NATIONAL ACADEMY of EDUCATION

Science and Mathematics Education

EDUCATION POLICY BRIEFING SHEET

World-Class Science and Mathematics

We call on leaders in all levels of government to join with scientists and mathematicians, with working educators, and with major professional and scientific associations, to create and sustain a coherent 21st century science and mathematics education system for America. Today's economy rewards individuals who are skilled and knowledgeable in science and mathematics and who can use these skills to respond to new challenges. Strong science and mathematics education provides a bulwark for the nation's economy and security. To remain competitive, the nation must produce greater numbers of highly skilled scientists, mathematicians, engineers, and other innovative thinkers.

It is time to end the patchwork of curriculum, tests, and teacher development that characterizes science and mathematics education in the United States. Elsewhere in the world, coherent science and mathematics education is created through national standards, curricula, and assessments. If our state and local governance tradition prohibits such centralized programs, we can nonetheless create structures and tools that will support effective instructional sequences for students everywhere. The groundwork has already been laid. In mathematics, promising curriculum frameworks have gained broad acceptance. In science, educators and researchers are in good agreement about the necessary elements of a coherent science curriculum from kindergarten through middle school and choices among rigorous pathways through high school. It is time to bring these hard-won agreements-in-principle to reality-in-schools.

Efforts to improve the instructional capacity of schools must address four major components:

- A curriculum framework that focuses on essential concepts and skills, supports well-researched learning steps ("learning progressions"), and is realized in well-designed teaching materials;
- Teachers who can manage the give and take of multiple voices in the classroom, who know science or mathematics (or both) and how to teach that content in engaging ways, and who know how to analyze students' confusions and guide their learning of complex new ideas;
- Assessments that measure the full range of important skills and concepts in the curriculum framework; and,
- Effective teacher preparation and ongoing professional development, as well as sufficient space, equipment, and materials to teach these subjects.

The curriculum in science and in mathematics should weave together learning of basic concepts and the development of students' capacity to learn more complex skills through investigations and problem solving activities. Research on learning in science and mathematics shows that mastering complex ideas occurs over time and builds on students' understanding of related concepts and principles. It is critical, therefore, to teach sequences of specific content in science and in mathematics that build successively more sophisticated ways of reasoning. Most existing textbooks fail to provide this support, and accountability tests focus overwhelmingly on factual content and skills without much call for reasoning and analysis.

Recommendation: The federal government, working with consortia of states, should invest in the creation of model instructional packages to help schools develop their capacity to teach 21st century science and mathematics skills from kindergarten through grade eight.

These model instructional packages should address the components described above. Development work can be carried out by a variety of entities—research teams formed by multi-state consortia, public-private partnerships, or others. Building on successful past efforts, especially in mathematics, each "package" should encompass research-based learning progressions across grade levels and teaching materials that include effective uses of technology. The packages should recommend forms of professional development in how to teach this curriculum and provide closely aligned assessment tools. We recommend that multiple consortia be established to produce three to five comprehensive packages for a K-8 learning sequence for science, and likewise for mathematics. Funding multiple projects will give states and districts a choice of packages (to make sure that real choices result, the government should fund a set of projects likely to produce a range of approaches).

Recommendation: Study effective teaching practice in science and mathematics at all grade levels and use that knowledge to recommend specific improvements in teacher preparation programs.

Teaching science and mathematics is highly skilled, knowledge-intensive, complex work. Effective teachers are critical to the success of any instructional system. In addition to knowing the subject matter, science and mathematics teachers must have a specialized kind of knowledge that enables them to engage students in active conceptual learning. Such teachers can effectively provide examples and counterexamples to illuminate particular topics, recognize common naïve conceptualizations and misconceptions, and respond to common errors in students' work. Current research provides guidelines for teacher education and professional development that can produce teachers with these capabilities. We highlight here the need for specialized training programs for science and mathematics teachers including those teaching these subjects in the upper elementary grades.

Recommendation: The federal government should play a leading role in encouraging and providing resources for engineering design and research cycles to support the improvement of education, including in science and mathematics.

Too often, reforms in education are instituted without a solid research base for their design; when the reform fails to produce the desired result it is then followed by another attempt at reform. A more productive alternative is a *systems-engineering* approach to improving and redesigning programs. This approach to reform begins with a design phase that is driven by research and during which appropriate measures of progress are identified. As the design is implemented, progress is monitored, and evaluations based on measures of progress are then used to guide the redesign; further evaluations and refinements then follow.

This iterative cycle of research and development is needed in all areas of education and can be used to improve curriculum, teaching, teacher preparation, assessment, external support systems, and use of technology. The engineering-systems cycle should be a funded requirement for any educational innovation, including the projects to create model instructional and assessment packages that we recommend. This requirement, coupled with eventual randomized field trials, will help to identify approaches that work so that states, districts, and schools can make informed decisions about curriculum, instruction, and professional development.

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