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What Makes for Successful K-12 STEM Education

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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 not provide a basis for

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[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

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.

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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.

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.

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 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.

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[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.

[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.

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 3 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.

[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.

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 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]

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[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.

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 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.

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

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

[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.

others. Although not all of these supports need to be 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 5 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

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

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.