSF continue to support research that addresses more basic questions about fundamental processes that lie behind teaching and learning. Indeed, collaboration between IES at the Department of Education and EHR at NSF can help ensure that ongoing research covers the continuum from basic insights about STEM teaching, learning, and leading to research on applications as they are tested, replicated, and implemented at scale.

In addition to NSF and IES, numerous federal agencies have small roles in education research and programming. This scattershot approach should be reconsidered as the more concentrated investments at agencies where education research is the primary mission are likely to have higher yield.

Federal Support for Equal Opportunity

With the passage of the No Child Left Behind (NCLB) Act of 2001, the federal government greatly expanded its role in holding states, districts, and schools accountable for student performance. NCLB has galvanized the attention of educators and the public towards elevating achievement, and has highlighted the pervasive inequalities in achievement in U.S. education. Yet the Committee identified two major negative consequences of NCLB that could be addressed in new federal legislation.

First, the assessments used for accountability tend to be inadequate to promote deep understanding in the STEM domains. In mathematics, now tested in all states every year in grades 3–8, assessments commonly used for accountability focus on fragmented bits of information instead of more meaningful knowledge. By contrast, a system of assessments that spans the range from basic concepts to deep understanding could be equally well tied to standards and more supportive of instruction. Efforts to develop such assessments are currently under way in two multistate consortia supported by substantial federal funding. Similar efforts are needed in science. The National Research Council recently developed a new and generally acclaimed conceptual framework for 21st century science education standards.[12] Currently, over 20 states have signed onto an initiative by Achieve, Inc. to develop new standards. When the standards are complete, a major federal investment will be needed to develop assessments that align with the standards, so that student performance can be benchmarked to the new standards and student growth monitored over time.

Second, the Committee learned that NCLB's emphasis on reading and mathematics is squeezing out time for science instruction. Particularly at the elementary level, studies show that less time is being devoted to science, presumably because it is not a subject for which schools are held accountable. Yet other research points to the importance of capturing students' interest in science at an early age. This may be particularly important for disadvantaged youth who have fewer opportunities for science learning in their homes and neighborhoods. The Committee thus recommended that science should be elevated to the same level of importance as mathematics and reading in federal and state accountability systems. Science should be tested with the same frequency as mathematics and reading using assessments that support learning and understanding.

A major source of educational inequality in the U.S. is that which lies between states. While the federal government cannot compel states to adopt high standards, it can provide incentives that encourage states to promote high levels of STEM learning and to equalize opportunities for learning among students from all backgrounds.

Chairman BROOKS. Thank you, Dr. Gamoran.

Next, we have Mr. Heffron. You may begin your five minutes.

STATEMENT OF MR. MARK HEFFRON, DIRECTOR, DENVER SCHOOL FOR SCIENCE AND TECHNOLOGY: STAPLETON HIGH SCHOOL

Mr. HEFFRON. Thank you, Chairman Brooks and members of the committee, for the opportunity to testify on this critical topic facing our Nation. I applaud the foresight of the Committee to commission the National Academy study on successful K–12 STEM models in the country seeking to find what works.

I serve as the Campus Director of a 6–12 STEM school in Denver, DSST's Public Schools network of charter schools. DSST Public Schools currently operates five STEM open-enrollment charter schools, three middle school and two high schools, serving 1,500 students in Denver. Because we are a charter school, all of our students enroll through a non-selective, random lottery. As a result, our student body is diverse. Fifty percent of our students are low income and 70 percent are minorities. This is roughly half African American and half Hispanic. Our schools truly represent a cross-section of Denver, the city we serve.

DSST Public Schools operate some of the most successful public schools in Colorado. Last year, our schools operated the highest-performing middle school and high school in Denver. We are most proud, though, of our measures that show growth, meaning how much did a student learn from the first day of school to the last day of school? Within the State of Colorado, our schools showed some of the highest growth numbers of all public schools, according to the Colorado Model on State CSAP tests. And at DSST Stapleton High School, the school I lead, all of our four senior classes in the school's history have earned acceptance to four-year colleges. All of our students are prepared to study STEM fields of study in college,

[12] National Research Council. (2011). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: National Academies Press.*

and we estimate that 40 percent of our students are choosing to do so.

Most importantly, DSST proves without a doubt that all students, regardless of race or income, can earn a rigorous STEM high school diploma and attend a four-year college or university. Preparing every student to succeed in a four-year college with the opportunity to study STEM is at the center of our academic program, which is centered on three pillars.

First, our schools are built on the premise that all students deserve access to a high-quality STEM education. A majority of DSST students enter well below grade level in the sixth and ninth grades and could never test into a magnet science program. Many students are conditioned to believe that science and advanced math is an extra and only for smart kids. In our schools, these subjects are not extras but core subjects that all students are required to take. All students have access to STEM college preparatory curriculum.

Our second key belief is that schools must provide a rigorous STEM preparatory curriculum. We believe that the most important factor in a student choosing and ultimately completing a STEM degree is their preparedness to succeed at college and the graduate level. Regardless of their starting point at DSST, all students are expected to pass three years of integrated science in middle school and more than five years in high school. Many students choose more than that.

Students take algebra-based high school physics in the ninth grade. This provides students with a lab-based class to practice, apply, and synthesize the math skills they are learning elsewhere. All ninth grade students also take “Creative Engineering” where they learn the design process, how to conduct basic research, how to maximize and minimize constraints, and are hooked into engineering and sciences as careers that improve the human condition.

Students complete their high school requirements by taking a college-level physics class coupled with an engineering course or a college level biochemistry class coupled with a bio-technology class. Math is also a critical component. All students take four years and must successfully complete pre-calculus to graduate.

Lastly, we believe that the success of any school must be rooted in a strong school culture that focuses on building character and creating an accountable environment that expects all students to be college-ready. Students are challenged and supported in our schools. A peer-driven culture is reflected in each of our schools where going to college is cool and expected.

In sum, we agree with the recommendations of the National Academy’s Report. However, I would like to highlight four recommendations for further consideration by this committee: First, while we agree that there is a clear need to create more STEM schools, we urge this committee to stress the creation of open-enrollment, access for all STEM schools. Only through these schools will we tap into the potential of all children in our country to create new labor markets for our STEM fields.

Second, we must create rigorous STEM schools that go beyond “engaging” students into STEM to truly preparing them for STEM post-secondary study with rigorous math and science instruction. Getting students excited about STEM is important, but the larger problem lies in that most students lack open access to programs that truly prepare them for those STEM degrees.

Third, we must do more to simply create great schools built on high expectations and high accountability cultures. The emphasis needs to be on high-quality models, not just more STEM schools.

Fourth, we need to attract more high-quality candidates to teaching math and science. DSST Public Schools is a proud member of the 100Kin10 initiative to help recruit science and math teachers over the next decade. This is a critical area of focus and effort.

On behalf of DSST Public Schools, I thank you for the opportunity to share and welcome further dialogue around the importance of creating high-quality STEM education options in our country.

[The prepared statement of Mr. Heffron follows:]

PREPARED STATEMENT OF MR. MARK HEFFRON, DIRECTOR, DENVER SCHOOL OF SCIENCE AND TECHNOLOGY, STAPLETON HIGH SCHOOL

Thank you, Chairman Hall, and the Members of the Committee, for the opportunity to testify on this critical topic facing our nation. I applaud the foresight of the Committee to commission the National Academy study on successful K–12 STEM models in our country—seeking to find what works.

I serve as the Campus Director of a 6–12 STEM school in the Denver School for Science and Technology (DSST) Public Schools network of charter schools. DSST Public Schools currently operates five STEM open-enrollment charter schools, three middle schools and two high schools, serving over 1,500 students in Denver, Colorado.

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DSST Public Schools operates some of the most successful public schools in Colorado. Last year, DSST Public Schools operated the highest performing middle school and high school in Denver. We are most proud of measures that show growth—meaning, how much did a student learn from the first day of school to the last day of school. Within the state of Colorado, our schools showed some of the highest growth numbers of all public schools, according to the Colorado Growth Model on State CSAP tests. And at DSST: Stapleton High School, the school I lead, 100% of all four senior classes in the school's history have earned acceptances to four year colleges. All of our students are prepared to study STEM fields of study in college and we estimate that 40% of our students are choosing STEM fields after graduation.

Most importantly, DSST proves, without a doubt, that all students, regardless of race or income, can earn a rigorous STEM high school diploma and attend four-year colleges and universities.

Preparing every student to succeed in a four-year college with the opportunity to study STEM is at the center of DSST's academic program. Our STEM program is centered on three pillars.

First, our schools are built on the premise that all students deserve access to a high quality STEM education. A majority of DSST students enter well below grade level in the 6th and 9th grades and could never test into a magnet science program. Many students are conditioned to believe that science and advanced math "is an extra" and only for "smart kids". In our schools, these subjects are not extras, but a core subject for all students. All students have access to STEM college preparatory curriculum.

Our second key belief is that schools must provide a rigorous STEM preparatory curriculum. We believe that the most important factor in a student choosing and ultimately completing a STEM degree is their preparedness to succeed at the college and graduate level.

Regardless of their starting point at DSST, all students are expected to pass three years of integrated science in middle school and more than five years in high school—and many students take more. Students take an algebra-based high school physics in the 9th grade. This provides students with a lab based class to practice, apply and synthesize the math skills they are learning elsewhere. All 9th grade students also take "Creative Engineering" where they learn the design process, how to conduct basic research, how to maximize and minimize constraints, and are hooked into engineering and the sciences as careers that improve the human condition. Students complete their high school requirements by taking a college level- physics class coupled with an engineering course or a college level biochemistry class coupled with a bio-technology class. Math is also a critical component of a rigorous STEM curriculum. All DSST students are required to pass at least pre-calculus to graduate.

Lastly, we believe the success of any school must be rooted in a strong school culture that focuses on building character and creating an accountable environment that expects all students to be college ready. Students are challenged, but supported in our schools. A peer-driven culture is reflected in each of our schools where going to college is cool and expected.

In sum, we agree with the recommendations for the National Academy's Report. However, I would like to highlight four recommendations for further consideration by this Committee:

- First, while we agree that there is a clear need to create more STEM Schools, we urge this committee to stress the creation of open-enrollment, access for all STEM schools. Only through these schools will we tap into the potential of all children in our country to create new labor markets for our STEM fields.
- Second, we must create rigorous STEM schools that go beyond "engaging" students in STEM to truly preparing them for STEM post-secondary study with rigorous math and science instruction. Getting students "excited" about STEM is important, but the larger problem lies in that most students lack open access to programs with the rigor needed to prepare them for college STEM degrees.
- Third, we must do more to simply create great schools built on high expectations and high accountability cultures. The emphasis needs to be on high quality models that focus on STEM instruction, not just more STEM Schools.
- Fourth, we need to attract more high quality candidates to teaching math and science. DSST Public Schools is a proud member of the 100Kin10 initiative to help recruit and retain 100,000 new math and science teachers over the next decade. This is a critical area of focus and effort.

On behalf of DSST Public Schools and Denver Public Schools, I thank you for the opportunity to share, and welcome further dialogue around the importance of creating high quality STEM education options for our country.

Chairman BROOKS. Thank you, Mr. Heffron, for your testimony and insight.

At this point, the Chair will recognize Dr. Wilson for her five minutes.

STATEMENT OF DR. SUZANNE WILSON, CHAIR, DEPARTMENT OF TEACHER EDUCATION, DIVISION OF SCIENCE AND MATH AND EDUCATION, MICHIGAN STATE UNIVERSITY

Dr. WILSON. Thank you, Chairman Brooks, Chairman Wolf, Ranking Member Lipinski, and other Members of the Subcommittee for this opportunity to speak with you today.

In my prepared statement, I prepared—I provide an overview of the current teacher support system and comment on the challenges we face. In my comments now, I would like to emphasize what I consider to be our core problem and suggest to you how we might solve it.

The vision of STEM education in the NRC report is ambitious. It includes increased study of engineering and technology and it also includes learning science and mathematics in challenging and rigorous ways. Unfortunately, most of the 3.6 million teachers who now teach in our schools, as well as the 1.7 million teachers we will need in the next seven years, have themselves never had opportunities to learn engineering and technology nor engage in the practices of deep study of science and mathematics and so they teach what and how they were taught. This is a vicious cycle that we need to break.

Part of the solution is the development of good assessments and curriculum. Part of the solution is creating schools that are good environments for learning by students and by their teachers. Part of the solution is improving initial teacher training and ongoing teacher development so that teachers can learn this new content and learn to teach it.

Let me make clear to you just how localized and uncoordinated our so-called system of supplying quality STEM teachers is. We stand out among other leading countries for our lack of a national infrastructure for high-quality schooling. Here is what I mean: there are over 1,200 teacher preparation programs at universities; there are another 130 alternative routes; there are as many if not more early career professional induction programs; there are 1,500 school districts in the United States, and each has an entirely independent portfolio of training for its teachers. There is no coordination and the quality and effectiveness is both variable and often weak.

This “system” of professional training is a carnival. It is crowded, it is noisy, it is alternatively attractive and seedy with no order or coherence. Teachers walk down the midway and wander as they please. They attend a teacher preparation program with one particular emphasis and then they head off to an induction program with another. They sign up for professional development because of their interests, their convenience, or mandate.

Considerable personal, public, state, and federal resources are poured into teacher development programs. Despite the investment of these material and human resources, teachers seldom receive coordinated guidance about what they should study or have opportunity to select professional development that builds on their previous experiences. This is irresponsible. It has adverse effects for our young people and on our Nation’s position in a rapidly changing world and global economy.

If we expect to excel in STEM education, we must build a system to deliver it. We can no longer leave to local preference what teachers know and what they can do. Teaching well demands substantial skill and should not be made up one school, one district, even perhaps one state at a time. In no other professional where skilled trade do we leave so much up to chance. We are in a position to fix this problem. The Federal Government can help.

We can establish specific standards for teaching practice and build a professionally valid licensure system which would include common core state standards for teachers that are aligned with but go well beyond the common core state standards for K–12 students; teacher preparation and professional development programs that are aligned with those standards; high-quality, rigorous training that is anchored in classroom practice and that is designed to support teachers over time; teacher training that differentiates between the needs of beginning teachers and experienced teachers and that focuses on a few empirically validated high-leverage teaching practices; classrooms and schools that are designed to support instruction and its continuous improvement; credible and predictive assessments of teacher knowledge and skill that can both provide feedback to those who need to improve and differentiate between the teachers who can teach and those who should be let go.

And if we are to hold teachers and teacher preparation programs accountable for the kind of student learning and engagement that is portrayed in this report, we also need K–12 student assessments that focus on the kind of outcomes envisioned and not what is easiest to test.

Thank you for your time.

[The prepared statement of Ms. Wilson follows:]

PREPARED STATEMENT OF DR. SUZANNE WILSON, CHAIR, DEPARTMENT OF TEACHER EDUCATION, DIVISION OF SCIENCE AND MATH, EDUCATION, MICHIGAN STATE UNIVERSITY

Thank you Chairman Brooks, Ranking Member Lipinski, and the other Members of the Subcommittee, for this opportunity to discuss the Federal government's role in K–12 STEM education. I am pleased to add my perspective on the Committee's questions, drawn from nearly 35 years in academia as first a high school mathematics teacher, then, teacher educator and education policy researcher, and now as chair of the Department of Teacher Education at Michigan State University, where I also conduct research on the effects of teacher preparation, professional development, and education policy. I also note that I was commissioned to prepare a review of the literature for the National Research Council's (2011) Board on Science Education and Board on Testing and Assessment workshop on Highly Successful K–12 STEM Education in School. I have also served on several NRC panels, including the one that issued the report on teacher preparation and Congressionally mandated (Preparing Teachers, 2010), and am a newly appointed member of the Board on Science Education. I also chaired the National Academy of Education's (2009) White Paper committee on teacher quality, which was also undertaken in response to the requests of several senators.

My expertise is in the area of teacher quality policies and practices, specifically teacher preparation, induction (early career support), and professional development. I will keep my comments focused on that domain.

The Critical Role of STEM Teacher Preparation, Induction, and Professional Development

While there is currently considerable debate about where and how teachers should be prepared, there is little question that STEM education depends on the sound preparation of K–12 teachers. Research clearly shows that it takes between 3–8 years to become an effective teacher, which underlines the importance of strong early career support (often called induction). And given the lackluster performance of U.S. schools in STEM education overall—as well as the push for higher and more demanding standards—there seems little question that we need equally strong professional development to build the capacity of practicing teachers. Further, there seems little debate about the need for all teachers to have sufficient content knowledge, as well as knowledge and skill in working with and adapting instruction for one's particular students, selecting and using appropriate curriculum materials, assessments, and other resources.

However, beyond that, there is much less agreement on who should prepare teachers, how that preparation should be structured and organized, and how to differentiate between the initial preparation of teachers and support they receive over their careers. This has resulted in what some have called a "non-system" of teacher support in this country: There are over 1200 teacher education programs at universities, another 130 "alternative routes," and at least as many induction programs. Every one of the over-15,000 school districts in the U.S. has multiple professional development programs sponsored by school districts, foundations, federal grants, universities, informal institutions, and other agencies. While there are similarities across some of these programs, there is considerable variation in content and quality.

However, we know that high quality teacher support needs to be anchored in clear and concrete vision of both what we want our K–12 students to learn and the instruction and other factors that lead to that learning. The NRC (2011) report, *Successful K–12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* accurately notes that effective STEM instruction:

> … students successively deepen their understanding both of core ideas in the STEM fields and of concepts that are shared across areas of science, mathematics, and engineering. Students also engage with fundamental questions about the material and natural worlds and gain experience in the ways in which scientists have investigated and found answers to those questions. In grades K–12, students carry out scientific investigations and engineering design projects related to core ideas in the disciplines, so that by the end of their secondary schooling they have become deeply familiar with core ideas in STEM and have had a chance to develop their own identity as STEM learners through the practices of science, mathematics, and engineering.

These are ambitious—and in the case of technology and engineering, new, ideas for what all students should learn and do in schools. Unfortunately, this kind of instruction is rare in U.S. K–12 schools. And because our future teachers come through those schools, there are many teachers, especially elementary teachers, who themselves have never experienced that kind of instruction. I also note that although the problem is exacerbated for prospective elementary teachers, the majority of prospective middle and high school teachers seldom have an opportunity for first hand experience with the "practices of science, mathematics, and engineering."

Breaking this cycle requires improved teacher preparation (both in terms of the quality and quantity of teachers' engagement with relevant disciplinary content and in terms of professional coursework and experiences), subject-specific support during induction, professional development that targets teachers' needs and systematically builds on prior STEM learning, and professional communities in schools where teachers and administrators collectively focus on their students' learning. It would also entail considerable research to identify both the effective instructional strategies, educational resources, school supports, and teacher development programs that would inform those changes.

Main Points

Before elaborating, I present four main points that frame my comments:

- We have high aspirations for mathematics and science learning, and some new ideas about what children should learn about technology and engineering.
- Many of our teachers have never experienced, as students, the learning we envision in those domains for their students.
- We have a massively incoherent system and very challenging contexts for instructional improvement.
- Yet we do know some things about improving instruction (including preservice and prospective teachers' training). And there are concrete things we can do to address the challenges that lay before us.

Challenges Facing STEM Initial Teacher Preparation

There is a growing consensus that initial preparation of teachers needs to include substantial study of the relevant disciplines. This is not identical to disciplinary majors, as the K–12 school subjects are not always taught in college majors. Thus, teacher preparation needs to be designed to explicitly address the content that will be taught. The development of the Common Core State Standards will help in this regard, as they clearly lay out the focal content that teachers will need to know how to teach. There is also consensus that teachers need professional knowledge that goes beyond subject matter, and that the process of learning to apply that knowledge in practice requires focused attention to a core set of teaching practices, over time, in structured and well-designed field experiences.

That said, teacher preparation currently faces several challenges:

- One overarching challenge has been the lack of a common curriculum that all teachers will teach. This has contributed to the diffuse nature of initial teacher preparation across the country since programs do not know what content or curriculum their graduates need to be prepared to use. The development of the Common Core State Standards might potentially help in this regard.
- Not surprisingly, therefore, there also exists no common curriculum for the preparation of teachers. And there is no agreement on what initial teacher preparation should focus on as opposed to the support of practicing teachers. This results in both variations in the content of what new teachers learn in their programs and an approach similar to the "a mile wide and an inch deep" char-

acterization of U.S. mathematics education offered by William Schmidt and his colleagues in the TIMSS study.

- Another challenge, specific to elementary school, is that teachers are expected to teach all subjects. Most universities limit the maximum credits required for an undergraduate degree; given the need to prepare all elementary teachers to teach all subjects, and the increasing number of mandates about what they need to know (special education, English Language Learners, the arts, all academic subjects, etc.), most prospective elementary teachers have limited exposure to STEM disciplinary content. Specifically, the average elementary teacher might take two mathematics courses, two science sources (neither of which engages them in genuine science inquiry), no engineering courses, and if they take a technology class it is likely about instructional technology, not technology generally.
- At the middle and high school levels, recruitment into STEM teaching continues to be a challenge, especially in terms of long-term solutions that can be institutionalized. Programs with financial incentives or benefits at the front end (subsidized preparation, for example) have uneven track records for preparing teachers who stay in the profession. In an age of shrinking resources, it is unclear how programs or schools will secure funding to continue those programs.
- Middle school STEM teacher preparation continues to be serious challenge. The most recent research by William Schmidt and colleagues suggests that middle school mathematics teacher preparation programs in the U.S. are wildly uneven. State certification laws also vary, and many middle school teachers were originally prepared as elementary teachers (and therefore have limited disciplinary content preparation (see above)).

To address these challenges, we must establish specific standards for teaching practice and build a professionally valid licensure system. Assessments would focus on teachers' content knowledge, their actual skill with the instructional practices most important for student learning, and their persistence in working to make sure that every one of their students learns. These assessments would be different from the ones we currently have in this country which do not, for the most part, focus on the ability to teach.

To prepare teachers for these standards, we need to engage prospective teachers in disciplinary study directly related to the school subjects they will teach. We also need to integrate more content concerning engineering and technology into the teacher preparation curriculum, without making the curriculum wider and thinner. In terms of professional preparation, we need to design a system of high-quality rigorous training that is centered on practice. This system would require three components:

1. A curriculum focused on the highest leverage instructional practices and specialized knowledge of the academic content that teachers teach;
2. Close practice and feedback in clinical settings so that teachers can be deliberately taught and explicitly coached with the skills to reach a wide range of learners.
3. Highly credible and predictive assessments of professional knowledge and skill so that no one enters a classroom without demonstrated capacity for effective performance as a beginning teacher.

In addition, we might want to consider alternative staffing patterns in elementary schools so that teachers can specialize in particular content.

Challenges Facing Professional Development

There is also a growing consensus among researchers regarding characteristics of high quality professional development, especially of effective science professional development. In particular, the *National Science Education Standards* (National Research Council, 1996) published professional development guidelines for teachers. Those standards emphasize the importance of professional development that focuses on subject matter, draws upon teachers' current practices and experiences, and is intensive and sustained. This resonates with the NRC report's findings, specifically the statement that:

- In any discipline, effective professional development should
  - focus on developing teachers' capabilities and knowledge to teach content and subject matter,
  - address teachers' classroom work and the problems they encounter in their school settings, and

- provide multiple and sustained opportunities for teacher learning over a substantial time interval. (p. 21)

However, as the report authors note, the empirical evidence supporting these professional development characteristics is not always consistent and little research allows us to trace "the causal pathway from professional development to student achievement." Additionally, other factors pertaining to teachers and schools also appear to play a noteworthy role in each characteristic's importance.

STEM professional development programs in this country vary enormously in terms of their content and character and the challenges they face include:

- There is no agreed upon curriculum for professional development of STEM teachers. Professional development leaders often identify "big ideas" that transcend particular curricula: in science that might include the nature of science or scientific inquiry, or key concepts (like force and motion or natural selection) that seem foundational to scientific disciplines (like physics or biology). In mathematics, this might include fractions, patterns and functions, or reasoning and proof. But these big ideas are not selected in any systematic or deliberate way, and most professional development does not build on what teachers have already learned. Here too the Common Core State Standards might provide some guidance.
- Inconsistency and lack of predictability in terms of what teachers have learned prior to specific professional development. Thus, professional development leaders can have very experienced and brand new teachers in the same workshop, and those teachers can have little to high knowledge of STEM content.
- Lack of diagnostic information concerning what teachers need to learn. We do not tailor professional development in this country to the learning needs of the specific teachers in the class.
- Lack of centralized funding for professional development or plans to use funding in coherent ways. This includes a lack of integration and coordination of professional development concerning STEM education and other knowledge/skills teachers need to work on, including teaching STEM content to English Language Learners, or adapting STEM instruction to diverse student populations.
- School districts and states lack policies, practices, and resources that support the long term, sustained, collective focus that research suggests is necessary for high quality professional development.

In sum, professional development for STEM teachers is most often a patchwork of fragmented and disconnected experiences. The teachers who need the most support often do not pursue such opportunities. The NRC report authors note that:

> professional development alone is not a solution to current limitations on teachers' capacities. Instead, it is more productive to consider teacher development as a continuum that ranges from initial preparation to induction into the practice of teaching and then to systematic, needs-based professional development, including on-site professional support that allows for interaction and collaboration with colleagues. (p. 21)

To address these challenges, we need to radically change the way that states and school districts think about professional development. On-going teacher learning needs to be part of the mission of every school. Schools have to be structured and resourced so that teachers have clear instructional guidance, sound materials, a strong school leader, and time to work with other teachers on improving instruction and tailoring it to the specific children in that school. Professional development needs to be focus on the content teachers are responsible for teaching, and it needs to be tailored to the learning needs of the teachers involved. It needs to gradually become more and more sophisticated along the career paths of teachers.

Similar to initial preparation, the components of professional development would include:

1. A well articulated curriculum focused on the highest leverage instructional practices and specialized knowledge of the academic content that teachers teach, building on what teachers mastered during their initial preparation;
2. Close practice and feedback in their classrooms, including coaching.
3. Highly credible and predictive assessments of professional knowledge and skill so underperforming teachers can be identified and supported or, if they do not improve, removed.

The Current State of Teacher Assessment

Teacher assessment is under a great deal of scrutiny. In many current evaluation systems teachers receive almost universally high ratings. As many of these systems use a binary means of scoring (satisfactory or not), the systems also do not give teachers useful information to improve their practice. There has been a great deal of research and commentary on the quality of value added measures of teachers. However promising these methods might be, there are still several enormous challenges to the measurement and policy community related to these measures:

- Student achievement and gains are influenced by other factors besides the teacher, including, school factors such as class sizes, curriculum materials, instructional time; home and community supports; individual student needs and abilities, health, and attendance; peer culture and achievement; and prior teachers and schooling, as well as other current teachers. Most of these factors are not actually measured in value-added models. (AERA/NAE, 2011)
- Second, value-added estimates are based on test scores that "reflect a narrower set of educational goals than most parents and educators have for their students. If this narrowing is severe, and if the test does not cover the most important educational goals from state content standards in sufficient breadth or depth, then the value-added results will offer limited or even misleading information about the effectiveness of schools, teachers, or programs" (NRC, Getting Value Out of Value-Added, 2010).

For the purposes of this committee's discussions, tests currently do not measure the "practices" of the disciplines, for instance, the ability of students to engage in scientific inquiry or reason mathematically. Nor do the tests measure students' continued interest in, commitment to, or engagement in STEM fields. Here one can see the interdependence of research on student and teachers. Without good research on student engagement and learning, any and all attempts to measure teacher effectiveness are hamstrung.

There is other work underway in teacher assessment as well, specifically in the area of creating observation protocols for measuring teacher quality. This would allow for more refined documentation of instruction. However, preliminary work suggests that training raters to score such protocols reliably continues to be a challenge.

The Role of the Federal Government in K–12 STEM Education

While our teacher preparation and professional development practices may appear inconsistent— like the larger educational system they serve—they were built from the bottom up, school-by-school, program-by-program; and were designed to serve locally managed and funded markets. This is not to say that they were or are immune to national issues; consider that with the Elementary and Secondary Act of 1965, and continuing even today, they have steadily worked at better serving students across lines of race, gender, and ability with the goal of achieving equality. At present, and for indisputably good reason, the national press in on for quality in addition to equality.

In terms of teacher preparation, induction, and professional development, the primary role of the federal government has been to produce resources to stimulate thinking about state and district level policies, programs, and practices, as well as to press for increased evidence of effectiveness. In particular, research and development work sponsored by the National Science Foundation and the Department of Education, including the Institute for Education Sciences has played a major role in influencing how we think about teacher preparation and professional development, as well as how we assess its effectiveness (see below). But that support has been limited, especially in the area of teacher preparation, and it has not been leveraged to catalyze coherence or the accumulation of knowledge.

What role might the federal government play to shape reform in STEM education? There are several avenues to pursue that could encourage more coherence and focus.

- Use the Common Core State Standards to focus the initial preparation of teachers. Because states control teacher licensure, this might include providing guidance and resources to states to align state policies with the CCSS.
- Federal investment in the development of resources might focus on programs and materials that also align with the CCSS so that teachers have strong instructional materials.
- Expand investment in the assessment consortia to include assessments that go beyond content knowledge in ways that align with the recommendations of the NRC report (these are essential for anchoring teacher assessment/evaluation).

- Create consortia for the development of **teacher** assessments that align with the knowledge/skill teachers would need to master to effectively teach to the CCSS.
- As all teacher preparation programs are pressed to tie their graduates to K–12 student outcomes, invest in strategies that would enable teacher preparation programs to track their graduates across states.

The Role of the National Science Foundation in Teacher Preparation, Induction, and Professional Development

The NSF plays a critical role in supporting both innovation and research on teacher support programs. It has played three roles: (1) the development of programs, practices, and tools (curriculum, assessments, etc.) for teacher development; (2) the development of networks (i.e., "systems" or "partnerships ") of stakeholders who collaboratively work in those programs and/or use those tools; and (3) sponsoring research on the effectiveness of some of those programs/practices/tools.

In the sprawling landscape of programs for teacher support, NSF-sponsored programs play an important role. Most of the time, funding is for four or five years, which allows for a program to be carefully planned and launched. NSF-sponsored programs are required to have a well-articulated theory-of-action, as well as plans for evaluations, so all such programs tend to be more carefully constructed and data driven.

However, the emphasis on launching innovation, however, means that many of those launched programs are not then studied over time in terms of their effects on students or teachers. And because the field lacks robust metrics for student and teacher effects, the limited budgets for evaluation do not allow for extensive research.

Another contribution that NSF-sponsored programs make to the larger field is in the development of professional development leaders. Even when funding ends, programs leave in their wake increased human capital that schools and districts tap into for their own local efforts.

Unfortunately, the three NSF foci (program development, networking, and research) are—at times—in competition with one another, so that the development of programs comes at the expense of empirical research on how teachers learn, what teachers need to know, or the effects of various programs on student engagement and achievement or on teacher knowledge, skill, and practice. It is important that NSF and IES continue to both support the development of innovative programs and fund ambitious basic and applied research on both how teachers learn and the effects of various programs.

Research Gaps in STEM Teacher Preparation and Professional Development

Several Congressionally-mandated efforts have made suggestions concerning the most pressing research areas. As the authors of the NRC's (2010) *Preparing Teachers: Building Evidence for Sound Policy* note:

> There is no system in place to collect data across the myriad teacher preparation programs and pathways in the United States. Thus, we can say little about the characteristics of aspiring teachers, the programs and pathways they follow, or the outcomes of their preparation. (p. 174)

This is equally true of professional development programs. The federal government could play a major role in the development of such a data system.

The authors of Preparing Teachers argued forcefully that we need research that studies core features of teacher preparation, not research that contrasts "traditional" and "alternative." Given the recent diversification of teacher preparation, the three areas they nominated were:

1. comparisons of programs and pathways in terms of their selectivity; their timing (whether teachers complete most of their training before or after becoming a classroom teacher); and their specific components and characteristics (i.e., instruction in subject matter, field experiences);
2. the effectiveness of various approaches to preparing teachers in classroom management and teaching diverse learners; and
3. the influence of aspects of program structure, such as the design and timing of field experiences and the integration of teacher preparation coursework with coursework in other university departments. (p. 174)

The National Academy of Education/NRC Ed in ’08 committee on teacher quality made recommendations that resonate with this, noting that

> States, school districts, and the federal government should support research on a variety of approaches to teacher preparation. Investments should be made in research and development on the core practices and skills that early career teachers require; preparation programs should then focus on these skills. (p. 2)

In the area of professional development, the characteristics of high quality professional development nominated by researchers are not linked to measures of impact in terms of student engagement, motivation, continued interest in pursuing STEM disciplines, or student achievement. And because research has demonstrated that school culture and resources play an important role in developing effective teaching,we also need research that links student outcomes to teacher outcomes to school culture, in particular for schools that serve children who do not typically pursue STEM fields.

Finally, there is extraordinary need for research and development in tools and metrics to assess the effects of teacher support programs. These would range from measures of student learning/engagement, of teacher content and professional knowledge, and of classroom practices and school quality.

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Chairman BROOKS. Thank you, Dr. Wilson. I couldn’t help but think when you were using the word “carnival” and somewhat chaotic system, that reminded of a Winston Churchill quote to the effect of that America can always be depended on to do the right thing after it has first tried everything else.

That having been said, Dr. Allensworth, if you would please share with us your insight for five minutes.

STATEMENT OF DR. ELAINE ALLENSWORTH, SENIOR DIRECTOR AND CHIEF RESEARCH OFFICER, CONSORTIUM ON CHICAGO SCHOOL RESEARCH, UNIVERSITY OF CHICAGO

Dr. ALLENSWORTH. Yes, thank you. Thank you, Chairman Brooks and Chairman Wolf and members of the committee.

I come from the Consortium on the Chicago School Research at the University of Chicago where I have been studying the Chicago public schools for the last 15 years. Chicago has attempted to improve students' achievement in science and math through a number of large-scale, bold initiatives, many of which have been followed by similar policies at the federal level. I am going to briefly talk about three.

I am sorry. These are the wrong slides. I will not show the slides. Those are the wrong slides.

I am going to briefly talk about three, which are curricular standards, changing curricular standards, hiring for teacher quality and accountability. While each of these has the potential to improve STEM outcomes, they also have the potential to unintentionally make them worse, particularly in schools that are struggling the most with low achievement, such as many of our schools serving mostly minority youth in urban areas like Chicago.

In terms of curricular standards, Chicago has tried to increase curricular rigor in a number of ways that have clear implications for states and districts implementing the new common national standards. In 1997, for example, Chicago required all students to take a college-preparatory curriculum and dramatically increased its graduation requirements. As with the new common standards, the goal was to increase equity and rigor by exposing all students to more uniformly challenging coursework.

After the policy, there was a dramatic rise in the number of science and math classes taken by students. However, there were a number of adverse consequences. Most students earned very poor grades in their science and math classes, which indicated minimal engagement and very little learning. As schools struggled to find teachers to expand high-level math and science courses to all students, high-achieving students were less likely to take physics, precalculus or calculus. The quality of math classes declined for high-achieving students as classrooms now contained students with a much greater variations in skills, and teachers had a hard time teaching college-preparatory work to classes with very low-achieving students.

In the end, low-skilled students had slightly higher failure rates in math, system-wide graduation rates declined slightly, and college entrance declined for the high-achieving students.

In 2006, Chicago implemented another new strategy where they implemented high-quality curricula in science, math, and English, aligned with the ACT college entrance exam, along with curriculum coaches and professional development. As with the increase in graduation requirements, there were no improvements in students' test scores or grades, and in some schools, test scores actually declined, even though teachers were using high-quality curricula with better pedagogy, a more academic demand, and aligned, formative assessments.

We found that a central challenge of the program was that classrooms became more disorderly as teachers struggled to implement the new curriculum, and learning declined.

What we found is that implementing rigorous standards for all students is an especially difficult challenge in schools serving large numbers of students with very weak academic skills. Schools need strategies for supporting teachers to teach more diverse learners, and they also need systems in place to support students so that they can handle the tougher material.

A second policy area for improving some learning is around accountability. Now, way back in 1995, Chicago was one of the first districts to enact very strong accountability sanctions to schools based on standardized tests and has been very active in closing and restructuring schools in response to low performance.

As federal initiatives such as the No Child Left Behind and Race to the Top have increased the use and focus on high-stakes testing, it is important to pay attention to some of the effects that accountability has had on learning generally and STEM in particular. While there have been some benefits to the emphasis on accountability, there have also been some very adverse consequences for students, especially in schools under the most pressure to increase test scores, which tend to be racially isolated scores where all students are African American or Latino. This includes the narrowing of the curriculum away from science and subjects other than reading and math, as Dr. Gamoran mentioned. It also means that schools now spend extraordinary amounts of time just practicing tests using up time that could be spent actually improving students' academic skills.

Another way that the government is trying to improve STEM education is by increasing the number of highly qualified STEM teachers. What we found in Chicago, though, is that teachers tend to leave schools with poor climates for learning, so you can bring in high-quality teachers but they won't stay if the environment is not good. And in fact they are not even successful in environments that are poor. What we found is that in order to make good use of high-quality curriculum, respond to accountability, and retain good teachers, schools need to have five essential supports: strategic school leadership, professional capacity that is professionals that work together collaboratively around instruction and learning climate, strong instruction, student-centered learning climate, and involvement of parents.

Thank you.

[The prepared statement of Dr. Allensworth follows:]

PREPARED STATEMENT OF DR. ELAINE ALLENSWORTH, SENIOR DIRECTOR AND CHIEF RESEARCH OFFICER, CONSORTIUM ON CHICAGO SCHOOL RESEARCH, UNIVERSITY OF CHICAGO

I have been studying the Chicago public schools for the past 15 years at the Consortium on Chicago School Research (CCSR) at the University of Chicago. Chicago is a district that is 85% minority, 85% low-income, where almost all students aspire to go to college, and many students aspire to enter STEM careers. But very few of the students who have those aspirations end up making them a reality.

Chicago has attempted to improve students' achievement in science and math through a number of large-scale, bold initiatives, many of which have been followed by similar policies at the federal level. I am going to briefly talk about three. While each has the potential to improve STEM outcomes, they also each have the potential to unintentionally make them worse, particularly in schools that are struggling the most with low achievement, such as many of our urban schools serving mostly minority youth.

1. **Curriculum standards.** Chicago has tried to increase curricular rigor in a number of ways that have clear implications for states and districts implementing the Common Core standards. In 1997, Chicago required all students to take a college-preparatory curriculum and dramatically increased its graduation requirements. As with the Common Core, the goal was to increase equity

and rigor by exposing all students to more uniformly challenging coursework. Prior to 1997, students entering high school had to complete any one science course, and many took remedial science. Beginning in 1997, students were required to take three laboratory science classes, one from each of these categories: 1) earth and space or environmental science, 2) biology or life science, and 3) chemistry or physics. Changes in science requirements were accompanied by increases in math requirements, where students could no longer take remedial math and had to take at least three courses in the math sequence, including geometry and advanced algebra (algebra 2). After the policy, there was a dramatic rise in the number of science and math classes that students took; almost all graduates received credit in full science and math sequences.

However, there were a number of unintended negative consequences as well. These negative consequences were a direct result of asking more of both students and teachers without providing them with sufficient additional supports. Under Chicago's College Prep for All policy, most students earned very poor grades in their science and math classes-Cs, Ds and Fs. Such low grades indicate minimal engagement and very little learning; in fact, comparisons with test scores tell us that it is only students earning As and Bs that show substantial learning gains in their courses. As schools struggled to find teachers to expand high-level math and science courses to all students, high-achieving students were less likely to take physics, pre-calculus or calculus. The quality of math classes also declined for high-achieving students as classrooms now contained students with a much greater variations in skills, and teachers had a hard time teaching college-preparatory work to classes with very low-achieving students. In the end, low-skilled students had slightly higher failure rates, system-wide graduation rates declined slightly, and college entrance declined for high-skill students. [1]

In 2006, Chicago invested deeply in another curricular reform that exhibited some of the same challenges as College Prep for All. Through a program called Instructional Development System (IDS), Chicago implemented high-quality curricula in science, math and English, aligned with the ACT college-entrance exam, along with professional development and coaches for teachers. As with the increase in graduation requirements, there were no improvements in students' test scores or grades. In some schools, test scores actually declined, even though teachers were using high-quality curriculum with better pedagogy and aligned, formative assessments. Our evaluation of IDS found that a central challenge of the program was that classrooms became more disorderly as teachers struggled to implement the new curriculum, and learning declined. [2]

As the IDS and College Prep for All examples demonstrate, implementing rigorous standards is not sufficient to improve student learning, especially in schools that already struggle with low levels of student engagement in their coursework. Engaging all students in more challenging work is crucial if they are to learn at high levels; however, it is important to note that such engagement requires more of both students and teachers. IDS and College Prep for All, like the Common Core, will require teachers to teach new and more challenging material to the students they serve. If schools do not have enough teachers with the content expertise to teach these new subjects, then more challenging standards can result in worse instruction and less learning. What is more, the Common Core will require that teachers be able to teach that material to students with diverse skills-including students entering their classes with skill levels so low that they have little chance of meeting standards without substantial support. If teachers don't know how to teach the standards to

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[1] Allensworth, Elaine M., Takako Nomi, Nicholas Montgomery, Valerie E. Lee. 2009. College Preparatory Curriculum for All: Academic Consequences of Requiring Algebra and English I for Ninth Graders in Chicago. Educational Evaluation and Policy Analysis, 31 (4). Montgomery, Nicholas and Elaine M. Allensworth. 2010. Passing Through Science: The Effects of Raising Graduation Requirements in Science on Course-Taking and Academic Achievement in Chicago. Consortium on Chicago School Research, Chicago, Illinois. Nomi, Takako. (2010) Unintended consequences of an Algebra-for-all policy on high-skill students: Evidence from Chicago Public Schools. Paper presented at the Association for Public Policy Analysis and Management, Boston, MA and the Society for Research on Educational Effectiveness conference, Washington DC.

[2] Hart, Holly, Sporte, S., Correa, M. (June 9, 2009). Adopting a rigorous curriculum: Successes and challenges of Chicago's High School Transformation initiative. Paper presented at Annual Symposium of the Illinois Education Research Symposium, Champaign, IL. Sporte, Sue, James Sebastian and Valerie Lee. (in progress.) Attempting Curricular Coherence: Three Years of Chicago's Instructional Development System Reforms and Developing a Framework for Assessing School Capacity: Insights from Curriculum Reforms in Chicago Public Schools.

their students well, students learn less than they would if teachers had remained focused on material with which they were comfortable.

Implementing rigorous standards for all students is an especially difficult challenge in schools that serve large numbers of students with very weak academic skills. Schools need strategies for supporting teachers to teach more diverse learners and to provide them support. They also need systems in place to support students so that they can handle tougher material. In other words, higher standards need to be accompanied by structures that will support teachers and learners.

2. **Accountability.** Beginning in 1995, Chicago was one of the first districts to enact very strong accountability sanctions to schools based on standardized tests and has been active in closing and restructuring schools in response to low performance. As federal initiatives such as the No Child Left Behind Act and Race to the Top competition have increased the use of and focus on high-stakes testing, it is important to pay attention to some of the effects that accountability has had on learning generally and STEM learning in particular. High-stakes accountability in Chicago has had some benefits for low-achieving students: teachers are more likely to pay attention to students scoring below standards, and there are more resources aimed at low-scoring students through summer and after school programs. Furthermore, schools that previously were not teaching students grade level material in math in the middle grades started teaching students the material they needed to know to pass the standards.

However, there have also been adverse consequences to the strong focus on test-based accountability, especially in schools that are under the most pressure to increase test scores. In Chicago, these schools tend to be racially isolated schools where all students are African-American or Latino. One consequence has been the narrowing of the curriculum away from science and subjects other than reading and math. Another adverse consequence has been that schools now spend extraordinary amounts of time just practicing taking tests—using up time that could be spent on improving students' academic skills. Furthermore, test practice and drilling test problems is boring for students, and leads them to be less engaged and interested in class. [3]

Too much of an emphasis on tests can lead it to appear as if learning is improving, when instruction is actually being narrowly focused to better test performance. This can be seen when districts change the assessments used for school accountability. In Chicago, for example, performance declined considerably at the schools under the most pressure to improve scores when the district switched tests in 2006—these schools had been tailoring instruction too narrowly to the old test. [4]

When so much pressure is placed on students' test performance, the goal of instruction becomes improving test scores, rather than making students into good learners. Ironically, test scores are not that predictive of later outcomes—including success in college. Getting students to do well on tests does not have much pay-off for students, unless it is done in a way that makes them more engaged in the subject and teaches them how to be better learners. What is much more important is the degree to which students are actively engaged and earning high grades in their science and math classes—regardless of their test scores. [5]

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[3] Allensworth, Elaine and Jenny Nagaoka. 2010. "The effects of retaining students in grade with high stakes promotion tests." Chapter 20 in Judith Meece (ed.), Handbook on Schools, Schooling, and Human Development, Taylor & Francis. Roderick, M., & Nagaoka, J. (2005). Retention under Chicago's high-stakes testing program: Helpful, harmful or harmless? Education Evaluation and Policy Analysis, 24(4), 309–340. Roderick, M., & Engel, M. (2001). The grasshopper and the ant: Motivational responses of low-achieving students to high-stakes testing. Educational Evaluation and Policy Analysis, 23(3), 197–227. Roderick, M., Engel, M., & Nagaoka, J. (2003). Ending social promotion: Results from Summer Bridge. Chicago, IL: Consortium on Chicago School Research.

[4] Luppescu, Stuart. Elaine M. Allensworth, Paul Moore, Marisa de la Torre, James Murphy with Sanja Jagesic. 2011. Trends in Chicago's Schools Across Three Eras of Reform. Consortium on Chicago School Research, Chicago, Illinois. http://ccsr.uchicago.edu/content/publications.php?pub_id=157

[5] Roderick, Melissa, Jenny Nagaoka, Elaine Allensworth, Vanessa Coca, Macarena Correa and Ginger 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. Consortium on Chicago School Research, Chicago, Illinois. Allensworth, Elaine M., John Q. Easton.

3. **Teacher Quality.** One of President Obama's key STEM initiatives has been his 100Kin10, a public-private effort to recruit and train 100,000 new high-quality STEM teachers within the next ten years. Chicago also has sought to increase the supply of highly qualified teachers by partnering with a number of organizations to try to increase teacher quality, and the system has succeeded in hiring many more high-achieving candidates. However, teachers tend to leave schools with poor climates for learning, or where they do not feel supported by their colleagues and administration.[6] Getting the best teachers in the worst schools doesn't help improve the schools if they don't stay in those schools. Furthermore, highly-qualified teachers are not even very effective in schools that are not well organized to support instruction. While student achievement tends to be higher in schools with more highly-qualified teachers, there is no relationship between teacher quality and student achievement in schools with poor climates for learning-places that are disorganized and where students and teachers do not feel safe and supported.[7] Thus, the federal investment in training and recruiting high-quality teachers is unlikely to have a positive effect on chronically low-achieving schools without a corresponding push to improve the organizational health of schools.

What we have learned from our 20 years studying Chicago Public Schools is that we need well-organized schools to make good use of high-quality curriculum, respond to accountability standards, and retain good teachers. Otherwise, these policies do not improve student achievement. Schools that do not have the capacity to respond to the policies react in counter-productive ways.

What matters most for school improvement and high learning gains is whether they are organized to support students as learners. Two decades of research in Chicago shows that this requires building the organizational capacity of schools in five essential areas.[8] Schools that are strong in three of five of these areas are 10 times more likely to improve student learning in math and reading than schools that are weak in any. These include:

Strategic school leadership. Principals must be strategic—focused on improving the other four organizational supports, and include staff and parents in school decision-making.

Strong professional capacity. Teaching staff should be skilled, but more important than the qualifications of individual teachers is the degree to which faculty and staff work together to improve the learning climate and instruction in the school.

Parent-community ties. Successful schools actively involve parents as partners in children's education and use local partners to support instruction in the school in a coordinated way.

Student-centered learning climate. Learning requires an environment that is safe, stimulating and supportive for all students.

Instructional Guidance. Student learning depends on instruction that engages them as learners, so that the focus is on students rather than on content. It also requires that curriculum be aligned across grade levels and subjects so that students are increasingly developing their skills through challenging tasks.

One of the key studies that examined these organizational supports compared reading and math improvement in 400 low-performing elementary schools in Chicago. As previously mentioned, this work showed that schools with strong organizational supports were 10 times more likely to improve learning gains over time than those with any weakness. No schools with a poor learning climate and weak professional capacity improved over the six years of the study. But half of the schools with an aligned curriculum and collaborative relationships among teachers or between teachers and parents showed large improvements in math and reading scores gains.

2005. The On-Track Indicator as a Predictor of High School Graduation. Consortium on Chicago School Research, Chicago, Illinois. http://www.consortium-chicago.org/publications/p78.html

[6] Allensworth, Elaine M., Stephen Ponisciak and Christopher Mazzeo. 2009. The Schools Teachers Leave: Teacher Mobility in Chicago Public Schools. Consortium on Chicago School Research, Chicago, Illinois.

[7] DeAngelis, Karen J. and Presley, Jennifer B.(2011) 'Teacher Qualifications and School Climate: Examining Their Interrelationship for School Improvement', Leadership and Policy in Schools, 10: 1, 84–120.

[8] Bryk, Anthony S., Penny Bender Sebring, Elaine Allensworth, Stuart Luppescu, John Q. Easton. 2010. Organizing Schools for Improvement: Lessons from Chicago. Chicago: University of Chicago Press.

All of these schools were high-poverty schools located in highly disadvantaged communities.[9]

Notably, those schools in the most disadvantaged neighborhoods were most in need of strong organizational supports to show improvements. In neighborhoods where external supports for schools were weak—where there were low levels of education and employment in the community and little participation in community or religious organizations—the internal supports needed to be stronger. In schools serving families and communities with more social and financial capital, schools could improve as long as the internal organizational supports of the school were not weak.

This suggests that for policies around standards, accountability, and teacher quality to succeed, they should be designed in ways that promote the development of the five essential supports. It is important to think about the organizational capacity that schools will need to successfully implement new policies, and whether additional resources will be needed for schools with low capacity to implement them successfully. For example:

- **Curricular Standards.** To make the new Common Core standards effective for improving learning, schools requiring the largest instructional shifts will need support for students and teachers so that learning climate does not decline with the challenge of the new curriculum. For the new standards to result in better outcomes for students, students need to be engaged in that curriculum. Teachers need help designing instruction in ways that keep students engaged around the rigorous material, and to continuously monitor how they are doing so that they can support them as soon as they start to struggle. This is more likely to happen if there are systems in place to support teachers in instruction, classroom management, and monitoring and assessment. Potentially beneficial supports include time in teachers' schedules to work together to help each other with instructional challenges, extra staff in classrooms as partners with teachers to help students as soon as they start to struggle or withdraw, and use of technology to help monitor students' engagement and provide immediate feedback to teachers and parents when students fall behind.[10]
- **Accountability.** In order for accountability to lead to real progress, the indicators that are tracked need to measure progress. This means looking at average gains, rather than tracking the percentage of students that meet particular scores corresponding with state or national standards. Furthermore, accountability metrics should include measures that are strongly associated with later outcomes, not just test scores. College acceptance rates, and whether students persist in college through graduation, are not subject to the problems associated with accountability based on test scores. Basic measures like attendance in classes, interest in math and science, and students' perceptions of challenge and support in their math and science classes are strong and valid indicators of later outcomes. These are also indicators that are easier for staff to work together to improve, and improvement in student achievement is most likely to happen when staff work together on common problems.

  The money that has been invested by the federal government in data systems allows for better use of data for intervention and strategy, not just for accountability. In Chicago, high schools have been making tremendous progress in high school graduation and college enrollment by tracking indicators such as student attendance, grades, college applications, and FASFA through student and school reports that are updated frequently. In Chicago, the percentage of students who are "on-track" to graduate after freshman year increased by 11 per-

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[9] Bryk, Anthony S., Penny Bender Sebring, Elaine Allensworth, Stuart Luppescu, John Q. Easton. 2010. Organizing Schools for Improvement: Lessons from Chicago. Chicago: University of Chicago Press.

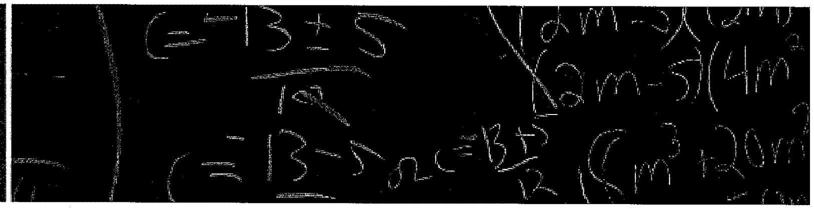
[10] In 2003, Chicago attempted to improve algebra performance for students entering high school with weak math skills by giving them twice as much instruction, and giving their teachers professional development to use the extra instructional time. While the policy only targeted students with below-average math skills, it resulted in higher test scores for all students. By giving extra support to low-skill students, they no longer held back the pacing and content of algebra classes for students with above-average skills, so that students with above-average skills also learned more (Nomi, Takako and Elaine Allensworth. 2009. "Double-Dose" Algebra as an Alternative Strategy to Remediation: Effects on Students' Academic Outcomes. Journal of Research on Educational Effectiveness, 2: 111–148.). For further discussion of this issue, see Luppescu, Stuart. Elaine M. Allensworth, Paul Moore, Marisa de la Torre, James Murphy with Sanja Jagesic. 2011. Trends in Chicago's Schools Across Three Eras of Reform. Consortium on Chicago School Research, Chicago, Illinois. http://ccsr.uchicago.edu/content/publications.php?pub_id=157

centage points between 2002 and 2010. This improvement should result in a commensurate increase in graduation rates. Those schools that have made the most progress use the reports to get staff working together to develop strategies and help each other improve those outcomes. They use data on individual students to build partnerships between teachers and parents.

- **Teacher quality.** It is vital to have teachers who know their subject well, and who know how to teach the students in their classroom. If we expect students who have very weak academic skills to master college-ready material, this means they need the strongest teachers. More importantly, those teachers need support, high-quality professional development that is embedded in their work at their school, and colleagues who are collaborative and will help them when they need it.[12] It is difficult to mandate cooperation, but the government can provide resources so that teachers have the time to work together, and resources that help them use that time effectively. They can encourage the use of teacher evaluation systems that promote collaboration with colleagues and with parents.

Rigorous curriculum standards, high-stakes school accountability, and efforts to attract more teachers with strong backgrounds are all strategies that may have potential for improving student achievement; however, they have had little pay-off in Chicago's schools. As the federal government works to implement similar strategies it would be wise to learn lessons from Chicago's efforts and carefully consider when designing new initiatives the capacity of schools to implement those standards, respond to accountability, and keep and support strong teachers. This is especially critical if there is to be real improvement in STEM learning and STEM careers among minority youth concentrated in low-performing urban school districts.

[12] Bryk, Anthony S., Penny Bender Sebring, Elaine Allensworth, Stuart Luppescu, John Q. Easton. 2010. Organizing Schools for Improvement: Lessons from Chicago. Chicago: University of Chicago Press.



Lessons from Chicago for STEM Education Policies

Elaine Allensworth

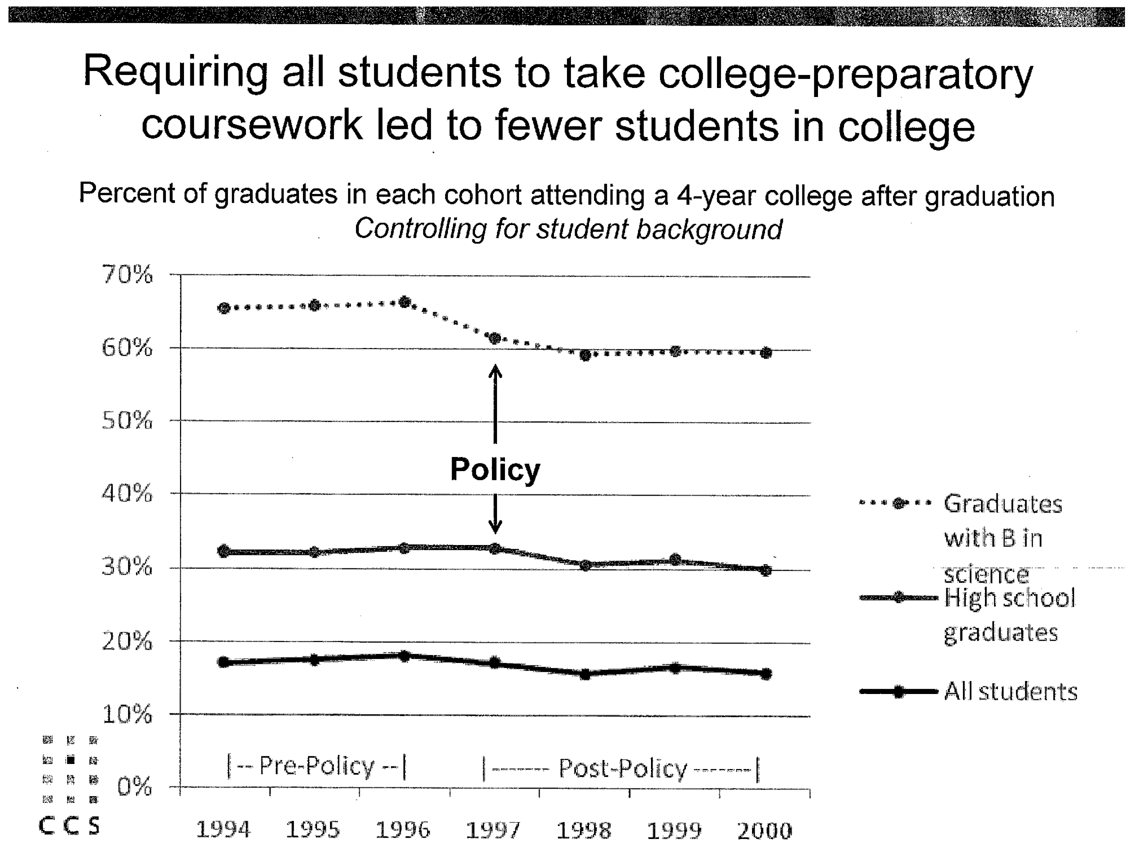
THE CONSORTIUM ON CHICAGO SCHOOL RESEARCH
AT THE UNIVERSITY OF CHICAGO / URBAN EDUCATION INSTITUTE

Chicago was an early adopter of popular strategies to improve student achievement

- Increasing curricular rigor
  - Eliminating remedial coursework (1997)
  - Requiring a college-prep curriculum for all students (1997)
  - Instructional Development Systems, IDS (2006)
- Implementing high-stakes accountability (1995)
  - Closing schools in response to low performance
- Hiring new teachers with strong qualifications

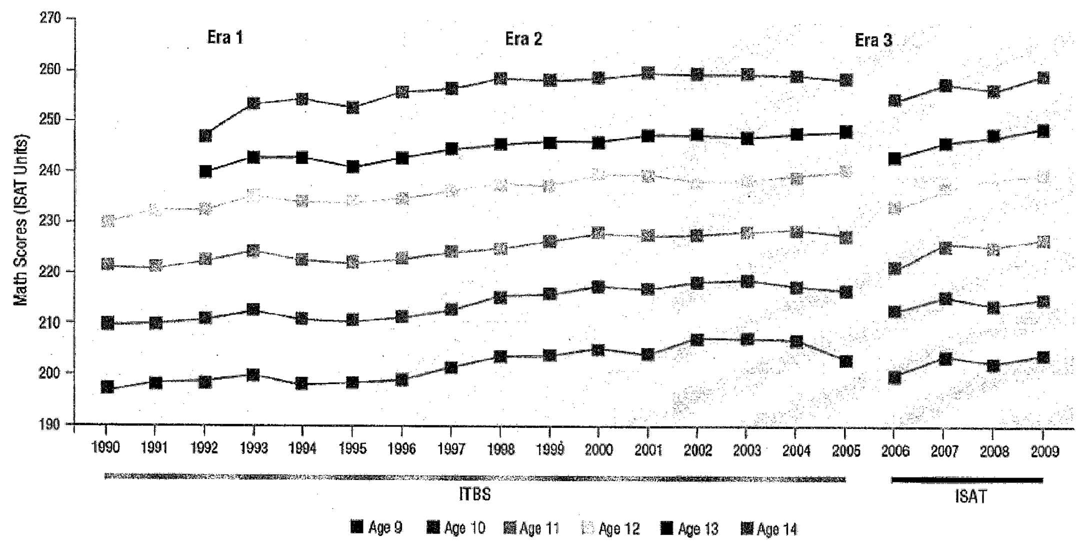
These strategies had unexpected results

ccsr


Requiring all students to take college-preparatory coursework led to fewer students in college
Percent of graduates in each cohort attending a 4-year college after graduation
Controlling for student background
70%
60%
50%
40%
30%
20%
10%
0%
Policy
|-- Pre-Policy --|
|------- Post-Policy -------|
1994
1995
1996
1997
1998
1999
2000
Graduates with B in science
High school graduates
All students
CCS

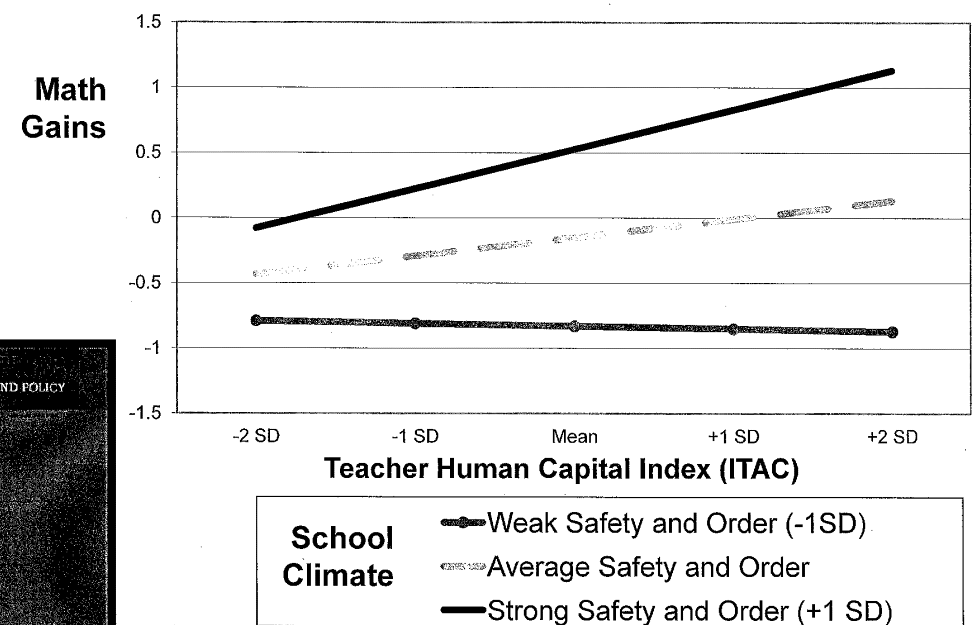
Math scores dropped at low-performing schools when the district switched tests—teaching to the test

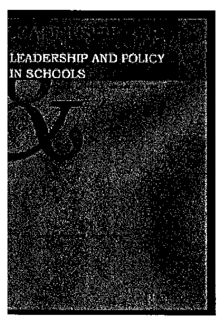
Average Math Test Scores for Nine through 14-Year-Olds across the Three Eras



ccsr

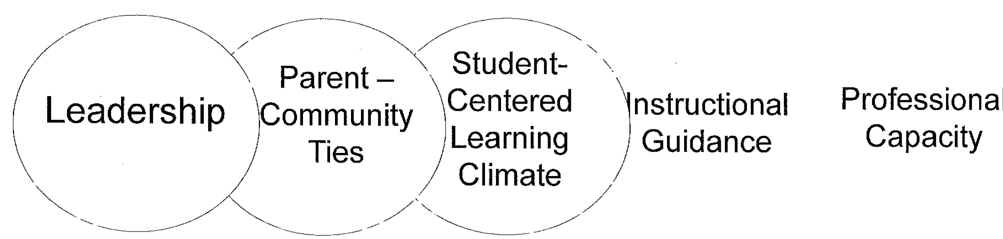
Regardless of teacher quality, a poor school climate prevents learning gains





Five Essential Supports for School Improvement

Schools strong on three or more supports are **10 times more likely to improve** than schools that are weak on any



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Policies need to improve collaboration and classroom environment

- Rigorous Curricular Standards
  - Resources for professional development and collaboration around content AND pedagogy for diverse students
  - Systems for monitoring students and giving support
- Accountability Systems
  - Early warning data for strategy and intervention on indicators that are actionable
- Teaching quality
  - Strong school environments where teachers want to stay
  - Structures that encourage collaboration among teachers, and between teachers and parents

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Chairman BROOKS. Thank you, Dr. Allensworth.
And next, we have Dr. Means for five minutes.

STATEMENT OF DR. BARBARA MEANS, DIRECTOR, CENTER FOR TECHNOLOGY IN LEARNING, SRI INTERNATIONAL

Dr. MEANS. Chairman Brooks, Ranking Member Lipinski, Chairman Wolf, and Members of the Subcommittee, thank you for this opportunity to testify.

I am going to address what I believe is one of the most vexing questions facing STEM education today. Given the many innovations that show promising results in early studies, why does so little rise to the scale where it makes a real difference in schools across the country? As Dr. Gamoran noted, we need rigorous longitudinal studies to help us understand how to develop and nurture STEM interest, persistence, and learning among all students. And we also need effective strategies for putting the insights that come from such studies into practice on a broad scale.

Conventional thinking is that once we have identified an effective educational product or approach, we should simply roll it out to as many schools and classrooms as possible. The assumption is that these schools will experience the same positive outcomes observed earlier. My basic message is that this assumption is flawed and that efforts to improve or to implement innovative K–12 STEM education approaches on a large scale need to be combined with rigorous research on those approaches in multiple contexts.

Educational effectiveness is a function of what gets implemented, not simply the elements of an innovation's design or a government policy. And aspects of context—by which I mean factors such as grade level, school size, accountability measures, student characteristics, family, and community resources—have profound effects on how educational programs get interpreted and actually implemented.

Take the case of STEM-focused high schools. Selective STEM high schools were designed to serve our brightest students, and test scores are a major factor in gaining admission. The bold idea behind inclusive STEM schools such as that in Denver is to offer the same intensive focus on STEM subjects to students who are not selected by examination, to develop STEM expertise rather than selecting for it. It is easy to understand that instructional approaches and materials that work well with northern Virginia's highest-scoring students who gain entrance to Thomas Jefferson High will need to be modified to be effective with students who enter an inclusive STEM high school a year or more behind in mathematics.

Before promoting inclusive STEM high schools as a policy, we should have well designed research demonstrating that such schools increase the likelihood that their students will be interested in and prepared for STEM college majors and careers. But this kind of research, though important, is not enough. If inclusive STEM high schools are effective, we will still need to figure out how we can make them widely available.

For example, Texas has been particularly active in promoting inclusive STEM high schools. Although there are scores of these schools in Texas, less than one percent of the State's high school students attend one. So solid evidence that these schools are effective would lead us to the next and more difficult question: How can we obtain similar results for all students? The approach that works with T–STEM schools of 400 students likely would have to be modified for schools with 1,000 or 2,000.

The rationale for bringing a new, potentially effective educational approach to many students is obvious, but the need to support initial large-scale implementations with research is less understood. We tend to plan for replicating a successful education approach as if we could simply have an assembly line produce more widgets. But the components of an education approach interact with and are shaped by the elements of context where we try to implement them. For this reason, we need to combine scaling with research on the approach as implemented under different conditions.

I will illustrate with something found in the New York Times last weekend. The National Evaluation of Educational Technology Interventions, of which I was a part, examined the effectiveness of 16 reading and math software products. These products were selected for the study because they had prior evidence of effectiveness. In the large-scale national study, however, on average none of them produced significantly better achievement than was attained by students in classrooms assigned to the control condition.

On the other hand, for virtually every product there were some schools where those using the software outperformed the control classrooms and some schools with the opposite pattern. We learned that features such as the student's grade level, the school's technology infrastructure, and district policies around curriculum and assessment influenced the extent to which and the way in which software was implemented.

To increase the odds that new K–12 education approaches will have positive effects when implemented on a large scale, researchers should be brought in to work with educators. Researchers can contribute their expertise to implementation planning and to building in data collections that can serve as feedback for those in charge of the program. We need collaborative efforts aimed both at scaling up approaches with prior evidence of effectiveness and studying what happens in multiple settings while advising those responsible for implementing the education approaches.

Thank you for your attention and the opportunity to submit this testimony.

[The prepared statement of Dr. Means follows:]

PREPARED STATEMENT OF DR. BARBARA MEANS, DIRECTOR, CENTER FOR TECHNOLOGY IN LEARNING, SRI INTERNATIONAL

Chairman Brooks, Ranking Member Lipinski, and other Members of the Subcommittee, thank you for this opportunity to participate in this hearing on What Makes Successful K–12 STEM Education.

My name is Barbara Means and I direct the Center for Technology in Learning at SRI International, an independent nonprofit research organization based in Menlo Park, CA.

I was a member of the National Research Council committee chaired by Dr. Gamoran that produced the *Successful K–12 STEM Education report.*

In my testimony today, I'm going to first underline my support for what I regard as key aspects of that report and then address what I believe is the most vexing question that faces us today: Given that the federal government funds so many wonderful innovations that show promising results in the early studies, why does so little rise to the scale where it makes a real difference in schools across the country? And just to foreshadow where I'll be going, I will argue that our greatest unmet

R&D need is learning how we can achieve consistently high-quality implementation of good ideas across all the variation found in American schools.

I believe that the Successful K–12 STEM Education committee's articulation of K–12 education goals not just for universal STEM literacy but for preparing broader sections of our student population for advanced-degree STEM and STEM-related occupations as well is very important. A balanced K–12 STEM education agenda will work toward all three of these goals.

And meeting these goals will require research addressing not only math and science achievement but also students' interest in STEM, their persistence in STEM courses in high school and postsecondary study, and their participation in STEM-related activities outside of school and in the job market. As Dr. Gamoran noted, we need rigorous longitudinal studies to help us understand how to develop and nurture STEM interest, persistence, and learning among student groups that now shy away from these subjects.

I am going to focus the remainder of my remarks on the steps needed to put the kinds of insights that could come from such studies into practice on a broad scale. The big challenge is scaling up what appear to be successful programs in ways that produce positive results for most or all of our students.

Conventional thinking on the part of many federal and private philanthropic programs has been that once we've identified an effective educational product or approach, we should simply roll it out to as many schools and classrooms as possible. The implicit assumption is that these schools will experience the same positive outcomes for the approach observed originally. I am going to argue that this assumption is flawed and that efforts to implement innovative K–12 STEM education approaches on a large scale need to be combined with rigorous research on those approaches in multiple contexts.

Need for Combining Scaling and Implementation Research

Educational effectiveness is a function of what gets implemented, not simply the elements of an innovation's design or a government policy.[1] And aspects of context—by which I mean factors such as grade level, school size, accountability measures, students' characteristics, and parent and community resources—have profound effects on how educational programs are interpreted and implemented.

I will illustrate this argument with the case of STEM-focused high schools. Selective STEM high schools were designed to serve our brightest students, and test scores are a major factor in gaining entrance. The bold idea behind inclusive STEM schools is to offer the same intensive focus on STEM subjects to students who are not selected by examination-to develop STEM expertise rather than selecting for it. It is easy to understand that instructional approaches and materials that work well with Northern Virginia's highest-scoring students who gain entrance to Thomas Jefferson High School will need to be modified in order to be effective with students who are a year or more behind national norms in math achievement when they enter an inclusive STEM high school.

Before promoting inclusive STEM high schools as a policy, we should have well-designed research demonstrating that such schools increase the likelihood that their students will be interested in, and prepared for, STEM college majors and careers. In fact, with a grant from the National Science Foundation (NSF), I am starting to examine the feasibility of conducting such a study. But this kind of research by itself is not sufficient.

If today's inclusive STEM high schools are effective, we need to figure out how we can make them widely available. For example, Texas has been particularly active in promoting inclusive STEM high schools. The Texas design for inclusive STEM schools calls for providing students with personal attention, in part by limiting school size to 100 students per grade. Although there are scores of these schools in Texas, less than one percent of the state's 1.4 million high school students attend them. So solid evidence that these schools are effective would lead us to the next, more difficult question. How can we obtain similar results for all of our students? The approach that works with schools of 400 students would have to be modified for schools with 1,000 or 2,000 students, and we would not know whether it would still be effective.

The rationale for bringing a new, potentially effective educational approach to many students is obvious, but the need to support initial large-scale implementations with research is less easily understood. We tend to plan for replicating a suc-

[1] McLaughlin, M. W. (1987). Learning from experience: Lessons from policy implementation. *Educational Evaluation and Policy Analysis,* 9, 171–178; Spillane, J. (2004). *Standards deviation: How schools misunderstand education policy.* Cambridge, MA: Harvard University Press.

cessful education approach as if we could simply have an assembly line produce more widgets. But the components of an education approach interact with, and are shaped by, the elements of the context in which we try to implement them, as Dr. Allensworth's research illustrates. For this reason, we need to combine scaling with research on the approach as implemented under different conditions.

Over the last decade, we have invested in large-scale experimental studies to answer the question of whether certain prominent educational approaches on average produce a significant benefit. Such studies are valuable in building a knowledge base, but educators care about results for their students, not averages. And they want to know not just whether they can expect good results in their setting but how to implement the approach to maximize prospects for success.

Let me illustrate my point with an example that found its way into a *New York Times* article last weekend.[2] The National Evaluation of Educational Technology Interventions, of which I was a part, examined the effectiveness of 16 reading and mathematics software products implemented in grades 1, 4, 6 and high school. These particular software products were selected for this large-scale experiment because they could point to some evidence that they were effective. In the large-scale national study, however, on average, none of the products produced significantly better student achievement than was attained by students in classrooms assigned to the control condition.[3] On the other hand, for virtually every product, there were some schools in which the software-using classes out-performed the control classes, some schools where the control classes outperformed the software-using classes, and some schools where the two were equivalent. We can choose to treat such variation as random "noise," or we can focus on it as an object of study. I am among those advocating the latter stance.[4]

In the case of the national experiment on educational software, for example, we learned that features such as the students' grade level, the school's technology infrastructure, and district policies around curriculum and assessment influenced the way in which software was implemented. For example, some elementary school teachers had a set of computers in their classrooms and could have some of their students using the software while others worked with the teacher or did silent reading. Such flexibility was rare in middle and high schools where it was more common to have the whole class use the software on selected days, often in a separate computer laboratory.

The physical environment makes a difference in how an educational approach is implemented. In an extreme example, a sixth-grade class tried to use math software on laptops passed out to students in a large auditorium. The teacher could not help students because they were tightly packed in rows, so students could not get instructor assistance if they were having difficulty with the software program.

This class also provided an illustration of the inter-connected roles of teacher judgment and district policies. The math software was designed to individualize instruction, with each student working on a learning objective until he or she had mastered it. The teacher had different ideas, based upon his interpretation of school district policy. The district had instituted benchmark tests in mathematics every six weeks along with associated pacing charts indicating what should be taught in each period. In this context, the teacher felt there was no time to teach to mastery even though many of his students were English language learners who struggled with math. The infinitely patient technology tutor might have been ideal for such students, but the teacher believed that the district's policies required him to "touch upon a topic and move on."

I do not want to leave the impression that the effects of local context are always negative. Modifications of an education approach to better fit with local circumstances or the needs and interests of a particular set of students and instructors may enhance effectiveness in that setting. We found a number of examples in our studies of GLOBE, an Internet-based Earth science education program in which students took weather, vegetation, soil, and water measures for a local study site and uploaded them to a worldwide database used by both scientists and educators. Students whose teachers elaborated on the practices in the Teachers Guide by adding data analysis activities performed better than students of other GLOBE teachers on

[2] Gabriel, T., & Richtel, M. (2011). Grading the digital school: Inflating the software report card. *The New York Times,* Oct. 9, 2011.

[3] Dynarski, M., Agodini, R., Heaviside, S., Novak, T., Carey, N., Means, B., et al., (2006). *Effectiveness of educational technology interventions.* Report prepared for Institute of Education Sciences, U.S. Department of Education. Princeton, NJ: Mathematica Policy Research, Inc.

[4] Bryk, A., Gomez, L., & Grunow, A. (2010). Getting ideas into action: Building networked improvement communities in education. Available at http://www.carnegiefoundation.org/print/7645.

an assessment of science inquiry.[5] We found also that classes of teachers who designed extensions of the GLOBE investigations focusing on questions about their local environment were more active in the program (contributed more data to the database) than did other classrooms.[6] We brought these practices to the attention of the GLOBE program staff who were then able to build training and support for such practices into their program.

SRI spent over ten years conducting research in support of the GLOBE program, an unusually long-lived collaboration. At the start of this joint work, the GLOBE program staff assumed that they could promote effective STEM learning activities if they simply trained teachers in how to conduct the scientific data collection protocols. They expected teachers to know how to make the data collection activities instructionally meaningful. Early on, we were able to show program staff that many teachers struggled to relate GLOBE activities to their local science curriculum. While high school teachers brought greater knowledge of science content, many of them were inexperienced in conducting hands-on activities with small groups of students. The program needed to entirely revamp its teacher training approach to address the range of needs uncovered by the research.

To increase the odds that new K–12 STEM education approaches will have positive effects when implemented at a large scale, researchers should be brought in to work with educators. Researchers can contribute their expertise to implementation planning and to building in data collections that can serve as feedback for those in charge of the program. At the same time, by studying implementation in multiple contexts, researchers can advance our understanding of the necessary preconditions, critical elements, and both therapeutic and harmful adaptations of the approach.

In short, I am calling for a much closer relationship between STEM education research and K–12 STEM education practice. We need collaborative efforts aimed both at (1) scaling up approaches with prior evidence of effectiveness and (2) studying what happens in multiple settings while advising those responsible for implementing the education approaches.

Approaches to Implementation Research

In recent years the Carnegie Foundation for the Advancement of Teaching has been promoting what it calls "improvement research" incorporating design, educational engineering, and development (DEED) activity.[7] Applied to K–12 STEM education, DEED collaborations would involve scientists, researchers, and education practitioners in jointly defining a problem of practice and then developing, trying out, evaluating and revising education approaches. Repeated cycles of design, development, measurement and feedback are central to this approach.

Many of the same elements can be found in educational researchers' call for "implementation research"[8] or "design-based implementation research."[9] Defining elements of this approach are:

- a focus on important problems of educational practice as defined by practitioners and researchers,
- commitment to iterative, collaborative design,
- interest in developing a theory of program implementation through systematic inquiry, and
- concern with developing education systems' capacity for change.

Implementation research requires a kind of partnership between education research organizations and schools and districts that is rare at present, but there are

[5] Means, B., & Penuel, W. R. (2005). Scaling up technology-based educational innovations. In C. Dede, J. P. Honan, & L. C. Peters (Eds.), Scaling up success: *Lessons from technology-based educational improvement.* San Francisco: Jossey-Bass.

[6] Means, B., Penuel, W. R., Crawford, V. M., Korbak, C., Lewis, A., Murphy, R. F., et al. (2001). *GLOBE Year 6 evaluation: Explaining variation in implementation.* Menlo Park, CA: SRI International.

[7] Bryk, A., & Gomez, L. M. (2008). Ruminations on reinventing an R&D capacity for educational improvement. Available at http://www.carnegiefoundation.org/improvement-research/approach.

[8] McLaughlin, M. W. (2006). Implementation research in education: Lessons learned, lingering questions and new opportunities. In M. I. Honig (Ed.), *New directions in education policy implementation: Confronting complexity* (pp. 209–228). Albany, NY: SUNY Press.

[9] Penuel, W. R., Fishman, B. J., Cheng, B. H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher,* 40(7), 331–337.

several existence proofs involving mathematics or science education.[10] When the focus is STEM instructional materials, science institutions should be brought into the mix as well.

A key difference between the K–12 STEM education implementation research agenda I am advocating and many existing federal K–12 STEM education expenditures is the principle of striking a three-way balance between scientists, education researchers, and education practitioners. Federally funded K–12 STEM education R&D should reflect deep expertise in STEM, address problems that educators care about, and have the potential to produce generalizable insights regarding organizational change, learning, and instruction. Funded initiatives should be neither research for its own sake, nor federal underwriting of K–12 education as usual, nor feel-good programs of scientists visiting classrooms for show and tell. I am advocating long-term, sustained collaborations with the three types of partners (scientists, educators, and education researchers) having equal roles in setting the agenda.

Federal Role in K–12 STEM Education

In this country, public education is a state and local responsibility. So what role should the federal government have in K–12 STEM education? I believe that the federal government has two responsibilities in this realm. First, it can articulate our country's goals for K–12 STEM education and a vision of how to attain them. The *Successful K–12 STEM Education* report provides a starting point for articulating goals. Second, the federal government has a responsibility to support the infrastructure for improving STEM education and measuring that improvement. This infrastructure includes both concrete resources, such as assessment tools and data systems, and R&D activities, such as those I've described as implementation research. The bringing together of research and educational practice that I have described would require both intellectual and monetary investments. Individual states and districts lack the resources and the broad national vision for this undertaking.

Funding K–12 STEM Education Implementation Research

How do we fund this kind of research and implementation at scale in this time of limited resources? I am no expert in federal agency budgets, but I suspect that we could implement a significant program of K–12 STEM education implementation research using money that we are already spending that could be put to better purpose. I would look to programs that add a small K–12 education component to grants intended for STEM research activities or that add a token evaluation component to grants for STEM educational activities.

Pro forma outreach activities where a STEM professional makes a one-time visit to a classroom are unlikely to have long-term effects for education institutions, teachers or students. STEM education programs where 95% of the resources go to providing services and less than 5% to measuring whether and under what circumstances those services had positive effects are unlikely to build a robust knowledge base about how to implement effective STEM education at scale. Funding that is thinly spread across many grants and programs for "light touch" STEM education activities and perfunctory evaluations could be re-allocated toward a smaller number of significant implementation research efforts.

In 2007 the Academic Competitiveness Council reported that a dozen different federal agencies were supporting 105 STEM education programs at a cost of over $3 billion ($574 million of which was for K–12 programs). Some of these are surely valuable programs, but others are likely to be too superficial to be serving our national STEM education goals. A portion of those targeting K–12 education could be consolidated or eliminated to free up funding for a significant program of K–12 STEM education implementation research.

Networks of multiple K–12 STEM education research and development collaborations, working on the same problem and sharing a common analytic framework, could accelerate the generation of knowledge about what approaches work in what contexts and with what range of implementation practices.

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[10] Cobb, P. A., Henrik, E. C., & Munter, C. (2011). Conducting design research at the district level. Paper presented at the annual meeting of the American Educational Research Association, New Orleans. Roschelle, J., Schechtman, N., Tatar, D., Hegedus, S., Hopkins, B., Empson, S., Knudsen, J., & Gallagher, L. (2010). Integration of technology, curriculum, and professional development for advancing middle school mathematics: Three large-scale studies. *American Educational Research Journal,* 47(4), 833–878. Songer, N. B., Kelcey, B., & Wenk Gotwals, A. (2009).

Policy Implications

Education approaches that are significant enough to have long-lasting consequences are necessarily complex. We need research on the resource requirements, key choices and practices in implementing K–12 STEM education approaches, and on how the approaches can be implemented to good effect in different settings.

At present, the National Science Foundation encourages proposals for implementation research under one of its field-initiated grant programs, but STEM education implementation research is not a core responsibility of any federal agency. The National Science Board Commission on 21st Century Education in STEM called attention to this gap in its 2007 national action plan (p. 14) and called for NSF to promote STEM education research on critical challenges defined by the field of educational practice.

Research on STEM learning, instructional practices, and infrastructure needs to be coupled with the study of implementation and local infrastructure reform. The work needs to be designed in such a way that it both enhances the practice of participating education institutions and yields generalizable insights that build knowledge for the field. Such collaborations require new practices and new sets of skills on the part of scientists, educators, and researchers alike. Field-building activities, promoting the needed skills both in people being trained for STEM professions, education research, and education administration and in those currently engaged in these professions, will be necessary. We have seen a few isolated examples of such collaborations, but we are unlikely to see them become common without leadership and support at the federal level.

Thank you for your attention and the opportunity to submit this testimony.

Chairman BROOKS. Thank you, Dr. Means.

Just by way of background, my wife used to be a certified public accountant, had kids, went back to school, got a math degree, taught math at middle school and I am very familiar with the STEM program. My father and two sons, they are all engineers. I am the wayward one that Chairman Wolf referred to earlier who became a lawyer.

Having said that, for decades now we have been discussing the benefits of STEM education to United States innovation and economic competitiveness. Bookcases can be filled with the reports dedicated to this topic. We have spent tens of billions, perhaps hundreds of billions of dollars, looking at ways to improve K through 12 STEM education and all indications are that we are not making the kind of vast improvements we would expect from those large expenditures.

I am not suggesting stopping these investments, certainly not that, but I would like to ask all the witnesses what have we gotten for our investments to date? How will putting more money towards research and programs produce a better quality and quantity of STEM students? Not just at the K through 12 level, which is certainly where you all have focused, but as I understand it, you are focusing at STEM at K through 12 in hopes of our being able to graduate from our universities with BS degrees, master's degrees, or Ph.D. degrees individuals who have the kind of skills in the STEM subjects that empowers America and empowers our economy to a technological advantage that we would not have if we did not have those students going into those areas.

So with that having been said, how would you evaluate the expenditures so far and where would you prefer we put the money if you have a different preference on how to get to the end game, and the end game being the additional BS, master's, and Ph.D. diplomas in the STEM subjects? Please, Dr. Gamoran?

Dr. GAMORAN. Well, your question focuses on one of the three goals that we identified. You are talking about nurturing some of our most talented students from all walks of life and getting them into these high-level STEM careers. That is extremely important along with creating a broader STEM-capable workforce and encouraging scientific literacy.

But what we have learned from research is that there are programs and schools that can foster these effects. One thing you gain by going through the research carefully is you find out what we do know and you also find out what we don't know. And I think this is a good moment in time to have taken stock and to say here is where the critical investments are needed. For example, research that connects the outcome to specific practices within these high-flying schools, research that connects student outcomes to specific practices in a broad range of schools as well.

With respect to investments, as I said in my written testimony, I think the Education and Human Resources Directorate at NSF and IES, which are the leaders—IES is in the Department of Education—which are the leaders in supporting STEM education research are well positioned for this role. We invest in STEM education, programming, and research in a wide range of federal agencies, and I know that the Office of Science and Technology Policy is reviewing that, and I think we should take a close look at that to see whether narrowing our investments to agencies that specialize in STEM education research would produce a higher yield.

Chairman BROOKS. Thank you, Dr. Gamoran.

Any other comments? If not I have got another question or two, but anyone has anything to add, please do so. Dr. Means?

Dr. MEANS. I would just reiterate that I think the important point here is to try to combine things that we are funding as implementation of programs with research on the effectiveness of those programs. Too often we have treated research and implementation as separate activities, and I am arguing that we really need to put these things together and not implement broad policies in the absence of having research support for their implementation and research that helps us learn from those broad implementations.

Chairman BROOKS. Thank you.

It seems to me one of the issues we have is motivation of students so that they will focus on the STEM subjects. In turn, to some degree that involves the motivation of parents. You motivate the parents, we all know that parents can to some degree help motivate the students. That having been said, one of the ideas that I have toyed with—and there are a lot of out-of-box thinking approaches that can be used, and again, I welcome whatever insights you all may have of an out-of-the-box nature—but we spend over $30 billion a year promoting STEM in one shape, form, or fashion, and just doing some math that—you could spend $10,000 a year per pupil in our universities as scholarships as an inducement to go into the science, technology, engineering, and math fields and still have billions of dollars left over for what we are now doing.

Do you all have any insight as to whether $10,000 a year would be an incentive for people—students and parents in the K through 12 levels to focus more on the STEM subjects and then enter those in college if they knew that kind of scholarship was coming? Yes, sir? Mr. Heffron?

Mr. HEFFRON. So I could speak to that. I think that if there is funding tied to STEM fields as far as scholarships, that is hugely impactful to a kid who is trying to decide where they are going to go to school. The only problem there is if they get to the 12th grade and they are not prepared for those degrees and those fields of study, it doesn't matter if there is money out there. So I guess I just want to go back to kind of the importance of preparing every kid with a rigorous education so that when they get to their senior year and there is more money out there for a particular field, they actually have the capacity to go after it.

Chairman BROOKS. So you see the scholarship as impacting 12th grade but not K through 11th?

Mr. HEFFRON. I see it impacting a student who is prepared and is trying to decide whether they are going to go to law or medicine or engineering or something like that, but I don't think it is big enough, I don't think it is going to affect a ninth grader when they are really trying to make a decision about—or even a ninth grade family around what they are taking or what a school is potentially offering.

Chairman BROOKS. Okay, thank you.

Dr. Allensworth?

Dr. ALLENSWORTH. Yeah, I absolutely agree. And, you know, I come from Chicago. It is a low-income, high-minority district. Lots of students actually want to go into STEM careers when they are in ninth grade and tenth grade but they have no idea how to get there and they don't realize that they are vastly underprepared. They are not being closely monitored, they are not being closely tracked to make sure that they actually do what they need to do to get on a path. And then they get to 12th grade and they are very under-qualified to get into college and go into STEM careers. Many of them haven't taken the classes they need, and more importantly, they haven't been engaged in those classes.

In Chicago, we find that tracking—having data systems in place that actually track how students are doing and giving them—giving students information and parents information about what they need to do to actually end up college-ready, end up ready to go into a STEM career early on and then really monitoring them to keep them on that path makes a huge difference for students.

Chairman BROOKS. Thank you, Dr. Allensworth.

My time has expired. I now recognize the Ranking Member, Mr. Lipinski of Illinois.

Mr. LIPINSKI. Thank you, Mr. Chairman.

I again thank all of the witnesses for their testimony.

Let us start with Dr. Gamoran. I know that the NRC report includes a wealth of information about what we need to be emphasizing in STEM education. and approaches to the problem that have been successful. Can you tell me what is being done to disseminate this potentially helpful information to STEM education practitioners or whether there are plans to further publicize the results of this report?

Dr. GAMORAN. Yes. The National Research Council has prepared a research brief, a two-page research brief which has been widely distributed. There was also a public event in Philadelphia recently which was widely covered. A large number of copies of the report itself has been printed. And I think I could call on the National Research Council to pass more specific information on the dissemination activities to you subsequently.

Mr. LIPINSKI. Yeah, I would like to see that. Since we have this report I think it is very important to disseminate it. Obviously, we have a lot of—we have heard about what is working, what is not working. It is also a matter of really getting people knowing what we have learned.

Now, one other question, Dr. Gamoran. Have you gotten any feedback from the community on this and if so has there been any ideas for follow-up research?

Dr. GAMORAN. With respect to feedback, we have received a great deal of positive feedback such as that which Mr. Heffron stated, that practitioners are affirming the findings. To some extent people are saying well, this is information that we know, and that is good because our job wasn't to do new research; it was to pull together the findings and evaluate the findings from research that is out there.

With respect to next steps, we are getting advice that the study should be—or the report should be done in another five years or so to see what progress has been made, and that is one suggestion for follow up that has come up.

Mr. LIPINSKI. Well, I have a general question then for everyone. If we—do we need to have—well, I think we need to have more information but the information we have out there, are we making use of that, of the research that has been done, what we have learned? Some of what Dr. Wilson said seems to suggest that we are simply not doing that, that there are so many ways in teachers' training that teachers will go from one course to another one, from one place to another and it is not reinforcing the same lessons for the teachers. It is something completely different. So what can we be doing better to take what we already know, what we have learned and really put that into practice? So let me start on the—Dr. Means, do you have any suggestions on that, what we could be doing better to actually put this into practice?

Dr. MEANS. I think we can not only review our existing programs to see whether they are consistent with the research that we do have that is in the report, but I also think it is important for us to have the kind of capability they built in Chicago where they are gathering data along the way, looking at factors we know are important, things like school climate, things like support from the parents and communication to parents, whether the teachers actually collaborate and support each other in providing STEM. And I think having more of those feedback systems where you really try to build in feedback according to whether you are implementing the things we do know are effective practices would help us do a better job all the way up and down our education system.

Mr. LIPINSKI. You are not just saying that because I have a systems engineering degree at Stanford, are you?

Dr. MEANS. No, but I was aware that you are an engineer.

Mr. LIPINSKI. Dr. Allensworth, Dr. Means mentioned Chicago. What—how would you respond to that?

Dr. ALLENSWORTH. I would say Chicago is doing some things—doing some great things but also has the same kinds of problems as every place else. It is very difficult oftentimes when people want a quick solution to really think about the theory of action behind the policies that are being suggested and whether they are likely to have a beneficial impact on schools and also to think about the context of different schools and the different kinds of supports that they will need to actually make those benefits happen with those policies. Too often, things are done quickly without thinking about the research evidence that is out there.

On the other hand, Chicago has put into place a number of data systems which allow—which are increasingly allowing practitioners to base decisions on data and coming up with strategies that are based on where their children are and how they are doing in the school. And I think there is a lot of hope there.

Mr. LIPINSKI. Anyone else want to jump in? Dr. Wilson?

Dr. WILSON. Just to reiterate what I hear my colleagues saying. I think that we are at a stage right now where we have an opportunity because we have come to understand the need to think about things systemically so that it is components of curriculum and school culture and teacher support, that we don't think about those as isolated, that we need to change the culture of our schools, our educational system, and our research so that we do the kind of research that can be produced quickly and put into symbols—systems that become much more nimble about responding to that data, that we need a clear vision like the one that is articulated in this report about what teaching and learning looks like and what we are aiming for, and that we have articulated standards.

I think the Common Core State Standards are going to help us ground our work in schools by saying that we are all focusing on the same thing. One of the huge problems for the teacher support system is that people who have been supporting teachers don't know what those teachers are going to have to teach. So the combination of those four strategies, we have never been in that kind of position before as a Nation and I think it is time to take advantage of the fact that we have learned that largely from school districts that have tried to do these kinds of things and research that has been produced in this sort of carnival-esque world but where we can sort out what the good stuff is and choose to focus on that now.

Mr. LIPINSKI. Mr. Heffron?

Mr. HEFFRON. So on page 27 of the report, the fifth bullet says, "District should provide instructional leaders with professional development that helps them to create the skill conditions that appear to support student achievement. School leaders should be held accountable for creating school contexts that are conducive to learning in STEM." I would suggest that we remove the "in STEM." If you can create a school environment that promotes learning and a school leader that is held accountable, then you can drop "STEM" in there, you can drop "art" in there, you can drop "business" in there with the right leadership and the right expertise. And I think that that is the thing that didn't show up in the next page, which is really what the Commission suggested we do next, and I think we really need to reprioritize and say, you know what? This has got to be a school that is run effectively, that the leadership is accountable to that, that there are students in that building who are supported and able to learn, and then you can drop "STEM" in there and it will work. And if you don't, you can try program—all these programs that are being tried and some places they work and some places they don't, they are going to work where there is a school culture that supports that learning and they are not going to work everywhere else. And that should be reprioritized I think.

Mr. LIPINSKI. Thank you.

Chairman BROOKS. Thank you, Mr. Lipinski.

Next, the Chair recognizes Representative Tonko of New York.

Mr. TONKO. Thank you, Mr. Chair. Good morning, everyone.

As an engineer, I am very interested in this topic. If you could cite for me any good partnerships with states out there, and is there a way to better involve states with federal policy to maximize the outcome here and achieve our goals?

Dr. MEANS. I certainly think that is the attempt under a number of the Race to the Top initiatives that are going on now. We have a very strong STEM focus on the initiative in North Carolina, for example, which is really focusing on STEM issues and preparing the population for STEM careers and STEM-related careers in a variety of different places. Those things are just unfolding now, so it is a little early to say how fruitful they have been, but certainly they have harnessed state energy and state policy. And from the leading universities and the Superintendent of Instruction's Office, I think we see a lot of action in that particular State and we will know better in a few years how effective it has been.

But they are establishing a number of STEM-focused specialty schools, some of them focused on careers, some of them focused more generally, and they are watching those very carefully.

Mr. TONKO. Does anyone else want to—yes, Dr. Gamoran?

Dr. GAMORAN. Well, the partnerships with states has been challenging because of the states' dual role in regulation and implementation and the challenges of gaining capacity for real reform at the state level. I think the Federal Government has provided states with extremely important tools in the regulatory environment of the last ten years and in the new approaches to school improvement grants and school turnaround. And I think that is a place we can look to in the future for the kind of progress we are talking about.

Mr. TONKO. If I could just broaden the segue to STEM. We have had a lot of discussion about high schools and some about middle schools and developing the cultural aspects of science, tech, and engineering and math, but with education being like the whole segue, the mission of self-discovery, and at times to combat fear that might be developed before you even enter into this sphere, the role of elementary education and the training of elementary teachers, science and tech awareness, science and tech acumen at that level, introducing children to that, drawing forth their self-discovery, perhaps combating the fear factor which is subliminal, but is there a way to address some development in that K through six, or pre-K through seven discipline where we can introduce science and tech in a way that combats the fear factor and enhances the self-discovery of the student? Yes, sir, Dr. Wilson?

Dr. WILSON. I think that there are—this is another case where I know of some examples of some very good programs and approaches, but they are local and they haven't been tested or tried to be spread and tested so that we know what is—what will spread and what will not spread. These programs tend to focus both on developing—there is one example, for instance, is the Urban Advantage Program in New York City itself where the cultural institutions in the city took responsibility for helping the schools, and one part of that work was to help them with the curriculum and the standards for children in those schools. But then they didn't just help with the development of curriculum standards; they also thought about what role they play in teacher-professional development. And in that teacher-professional development, an important piece is also parent involvement. And so they work with—it is a middle school program, but a lot of middle school teachers tend to be elementary teachers who moved up to middle school, and I think that a lot of what goes on in urban advantage can be used to think about elementary.

They think about what parents need to learn, how they need to be pulled in, what kind of relationship they need to have both with the school and with the cultural institutions in the city because they have a lot to do with getting people over fear and getting them excited about science. They think about the curriculum, they think about a supportive assessment system because there is an exit exam in the city, and they think about what the teachers need to know and what kind of support the teachers need in order to be able to pull this off.

This is just one example but I think NSF—it is an NSF-sponsored project, and the city of New York also sponsors it. But I think there are other examples like that and I think it is time that we found them and we invested in figuring out how to leverage what we have learned from them rather than asking for other people to reinvent the wheel.

Mr. TONKO. Um-hum. Dr. Gamoran?

Dr. GAMORAN. Yes, I think this is a strength of NSF's Math-Science Partnership Program which establishes partnerships between institutions of higher education and school districts with math and science educators and mathematicians and scientists, as well as the K–12 personnel. At the elementary level, a fundamental problem is that elementary teachers have taken very little math and even less science, and we need content-focused professional development, and we need to work with our institutions of higher learning to infuse greater content in the elementary education preparation programs.

Mr. TONKO. Thank you. Mr. Heffron?

Mr. HEFFRON. So I think this has been said earlier, but I believe the report even indicated that science is getting less time in elementary school. I know it is getting less time in middle school. It is not getting less time in our high school, but that is a really purposeful change that we have made. And when I look at our testing program in Colorado, math and English and reading are tested every year grades three through ten and science is on an every-other, every-third-year program. The science assessments typically aren't as strong as some of the other assessments in our state testing system, so I think it needs more time, the assessments need to be more frequent and better, and with those things, you will have more time spent and it will be better time spent. That is one other way that we can help get more science infused in grades K through six.

Mr. TONKO. I think my time is up, so thank you.

Chairman BROOKS. Thank you, Mr. Tonko.

Next, we have Mr. Sarbanes of Maryland.

Mr. SARBANES. Thank you, Mr. Chairman. Thank you all for your testimony.

I am going to ask you to quantify—I always do this to people and it is impossible for them but I am going to ask you to do it anyway. If 100 is where we want to be with our STEM education in this country like on a 100-point scale—and you all I think probably have a pretty good sense from the research you have done, so forth, where we need to be as a country in terms of STEM education—where were we ten years ago? I will start with you, Dr. Gamoran. We don't necessarily have to go down the whole line, but give me your best show. Ten years ago where were we on a 100-point scale in terms of STEM education? Where were we five years ago and where are we today?

Dr. GAMORAN. Well, if we take 100 as where we want to be with the best—the most prosperous nations in the world in the STEM fields and 0 is where the least prosperous nations are in the STEM fields, we are around 50, and we have not moved the needle very much in the last ten years. We have moved it a little, so maybe we have gone from 48 to 52. We have also witnessed some closing of learning gaps among different groups in the last ten years, but again, very small progress.

So just as Chairman Wolf said, I think—excuse me, Chairman Brooks said in his first question, we have made some progress but it falls far short of the vast amount of progress that we need to make.

Mr. SARBANES. Does anyone on the panel differ substantially with that perspective? Okay.

I would be curious to know from each of you as briefly as you can describe what for you was the most surprising finding in the report that was issued, something that kind of came out of the blue if there was such a thing or if you want to substitute for that what you consider the most noteworthy? But I am most interested in stuff maybe that you didn't see coming that kind of jumped out at you as you think about the report. Just pick one if you could. Why don't we start at this end, Dr. Means, and go in that direction.

Dr. MEANS. This was not something that was new to me but I thought about it in a different way after being on the Committee. I realized that since No Child Left Behind and the annual testing in reading and math were implemented that science was getting less time. And in fact science programs I was studying that were very interesting were becoming more difficult to implement because the time was mandated for reading and math. And I realized that we have on the one hand our government saying that we think STEM education is really important and it is a national priority and on the other hand we have an accountability system that is not measuring it and that is undercutting efforts to do STEM education. So we actually have a contradiction in our national policies that is hurting one of our priorities.

Mr. SARBANES. Okay. Dr. Allensworth?

Dr. ALLENSWORTH. This wasn't a surprise to me but it was a surprise in that I was happy to see that it was in the report so prominently, and that was the suggestion that test scores are not the only measure of STEM progress in our schools. You might be surprised—and I was surprised because there is such an emphasis on test scores as the only indicator of learning in science and math but the fact is it is not the best indicator. Test scores are actually not very predictive of whether students will go to college, enter STEM careers, and actually get high earnings in the workforce. There are much better indicators including students' engagement in the classes, through their grades, their interest in science and math, their knowledge about science and math, and their—and how to do inquiry. And I was very happy to see that that was in the report because we need to start following these other indicators. And these are also indicators that it is easier to get teachers to work around to try to improve rather than just the focus on test scores.

Mr. SARBANES. Okay, thank you. Dr. Wilson?

Dr. WILSON. I was most happy to see the writing about assessments as well in large part because if we are going to find some way to measure teacher quality, we are going to have to in the end use student outcomes. And if we are going to do that, we need good student outcomes.

Mr. SARBANES. Right. Mr. Heffron? You need to put your mike on.

Mr. HEFFRON. I was especially pleased with the first paragraph, "Policymakers at the national, state, and local level should elevate science to the same level of importance as reading and mathematics." I think that is—that was the thing I was most pleased with and I think I stated earlier I was just surprised to see—to not see school culture and kind of accountability to leadership make the last page.

Mr. SARBANES. Okay. And Dr. Gamoran?

Dr. GAMORAN. I guess the two things that were surprising to me was first as Dr. Allensworth already indicated, how little research has been done on outcomes other than student achievement. I am always complaining that we don't have enough research on student achievement that is rigorous and it turns out there is even less when it comes to other outcomes. And especially when we are looking at young children, that has got to be equally if not more important.

A second issue alluded to by Mr. Heffron is the role of STEM-focused leadership and leadership for learning. The Chicago report that Dr. Allensworth was involved with came out shortly before our committee began its work I think or during the time, and it indicates the elements of school context that are so important for some of the reforms that we discussed to take place, I think our report is able to bring those together, the instructional practices and the school context conditions discussed in the Chicago report in a way that hadn't been done before.

Mr. SARBANES. Okay. Thank you. I yield back.

Chairman BROOKS. We have enough time for additional questions should any of the Members wish to follow up, and in that regard, Mr. Lipinski has informed me that he has additional questions. So Mr. Lipinski, the time is yours.

Mr. LIPINSKI. Thank you, Mr. Chairman. Thank you for allowing this time.

I would be remiss if I didn't say that my thoughts and my ideas about STEM education are not only shaped by my own experience as an engineer but also by my wife as an actuary. She was a math major in college. I hear a lot back home from manufacturers in my district and we talk about the state of manufacturing in this country, we talk about lack of jobs. I keep hearing from local manufacturers that they cannot find employees that meet their basic criteria of being qualified to do the jobs that they are doing.

Now, when we are talking about STEM education, I always think well, who are we really aiming for and is this a situation where we want to provide everyone—obviously—clearly, we want to provide everyone the basics of math, basics of science, and basics of engineers, which to me is just a logical thought process. But then there are others who will go on to be engineers, who will go to college and major in a STEM field. Then there is another group who will go to graduate school.

Now, are there different things that we have to do? At what point do these paths diverge? How do we do that because there is a lot of—you know, a few of you mentioned—I think especially Dr. Wilson—about—or maybe Dr. Allensworth about some students who were higher achieving—have shown higher achievement going off into more intense and higher levels of math. How does this all come together so that we are preparing a sort of basic level of what you need in STEM education, and the need for those who are going to go to college in a STEM field and then who are going to go to graduate school in a STEM field? How do we do that? Do we need to focus on—I think we need to focus on all of it, but that seems to add a complication to it perhaps. But as a general question, let me start with Dr. Gamoran.

Dr. GAMORAN. Well, that is a terrific question and it is a question that is fundamental to all areas of education, not just STEM. How do we set up an education system that provides equal opportunity for all and yet recognizes that young people are going to go off into different futures? What we have learned from research in this area is that providing rigorous set of curricular opportunities is essential all the way along. We shouldn't try to foreordain—well, this is the graduate student and this is the person who is going to go into a current technical occupation, and this is the person who needs to read the newspaper. We shouldn't try to foreordain those differences because young people surprise us. And the one who is not doing his homework today could be the engineer of tomorrow.

So it is I believe not until the high school level really where we need to have a different stream of classes available for our most advanced students at earlier ages. We need to try to provide rigorous opportunities for students at all performance levels and of all interests. Of course, there are extra school activities, extracurricular camps, activities after school, programs, and so on that students are going to choose by interest. And some of the differentiation you describe is going to come up through that process. But with respect to what we are offering in schooling, we should try to minimize the differentiation, particularly at younger ages, and introduce that differentiation only at the most advanced levels in high school. That is my view and it is based on—this happens to be an area of research of mine.

Mr. LIPINSKI. Thank you. Mr. Heffron, did you have——

Mr. HEFFRON. Sure. I just think back to my preparation. I was an engineer by training as well and I didn't have advanced math leaving high school. I just had pre-calculus like every one of our students at DSST has to have. So I think you have to be prepared, and if you are prepared, it doesn't mean you are going to be STEM-going but it means you can be STEM-going. The other side of the equation is, of course, the interest piece. So if you have a student that is interested and prepared, then you have got a match, and it is much easier to change the interest side. You can change the interest side by scholarships like Chairman Brooks suggested. You can change the interest side by activities and all kinds of things, but you can't quickly change the preparedness piece. That happens over time and only really happens if you have a really clearly defined rigorous path from at least ninth grade and probably before.

Mr. LIPINSKI. Anyone else? Dr. Allensworth.

Dr. ALLENSWORTH. Right. It is just a really critical and difficult issue and it is a matter of where you are going to put your resources and really think it out how to do it right because the tendency is always to teach to the students in the middle. And as Dr. Gamoran was saying, we don't want to take away opportunities from some students just to make sure that others have the opportunity. But if we are going to teach everybody at high standards, that means the students with the weakest skills are going to need extra support because if they get frustrated, they will withdraw, they will act out, and then they will learn less and everyone else will learn less, which means they need tutors, they need extra teachers in the classroom depending on how the classroom is structured.

At the same time, the students with very high achievement can often be ignored; they can coast and not reach their potential because it is easy for them. So we also need to make sure that we are paying attention to the students with high achievement to make sure they are reaching their potential potentially through extra opportunities.

Mr. LIPINSKI. Dr. Means?

Dr. MEANS. I just wanted to point out that in the report we set three goals for STEM education, and the second goal was to increase the proportion of our students who had preparation for STEM-related occupations. And by that we meant occupations that might require two years of post-secondary work or a certificate, and we talked about some of the research on career and technical education. And I think that is very important because for some of our adolescents, high school activities that aren't related to a future they can imagine for themselves are not very motivating. So I do think it is important for systems to consider these options for students who are going to go into STEM-related occupations but not necessarily earn a bachelor's or advanced degree.

Mr. LIPINSKI. Thank you. Thank you again, Mr. Chairman, for the opportunity.

Chairman BROOKS. My pleasure.

Mr. Sarbanes, I understand that you would like some time for follow-up?

Mr. SARBANES. I appreciate it, Mr. Chairman.

I am the author of something called the No Child Left Inside Act, which is a piece of legislation we have been bringing forth over the last two years here, and Senator Jack Reed is the author of the companion piece in the Senate. And basically what it aims to do is strengthen environmental literacy across the country, finds ways to better integrate into the instructional program awareness of the environment, an understanding of it, basic literacy with respect to the environment, and provide funding opportunities through the U.S. Department of Education to support environmental literacy with a particular focus on how you can integrate outdoor education opportunities and resources in our schools.

So the classic example would be a science teacher prepares the class for two or three weeks in advance of a field trip that is going to go to the Chesapeake Bay and take samples of the water to test its acidity and salinity and look at marsh grasses and all the rest and the class goes out for five, six hours and does this. Then they come back from that experience and they spend the next two or three weeks sort of analyzing the data and putting it in context and so forth. And the research suggests that when you integrate this kind of experience into the instructional program, particularly with respect to science classes that student achievement jumps significantly because the kids are just more energized by it and they see real-world application of what they are learning in the classroom.

I wanted to get your perspectives on that as sort of an opportunity for helping to boost and strengthen STEM education, this sort of outdoor education component. And I wondered whether the report, in looking at some of the schools that have been most successful with respect to STEM education, were able to identify that that is a resource or opportunity that has been taken advantage of in some places. And anyone who wants to speak on this can. Yeah, Dr. Gamoran?

Dr. GAMORAN. What you are expressing is fully consistent with the arguments in the report, the findings and recommendations. In fact, I think the report would add fuel to your fire because we have identified students' research experiences as one of the keys to students'—young people's further interest in science. In fact, at schools like Thomas Jefferson or the Illinois Mathematics and Science Academy, this is the kind of experience that they have. And extending that to a broader range of students would likely be effective and successful.

The approach that you are describing I think is consistent with the broader emphasis on importance of inquiry activities—asking questions, gathering data, analyzing the data and connecting it to existing knowledge that is science. Too much of our science instruction is reading a textbook and memorizing the definitions of concepts. The kind of approach to science learning—I am not surprised to hear that the kind of approach that you are describing results in a boost in children's achievement. I think that is consistent with the broader research literature.

Mr. SARBANES. I just have a minute and a half. Is there anyone else who wants to speak to this? Yeah?

Dr. MEANS. I would just say having studied environmental science programs that these activities can be done either well or poorly. It is really critical that that connection with the science curriculum and the analysis of data be included, that it not just be a matter of going outside for the day and that teachers need support in learning how to do this well. It is actually not something that all teachers are well prepared to do.

Mr. SARBANES. Yes, Mr. Heffron?

Mr. HEFFRON. I would concur wholeheartedly with that and just suggest that all those opportunities would build our program and help us build. We spend a lot of time and effort trying to recreate those things, and I feel like there is less things out there that are existing for us to easily take advantage of and the more the better, but again, it does need to have a culture that supports all those things that Dr. Means suggested.

Mr. SARBANES. Dr. Wilson, did you have something?

Dr. WILSON. I was just going to make the point that you cannot underestimate how much teachers need support in learning how to do this kind of instruction, because any good idea that comes into a school is often picked up enthusiastically by teachers, but what it takes to manage the students on such trips, what kinds of tools they need—the teachers need in order to have students actually understand what is going on, how to structure students' thinking, there is just a whole lot of stuff that we don't think about when we think of good things for teachers to do and ongoing support as well as the consequences for how the school culture has to change, teachers having the time to do that.

Mr. SARBANES. Right.

Dr. WILSON. The assessments being in place so that they don't feel like they are off track.

Mr. SARBANES. Well, and yielding back my time I would just observe that one of the key components of this legislation is to provide resources for the kind of training that you all have alluded to so that it is not just a field trip and timeout from school; it is actually a very fully integrated experience.

And I yield back. Thanks.

Chairman BROOKS. Thank you.

The Chair notices that Mr. Clarke of Michigan has arrived. We are in our second round of questions but would you like to have your first round? Mr. Clarke has five minutes.

Mr. CLARKE. Thank you, Mr. Chair.

And this question is posed to any and all Members. How can we enact policies that could help African American students, especially our young men, to get involved in STEM education? Here is why I say this is that right now we have got a challenge in the city of Detroit which really is an example of the problems that many big city school districts are facing where we have an enormously high dropout rate, especially among black males, yet those very men that end up dropping out and a lot of them end up going to prison really have an extraordinary potential to give a lot back to our country.

I will give you an example. I won't use a name since this person is known, but there was a gentleman that I know who I believe sold drugs as a teenager. He was enamored with numbers. Well, one of his athletic coaches introduced him to economics, so he ended up becoming a Ph.D. candidate in economics and is now a tenured professor in economics at a nationally known institution here in this country. And he is not that old so it was just my estimation that he sold drugs based on the circumstances.

All right, still, with me, all right, I am first-generation college. It was art because I used to draw pictures a lot, that was my gateway into education, so I have an undergraduate degree in painting. There are other young men that I know that have—that can integrate both of those, the artistic and the quantitative, which is exactly what we need in STEM education. So I wanted to share with you those anecdotes because they mean a lot to me.

My last point is I grew up with guys who used to help me out academically when I was in middle school. One of them never worked a day in his life because of an incident that occurred. He has been emotionally disabled all of his adult life. And you know, it may not be a waste to him because we don't know what mindset he has, but his disability definitely deprives our country of a contribution, a contribution from that perspective of growing up in the inner city, which I think is so valuable because it helps me represent people as a whole in these troubled economic times because I went through some of those.

But enough of the anecdotes. How can we get our young men involved in STEM who have the potential to do great things for our country?

Mr. HEFFRON. I have an anecdote of my own. I also had the opportunity to teach Calc II and three of my best students are a Hispanic female, a Hispanic male, and an African American male, and they are fantastic students. They are killing it, and they have been good students all the way along. But there is a series of other students who struggled in their middle school and are now in calculus and in pre-calculus. And I guess I would go back to the point that—and I think Dr. Gamoran said this—we don't know which of those students is going to turn around and when, but if we provide the support that Dr. Allensworth is suggesting and the high expectations and the avenue to get there and some opportunities to change a math track or somehow reengage at a higher level when that switch flips, that all of those students can be college-ready and many of them will choose those STEM fields if there is the preparation. And then all of the other things outside of the Art For You, the Robotics class at our school, or the fields trips and the other STEM possibilities as they are going up to CU Boulder or down to the Health Science Center to really engage in exciting STEM-related activities that are exactly what Dr. Means is talking about, really legitimate science and math, that is what I would suggest is the solution.

Dr. GAMORAN. With all of the talk about the importance of teachers' content knowledge in the STEM areas, we need also to remember that teaching is about relationships, that having teachers who can establish caring relationships with young people and help guide them as perhaps you were nurtured in your school experiences is fundamental to the success of our young people from all backgrounds, including the African American males that you described.

This is why teaching is not just a matter of knowing the subject; it is also about knowing how to convey that subject to young people and about establishing relationships and creating a safe and trusting environment where young people can learn and thrive.

Dr. ALLENSWORTH. So I come from Chicago where we went from having a graduation rate of about 47 percent to now about 69 percent. For African American males it has gone from about 30 percent to over 50 percent at this point. Dropout rate—dropout is a huge problem in our inner cities, in Chicago, in Detroit, and other places. We have been looking at why students drop out and what is really critically important. As Dr. Gamoran said, relationships are key. What makes for a trusting relationship? It is that students get the support they need when they need it. Students withdraw when they feel like they can't succeed or they have gotten further behind and they don't know how to catch up.

Schools that actually get more students to graduate and get them through their classes are schools where teachers closely monitor students. When a student is absent, they call home that day. They don't let a student get away with being absent for two weeks. Schools that have structures that are set up to actually track absences and make sure kids are coming right away get them back on track, have better-than-expected absence rates, they have better-than-expected grades and pass rates. And actually having teachers keep up with their grades and as soon as a student's grade slips, reaching out to the student, reaching out to the parent, finding out why their grade is slipping and getting that student back on track. It means having people in the school monitoring so that when a student gets an F, they call the parent, they call the teacher, they call the student into a conference and they figure out what needs to happen to get that student back on track.

When students feel like their teachers know when they are struggling and want them to succeed, they trust their teachers. When students feel like they are struggling and they don't know how to succeed and they don't know why they are getting bad grades, they don't trust their teachers, they get angry, they think their teachers are unfair, and they withdraw and it becomes this negative cycle that builds and builds. The key is monitoring and support and having systems in place so that it is easy for teachers in schools to monitor kids and give them the support they need when they need it.

Mr. HEFFRON. Can I just follow up with that really quick? I think that is perfect. In our school, what that looks like is each teacher is an advisor of roughly 15 students and so every week those teachers and advisors meet. It is called house meetings and there are 50 to 60 students that they are teaching all the same classes for and being advisors for. Who is struggling this week? Why is that? Is this ongoing? What have we tried already? Who has called home? Who is the teacher? Who is the advisor that knows this student best? Who is their support person? What do the parents say? Does the dean know about this? I think that is exactly what we are talking about and that is when I would go back to that whole culture piece around building a school condition that supports learning.

Chairman BROOKS. Mr. Clarke, you would like some follow-up time, feel free.

Mr. CLARKE. Thirty seconds, Mr. Chair, if you will.

Chairman BROOKS. Feel free.

Mr. CLARKE. Thank you. Thank you, Mr. Chair.

That advisory concept, where did you get that from?

Mr. HEFFRON. My understanding—because I didn't create the advisory structure. It was created before I came to our organization in its second year. But my understanding is that was kind of a meld from kind of the private school model and some of the other highly successful charter schools on the East Coast.

Mr. CLARKE. All right. Because we have an advisory structure in schools that are in the University Prep—this is a charter school in Detroit, which I think is effective, too. In fact, the model is some type of a homeroom that has 15 students and where that one instructor actually is that mentor. And the key is here is that many students now, they don't have any parental supervision or support in the home in the sense that maybe that advisory structure in some way could provide that nurturing that is not in the home or at least in support of the value of education. Any if you just remember even when you are—if you were first generation college back in the old days, your parent even though they didn't go to school or may not even—couldn't even speak or read, but they would value education precisely because they didn't have the opportunity to get that. You know, now in the inner city at least where I am from you have a lot of the parents who themselves need not only education but an education in the value of education so they could pass that onto their child.

Mr. HEFFRON. So that is exactly what the advisory program is for, and when a new teacher joins our school, I tell them if you are an advisor you are really that student's parent at school. And sometimes what happens is that advisor may actually be picking that student up and bringing them to school. I mean it has gone to that level where a kid is—this kid can make it but for whatever reason this kid can't get to school. And so that person is providing that support that is necessary to get that student to school so that they can learn.

Mr. CLARKE. Mr. Chair, I just want to make a comment that I think that this could be a feature that could be replicated in all of these urban schools, this type of advisory structure. I think it could work. I want to just put that out there on the record. That is something I would support. I do look at the reality right now of how these kids are not being raised many times in their home even if they actually have a home that you would call it that.

Chairman BROOKS. Thank you, Mr. Clarke. You managed to get your time for first round and second round in all at once.

With that, I want to thank the witnesses for the time that you have spent with us and also the Members for their questions. The Members of the Subcommittee may have additional questions for the witnesses, and if so, we would ask you to respond to those in writing. The record will remain open for two weeks for additional comments from the Members.

The witnesses are excused and this hearing is adjourned.

[Whereupon, at 11:44 a.m., the Subcommittee was adjourned.]

Appendix:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Adam Gamoran, Director,
Wisconsin Center for Education Research, University of Wisconsin

Questions submitted by Chairman Mo Brooks

Q1. You highlight the need for NSF to fund basic and applied STEM education research, but then mention gaps in basic research and the ability of the Department of Education's Institute of Education Sciences to do applied research. Is it really necessary for NSF to be funding any applied STEM education research, or should they focus funding solely on the fundamental research questions of "how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers." Why or why not?

A1. NSF plays a crucial role in supporting basic research that lays the foundation for improving K–12 STEM education. Moreover, a productive division of responsibility may be emerging in which IES pursues a mission that is largely applied, while basic research remains the province of NSF. Yet there are two reasons why, in my opinion, NSF should continue to fund applied as well as basic research.

First, research on education is most productive when it reflects a dynamic relationship between basic and applied studies. When successful, basic studies yield insights whose relevance to the real world must be tested in applied work. As an example, consider NSF's new program in Cyberlearning: Transforming Education, a collaborative effort among several directorates. The mission of this program is "to integrate advances in technology with advances in what is known about how people learn to

- better understand how people learn with technology and how technology can be used productively to help people learn, through individual use and/or through collaborations mediated by technology;
- better use technology for collecting, analyzing, sharing, and managing data to shed light on learning, promoting learning, and designing learning environments; and
- design new technologies for these purposes, and advance understanding of how to use those technologies and integrate them into learning environments so that their potential is fulfilled." (See: http://www.nsf.gov/funding/pgm—summ.jsp?pims—id=503581&org=EHR&from=home)

In this instance, findings about how people learn with technology and how effective learning environments can be designed achieve their ultimate aim when researchers "design new technologies" and "integrate them into learning environments." Moreover, there is a feedback loop from applied back to basic research as it is common for applied settings to reveal unanticipated challenges that lead back to the laboratory. Thus, basic and applied research are interrelated and a funding stream that supports both goals is appropriate.

A second reason for continuing applied research at NSF rather than yielding this ground entirely to IES is NSF's distinctive focus on STEM. Consistent with broader federal education aims, literacy and mathematics teaching and learning capture much of the IES portfolio. IES does support research on science teaching and learning, but to the best of my knowledge there are no IES-funded studies of engineering education, nor of technology education (as opposed to research on the use of technology in teaching and learning, which is well represented). IES is mainly interested in studies of learning and achievement, but the Successful STEM report identified outcomes other than test scores as an important gap in our knowledge. IES-supported research tends to focus on formal K–12 schooling, but NSF-supported research on learning science in informal environments may turn out to be crucial as investigators try to find ways of capturing student interest in science at early ages and maintaining it throughout the schooling years. For these reasons, also, applied as well as basic research at NSF will continue to point towards improvements in K–12 STEM teaching and learning.

Q2. You testified that it is difficult to determine "the extent to which a school's success results from any actions the school takes, or the extent to which it is related to which students are enrolled in a school." You say research designs to address this challenge are available, but have only recently started being used. How soon can we expect to see the results of this research.

A2. In my judgment we are 5–10 years off from widespread findings that address this challenge.

On the one hand, results from this type of research are already emerging. For example, the What Works Clearinghouse at http://ies.ed.gov/ncee/wwc/ has reviewed the results of rigorous analyses of 33 interventions in mathematics education. Of these, ten have shown evidence of effectiveness. As of yet, however, no studies have been reviewed in science education, nor in engineering or technology education.

On the other hand, the fact that this type of research is relatively new means that we are just beginning to confront the problems it reveals—particularly problems of implementing and scaling up effective programs. IES has funded a number of large-scale studies that use rigorous designs to assess program impacts, including some that address learning in mathematics. For example, the national study of educational technology carried out by Mathematica included a focus on middle and high school mathematics (http://www.mathematica-mpr.com/education/edtech.asp#pubs). This study, like several others, concluded that the programs assessed were ineffective at raising student achievement, even though the programs had been shown to be effective in smaller-scale studies. (Other such national studies include Reading First, tutoring under No Child Left Behind, charter schools, and so on.) This points towards scaling up effective programs as a major challenge and calls for further investigation of the scaling up process.

Similarly in my own NSF-funded work, my colleagues and I found that a large-scale roll-out of "science immersion," a sustained, inquiry-oriented science program in grades four and five, failed to elevate achievement scores as expected. We have now been able to pinpoint the problem to incomplete implementation in the classroom: teachers engaged in the first two steps in the inquiry cycle (asking questions and gathering data) but did not follow through to connecting the data to scientific knowledge nor to justifying and communicating scientific explanations. Without the connection to domains of scientific knowledge, it is not surprising that student learning of science content did not increase. Like the study of educational technology, our research suggests that although we can design effective classroom programs, we are often unsuccessful in implementing these programs in large numbers of schools and classrooms. Our findings offer important contributions for future efforts to design innovative science education programs that can be brought to scale.

The challenges of implementation and scale up mean that although the findings from research designed to disentangle program effects from selection are already beginning to emerge, findings that reveal large positive effects when taken to scale remain elusive. A few studies of comprehensive programs have yielded this sort of evidence (for example, the four programs funded for Scale-Up awards under the Department of Education's Investing in Innovation program), but it will take several more years for such studies to become widespread. Several conditions are contributing to the expansion of such research, including IES predoctoral and postdoctoral training programs, the establishment of a new scientific society on effectiveness research in education, a new academic journal with the same focus, the increasing salience of the What Works Clearinghouse, and more widespread understanding generally in both NSF and the Department of Education on the importance of using appropriate research designs to support causal conclusions. Thus, there is reason for optimism in the future.

Responses by Mr. Mark Heffron, Campus Director,
Denver School of Science and Technology, Stapleton Campus

Question Submitted by Chairman Mo Brooks

Q1. How do you ensure that your teachers are highly qualified to teach STEM courses at DSST? What pre-service training do you require? What in-service training do you provide?

A1. We go through a rigorous screening process requiring the following:

- Teaching candidates submit resume, cover letter and college transcripts that indicate background teaching experience and course material taught.
- We require teachers to prepare a sample lesson plan for a desired topic and then teach a sample lesson, either at our school or provide a video tape of the lesson being taught.
- We require attendance at a 3–5 day teacher induction program before any classes are taught that orient new staff to our mission, vision, curriculum and assessment program and school culture.
- Approximately every-other week, we provide 2–3 hours of collaborative planning time or Professional Development time with a department chair, or teaching partner. We require each new teacher to collaboratively plan and create common lesson plans and assessments 1–3 hours per week.
- Each new teacher receives additional organizational professional development for 2–3 hours per month.
- As an organization, we ensure that all teachers meet the highly qualified teacher requirement, per applicable state law.

Q2. According to your testimony, last year DSST operated the highest performing middle school and high school in Denver. Your testimony highlights many aspects of your program, from specific classes to school culture. We are interested in what makes your students and schools outperform other schools in the area. If someone were looking to replicate your results what are the key elements to take into account?

A2.

- Hiring and retaining high achieving staff members that are committed to the success of each student no matter the student's introductory skill level and motivation.
- Setting high expectations with a rigorous academic program that provides less student choice and more focus on required college preparatory coursework. (We require 5 1/2 yrs of science and a minimum of pre-calculus for all graduates.)
- Heavy focus on math and science in 9th grade-Algebra-based physics, along with at least Algebra/Geometry in the 9th grade to provide a strong math background in the 9th grade year.
- Our culture focuses on college from day one (for the majority of our students, that means 6th grade). Each student understands the expectation that they will be prepared and ultimately accepted to a four-year college or university. The school culture celebrates college success in all grades with college trips, return visits from Alumni and college celebrations that mimic what other schools might do to celebrate athletic success. It is cool to be smart and going to college at DSST.
- A relentless commitment that each individual (student and staff matters) with accountability and support systems in place to insure that students will not move on unless they are prepared for the next grade and tutoring and support classes to insure that they will not fail a class and ultimately be held back from advancing to the next grade without extraordinary efforts from peers and teachers and administrative efforts to remediate skill deficits.
- A high degree of support for first generation college-bound students and their families.

Q3. What unique and various challenges in STEM education exist for teaching and learning between the middle and high school grades, and how are they being addressed?

A3.

- Attracting and retaining highly qualified STEM teachers remains a significant challenge. The hiring pool is smallest in the most certain science fields especially at the high school level, for courses such as Advanced Chemistry and

Physics. These subjects also have the greatest turnover, as we have seen more of these teachers leave for higher paying careers.

- We continue to improve our induction and professional development programs. Our support has improved. We do not have funding to combat the market demands at this time.

- It is challenging to find and/or create specific engineering curriculum (especially at the middle school and early high school grades) that is engaging to students, teaches engineering principles and is well aligned to the math preparation of grades 6–10.
    - We are in the first year of a 9th grade STEM design course at our Stapleton High School Campus (the school that I lead). We are creating much of the curriculum. Once the first year of this course is complete, we may move to replication at other campuses, possibly lower grades depending on our experience.
- Our focus on a college preparatory curriculum with a math and science emphasis is considerably more rigorous than most surrounding schools in the district. We are a public charter school and not a magnet school by design to serve an underserved, under prepared and underrepresented future STEM workforce. We have greater attrition than magnet schools as student enter wanting a high quality college preparatory education but may choose to leave our school and attend a less rigorous school as they learn what is required to truly be prepared for STEM college degrees. (Our attrition rates are better than those in traditional Denver Public high schools.)
    - We don't presently have a solid answer to this challenge at the MS or HS level. Our currents efforts are focused on continuing to refine our support and intervention systems to help remediate students with low skills. There is no substitute for success and we absolutely find that students who experience success, even with greater effort, are more likely to stay in our STEM program. We now have three middle schools in our organization and within the next two years, we will open two more. The middle school program is essential to build the required foundational skills to be successful in rigorous STEM high schools.

Q4. What is the role of the local school administration, community, parents, teachers, students, and various government entities in creating these model schools and programs and in sustaining them?

A4.

- Hiring, training and retaining school leaders and administrators that have the skill and drive to create high accountability school cultures.
- Create funding sources that can be used to incent schools and teachers that produce outstanding student achievement in STEM subjects.
- Provide funding (through grants or otherwise) that can be used to hire staff and/or pay for programs that leverage parent and community resources in STEM fields for things such as:
    - STEM tutoring
    - Robotics and other STEM afterschool programs
    - STEM field trips
    - Academic Elective teachers (from Industry) that are qualified to teach cutting edge STEM electives that will interest and prepare students for STEM fields

Responses by Dr. Elaine Allensworth,
Senior Director and Chief Research Officer,
Consortium on Chicago School Research, University of Chicago

Questions submitted by Chairman Mo Brooks

Q1. Dr. Gamoran highlighted the need for NSF to fund basic and applied STEM education research, but then mention gaps in basic research and the ability of the Department of Education's Institute of Education Sciences to do applied research. Is it really necessary for NSF to be funding any applied STEM education research, or should they focus funding solely on the fundamental research questions of "how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers." Why or why not?

A1. Both types of research provide useful information, and can be complementary. Applied research is most useful when designed in a way to answer broad questions that are generalizable beyond the specific application. For example, rather than simply examining whether a policy or program works, asking how it worked and under what conditions, makes the research much more useful, since it is rare that a program is implemented in the same way over time or in different places. Just doing basic research is also eventually insufficient, because it is difficult to translate to practice. School practitioners need to know what worked and why and see models of changing practice to guide their own efforts.

Q2. When discussing the curriculum standards changes implemented in Chicago, the three negative effects—low-skilled students with slightly higher failure rates, system-wide graduation rates declining, and college entrance declines for high-skill students—are a trio of challenges other systems need to be sure not to replicate. Now that the common core of standards is gaining momentum, how can schools and systems looking to implement new standards and curricula steer clear from making similar mistakes to those experienced in Chicago, especially in STEM subject areas?

A2. This is absolutely a critical question at this point in time, if the potential of the common core standards are to be realized. First, we need to recognize that with expansion of challenging college-oriented curricula to all students, there is the real possibility of reducing the math and science preparation of the highest-achieving students, who are also the students most likely to go into STEM careers. In fact, because other students have such a low likelihood of entering STEM careers compared to high-achieving students, expanding math and science opportunities for other students at the expense of the opportunities for high-achieving students can easily result in fewer students overall entering STEM careers. One reason for the decline in opportunities for high-achieving students that can occur with an increase in overall standards is the lack of teaching capacity for high-level math and science classes. This can result in a reduction in the classes available to advanced students (e.g., eliminating pre-Calculus/Calculus so that there are enough sections of Algebra II for all students), or shift in the courses available (enrolling all students in Earth Science/Bio/Chem instead of Bio/Chem/Physics because it is easier to find Earth Science teachers than physics teachers). It can also lead to a lowering of the expectations in math/science classes as teachers who are used to teaching high-achieving students have difficulty teaching to students who enter their classes with weaker academic skills. There is a risk that if teachers do not know how to teach the new standards to students without strong academic skills—because they have not learned strategies for teaching to students with weak skills—students will withdraw in frustration and be more likely to withdraw effort and fail, lowering their own achievement and the quality of instruction for the class as a whole.

This suggests several issues that schools will need to consider as they increase curricular standards. First, they need to closely monitor the opportunities for high-achieving students, to ensure that they continue to enroll in the same degree of high-level math and science classes as they would have before the new standards were implemented. Schools may need additional resources to be able to offer more classes overall without reducing the classes that are currently available for some students. Second, teachers will need help expanding instruction in high-level math and science topics to students with weak skills, and students will need support handling the difficult material. This goes beyond curricular support, to assistance in pedagogical practice and skills in behavior management. Even the best curriculum is not effective if teachers can't get through the lessons and students are not engaged in learning.

Our research in Chicago has highlighted the key importance of monitoring students closely, and reaching out to provide support immediately if they start to fall behind (e.g., missing class, not turning in homework, doing poorly on a quiz/test). Often teachers and schools wait to respond until students are too far behind to catch up. We have seen some schools in Chicago show success by having co-teachers/tutors in the classroom to help students during class while the primary teacher attends to the rest of the class. Another strategy that has been successful in Algebra has been to provide a second period of instruction for students with weak skills, structured to help them handle the material in the primary class. This benefits students with high skills, as well, since their classroom peers with weak skills don't hold back instruction. The What Works Clearinghouse has noted that two programs—Check and Connect and ALAS—were successful mentorship programs; mentors with these programs closely monitored students' course performance to provide support right away when students fell behind.

Questions submitted by Ranking Member Daniel Lipinski

Q1. Mr. Heffron described an advisory structure in place at the Stapleton High School that appears to be an effective mechanism for providing support to students in his school. I'm interested in learning more about the effectiveness of advisory groups, and how successful models like those at Stapleton High School can be implemented in other schools across the country. What is the current state of research on the topic, and what does research tell us about what makes a successful sdvisory group structure?

A1. Advisories are in wide use in many schools across the country. There are some successful programs that use advisories effectively, and they can be a great tool for providing support to students. However, the way that advisories are implemented is important. Simply incorporating an advisory into a school's programming is not sufficient. In fact, it can take away from instructional time if it is not designed in a way that supports students' performance in their academic classes and their overall engagement at school.

Responses by Dr. Barbara Means, Director,
Center for Technology in Learning, SRI International

Questions submitted by Chairman Mo Brooks

Q1. Dr. Gamoran highlighted the need for NSF to fund basic and applied STEM education research, but then mentioned gaps in basic research and the ability of the Department of Education's Institute of Education Sciences to do applied research. Is it really necessary for NSF to be funding any applied STEM education research, or should they be focusing funding solely on the fundamental research questions of "how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers." Why or why not?

A1. I respectfully disagree with the proposition that NSF should focus on basic STEM education research while IES conducts applied research in this field. The two central arguments I offer for my position are that (1) there is an important category of STEM education research that addresses both basic and applied questions and that is best housed within NSF and (2) connections to disciplinary expertise and new advances in STEM fields are essential elements of the kind of STEM education research needed to support dramatic improvements to our current practice.

Basic research on "how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers" typically focuses on how individuals learn. But the problems of education concern how to promote learning in the contexts of groups of students and educators. Understanding "how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers" requires studying these phenomena in applied contexts, and we are unlikely to find answers without deep knowledge of how various interventions and practices are adapted in schools and classrooms. These basic questions need to be studied in realistic environments, not just university laboratories.

Professor Donald Stokes, in his 1997 book Pasteur's Quadrant, lays out a more differentiated categorization of research efforts than the traditional dichotomy of basic versus applied. He suggests that research can be described as either low or high in terms of two dimensions: relevance for the advancement of knowledge and relevance for immediate applications. By crossing these two dimensions he creates four "quadrants" or categories of research and names three of the quadrants after scientists whose work exemplified that category. Bohr's Quadrant consists of work that searches for fundamental knowledge with little concern for immediate applicability—essentially what is often called "basic research." Edison's Quadrant is work that is high in immediate applicability but low in the advancement of new knowledge—the kind of problem solving work that many people think of as applied research. Pasteur's Quadrant consists of research designed to both build fundamental knowledge and have high practical applicability. The questions motivating research in Pasteur's Quadrant arise from practice (Pasteur's own work on bacteria was inspired by concerns of the French wine industry), but the research is designed to yield generalizable insights as well as to address the immediate problem at hand. In reviewing the history of NSF, Stokes asserted that the agency added the most value by supporting work in Pasteur's Quadrant. What I described as STEM education implementation research in my testimony would fall into Pasteur's Quadrant because of its emphasis on research activities addressing questions that arise from practice.

Russ Whitehurst, the first Director of the Institute of Education Sciences, described the Institute's mission and his understanding of its statutory authority as lying within Edison's Quadrant (http://ies.ed.gov/director/speeches2003/04__22/2003__04__22a.asp). And indeed, IES specializes in rigorous, large-scale experiments on the effectiveness of well-defined, existing educational interventions.

In contrast, the STEM education work sponsored by NSF is intended to exemplify Pasteur's Quadrant. The work is carried out in applied settings and peer review of proposals focuses on the two criteria of building significant new knowledge for the field and likely practical benefit to STEM education.

An insight into the difference between the two agencies' respective research sponsorship capabilities—both of which are valuable to our nation—can be gleaned from their two catch phrases. IES is best known for the phrase "what works" (as in the "What Works Clearinghouse"), whereas NSF is best known for the phrase "transformative potential" (as in NSF's fundamental role in creating the Internet). To appreciate the importance of the latter, think back to the late 1980s. At that time, economic researchers were finding no measureable productivity gains from the rapid influx of technology into the workplace. We had no evidence that technology was "what works" to stimulate productivity, yet in hindsight we can now see that the Internet had vast transformative potential that could be released only after organizations changed their processes to take advantage of that potential. Despite the lack of "what works" evidence, NSF was right to keep investing in the transformative potential of the Internet. *STEM education today needs not only to sort out which of the currently available well-defined products or approaches do indeed "work" but also to invest in the development and refinement of new approaches with transformative potential to make vast improvements in STEM education.*

I see NSF and IES as having complementary roles with respect to STEM education research. IES focuses on research designed to identify causal relationships between education interventions and student outcomes. Such work is appropriate for programs that are well-defined and broadly implemented. IES tests interventions that can be tightly defined and scoped at proposal time. The NSF review process, on the other hand, seeks far-reaching advances that can emerge from the mutual influence of powerful ideas and insights from design research in realistic settings and is willing to fund investigations even when the resulting educational product cannot be precisely defined and scoped at proposal time. This latter kind of work—which will be essential if we are to make the kinds of breakthroughs in terms of improving STEM education that the Subcommittee on Research and Science Education and the National Research Council have called for—is the strong point of NSF.

NSF STEM education research is intended to promote the design and refinement of new education approaches. Its focus on innovation and building new knowledge means that these approaches are being tried out and modified in applied settings and, typically, are not yet ready for the kind of large-scale randomized control trials that IES sponsors. For these approaches to be truly innovative, NSF must be freed to conduct research in "applied" settings so the field can learn which designs, theories, and approaches have promise for unlocking transformative potential in real schools and classrooms.

This brings me to my second point. Conducting Pasteur's Quadrant education research in STEM subject areas requires not just social scientists but also STEM professionals and educators. Although there are many insights into how teachers and students learn, what motivates learners, and what conditions support the development of high-quality teachers that cut across different subject domains, there are aspects of these questions that are manifestly different in various STEM fields. We cannot prepare students for careers in new areas of science, such as bioinformatics, without a deep understanding of emerging practices in those fields. NSF takes a more lifelong view of STEM education (encompassing postsecondary as well as secondary education) than IES does and has ties to the communities of research scientists, mathematicians, and computer scientists that the Department of Education cannot duplicate. NSF's *Cyberlearning: Transforming Education* program, for example, is sponsoring exploratory, implementation, and deployment research that combines cutting-edge advances in computer science with advances in our understanding of how people learn. In its first year, this research program was inundated with proposals from multi-disciplinary teams including some of the most prestigious computer science departments in the country.

In short, I believe that it is extremely important that NSF continue to provide leadership and research funding in areas of STEM education that many would label "applied research," but that are more aptly characterized as the intersection between knowledge building and discovering the transformative potential needed to address the practical, yet deeply challenging, problems of STEM education practice.

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