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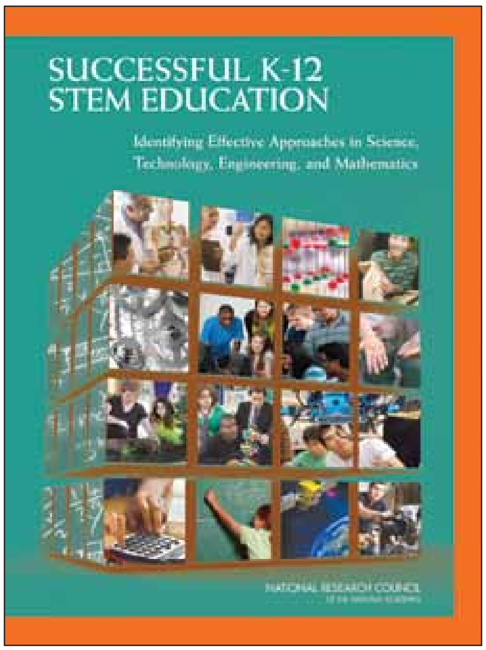
BOARD ON SCIENCE EDUCATION • BOARD ON TESTING AND ASSESSMENT

SUCCESSFUL K-12 STEM EDUCATION:
IDENTIFYING EFFECTIVE APPROACHES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS



Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics provides information that leaders at the school, district, state, and national levels can use to make strategic decisions about improving science, technology, engineering, and mathematics (STEM) education. Based on a workshop convened by the National Research Council (NRC) in May 2011,[1] the report examines research on STEM-focused schools, the broader base of research related to effective STEM education practices, and general research on effective schooling. The report focuses mainly on science and mathematics (rather than technology and engineering) because most of the research has been done on those fields.

Questions about the effectiveness of education can be addressed only in the context of the purposes or goals one wants to achieve. Three broad goals for K-12 STEM education are widely espoused in the United States: to increase advanced training and careers in STEM fields, to expand the STEM-capable workforce, and to increase scientific literacy for all students.

Several types of specialized STEM-focused schools and programs have the potential to address these goals. They include schools that are organized around the STEM disciplines and have selective admissions criteria; inclusive STEM schools with open admission; and STEM-focused career and technical education schools and programs, which emphasize application-based courses. Successful STEM education takes place in all of these types of schools. For instance, research experiences,

[1]See also the report of this workshop, *Successful STEM Education: A Workshop Summary.* Available: www.nap.edu/catalog.php?record_id=13230.

internships, mentoring, and content that is connected across different STEM courses make it more likely that students complete a STEM major in college. Effective STEM instruction and learning also occur in regular, non-specialized schools, often through programs such as the International Baccalaureate and Advanced Placement.

There is little evidence to suggest that any particular type of school is superior, on average, to another type of school. Several recent NRC reports and other syntheses studies, however, suggest two key aspects of practice that are found in successful schools of all types: effective STEM instruction and school conditions and cultures that support learning.

EFFECTIVE STEM INSTRUCTION

Effective instruction capitalizes on students' early interest and experiences, builds on what they know, provides them with experiences to engage in the practices of science, and sustains their interest in STEM. Students also engage with fundamental questions about the material and natural world, gain experience in the ways that scientists have investigated those questions, and carry out empirical investigations and engineering design projects related to core scientific ideas.

This type of STEM instruction remains the exception in U.S. schools. Further transformation is needed at the national, state, and local levels to meet the needs of all of the nation's students. Attending to some key elements of effective instruction can guide educators and policy makers in that direction.

Key element: A coherent set of standards and curricula. The poor average achievement of U.S. students in mathematics and science can be partially attributed to the curriculum. In any field, the curriculum needs to structure the material that is to be taught in each grade; be focused in terms of the number of topics and level of coverage in each grade; and be cognitively complex. Current work on the Common Core State Standards for mathematics[2] and the *NRC's A Framework for K-12 Science Education*[3] may allow states to develop curricula that are focused on the most important content and practices and are logically sequenced over time to develop more comprehensive understanding.

Key element: Teachers with high capacity to teach in their discipline. To be effective, teachers need content knowledge and expertise in teaching. Today, many middle and high school science and mathematics teachers are not certified in these subjects and did not major in a related field in college. Professional development for STEM teachers, when available, is often short, fragmented, and not designed to address their individual needs. Effective professional development should:

- focus on developing teachers' capabilities to teach content;
- address teachers' classroom work and problems in their schools; and
- provide multiple and sustained opportunities for learning over time.

Key element: A supportive system of assessment and accountability. Since implementation of No Child Left Behind (NCLB), there has been a shift from complex performance assessments toward multiple-choice items that limit the content and complexity of the skills and knowledge being tested. There is widespread concern that the heavy focus on test results, particularly from multiple choice tests, narrows the curriculum in all fields and leads to instruction that underemphasizes the development of complex understanding. Careful attention to building a system of science assessment that uses a variety of assessment strategies to meet the requirements of NCLB is needed.[4]

Key element: Adequate instructional time. NCLB has also affected the time allotted for STEM instruction in K-12. Particularly in elementary school, the predominant focus of instructional time has become mathematics and language arts because these subjects are tested annually for NCLB accountability. The decrease in time for science is of particular concern because there is some evidence that interest in science careers develops as early as the elementary school years.

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[2]See www.corestandards.org/the-standards/mathematics.
[3]See www.nap.edu/catalog.php?record_id=13165.

[4]For more information, see *Systems for State Science Assessment*. Available: http://www.nap.edu/catalog.php?record_id=11312.

Key element: Equal access to high-quality stem learning opportunities. Many factors, including poverty, contribute to well-documented achievement gaps, but states, schools, and districts can address some of them. For example, disparities in access to quality teachers and other school factors—such as access to adequate laboratory facilities, resources, and supplies—can be redressed to close the gaps in science achievement for underrepresented groups.

SCHOOL CONDITIONS AND CULTURES THAT SUPPORT LEARNING

School culture and conditions strongly influence student achievement, affecting what is taught, how it is taught, and with what results. For example, a study of 200 low-performing elementary schools in high-poverty communities[5] demonstrated that schools that improved learning shared five common elements:

1. School leadership headed by principals who are strategic, focused on instruction, and inclusive of others.

2. Professional capacity of faculty and staff—including the willingness to change and the capacity to work together—fostered by high quality, ongoing professional development.

3. Ties with parents and the community that involve active outreach to make school a welcoming place for parents, that engage parents in supporting their children's academic success, and that strengthen connections to other local institutions.

4. Student-centered learning climate that is safe, welcoming, stimulating, and nurturing for all students.

5. Instructional guidance focused on the organization of the curriculum, the nature of academic demand it poses, and the tools available to advance learning.

[5]See Bryk, A.S., Sebring, P.B., Allensworth, E., Luppescu, S. and Easton, J.Q. (2010). *Organizing Schools for Improvement: Lessons from Chicago.* Chicago: University of Chicago Press.

HOW EDUCATION LEADERS AND POLICY MAKERS CAN PROMOTE EFFECTIVE K-12 STEM EDUCATION

Policy makers and education leaders at all levels can take the following actions to bring STEM K-12 education closer to fulfilling the goals that the country expects:

- Policy makers at the national, state, and local levels should elevate science to the same level of importance as reading and mathematics.
- Districts should devote adequate instructional time and resources to science in grades K-5.
- Districts should ensure that their STEM curricula are focused on the most important topics in each discipline, are rigorous, and are articulated as a sequence of topics and performances.
- Districts need to enhance the capacity of K-12 teachers to teach STEM. National and state policy makers should invest in a coherent, focused, and sustained set of supports for STEM teachers to help them teach in effective ways.
- Districts should provide instructional leaders with professional development that helps them to create the school conditions that appear to support student achievement.
- States and national organizations should develop effective systems of assessment that are aligned with the next generation of science standards and that emphasize science practices.
- Federal agencies should support research that disentangles the effects of school practice from student selection, recognizes the importance of contextual variables, and allows for longitudinal assessments of student outcomes.

COMMITTEE ON HIGHLY SUCCESSFUL SCHOOLS OR PROGRAMS FOR K-12 STEM EDUCATION

ADAM GAMORAN (*Chair)*, Department of Sociology and Wisconsin Center for Education Research, University of Wisconsin-Madison; **JULIAN BETTS**, Department of Economics and San Diego Research Alliance, University of California, San Diego; **JERRY P. GOLLUB**, Natural Sciences and Physics Departments, Haverford College; **GLENN "MAX" McGEE**, Illinois Mathematics and Science Academy; **MILBREY W. McLAUGHLIN**, School of Education, Stanford University; **BARBARA M. MEANS**, Center for Technology in Learning, SRI International; **STEVEN A. SCHNEIDER**, Science, Technology, Engineering, and Mathematics Program, WestEd; **JERRY D. VALADEZ**, Kremen School of Education and Human Development, California State University, Fresno

National Research Council Staff: **MARTIN STORKSDIECK**, *Director, Board on Science Education;* **STUART ELLIOTT**, *Director, Board on Testing and Assessment;* **NATALIE NIELSEN**, *Study Director;* **MICHAEL FEDER**, *Study Director (until February 2011);* **THOMAS KELLER**, *Senior Program Officer;* **REBECCA KRONE**, *Program Associate.*

For More Information . . . This brief was prepared by the Board on Science Education and the Board on Testing and Assessment. Copies of the report, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering and Mathematics,* as well as the summary report of the workshop on which it was based *Successful STEM Education: A Workshop Summary*, are available from the National Academies Press at (888) 624-8373 or (202) 334-3313 (in the Washington, DC metropolitan area) or via the National Academies Press webpage at www.nap.edu. The workshop was funded by the National Science Foundation. Any opinions, findings, conclusions, or recommendations expressed in the publication are those of the authors and do not necessarily reflect those of the NSF.

Related Titles (see www.nap.edu):

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