What Research Says About K-8 Science Learning and Teaching
Major changes to curriculum sequences within and between K-8 grades are necessary if we want to improve science education.

Richard A. Duschl, Andrew W. Shouse, and Heidi A. Schweingruber

Since the aftermath of World War II, there have been two major reform efforts in science and mathematics education. The first was spawned by the creation of the National Science Foundation (NSF) in 1950, and was fueled by the launching of Sputnik in 1957 and the fear that the United States would lose military superiority and prowess if we did not invest in the education of future scientists and engineers. By the late 1960s, there were nearly 30 K-12 curriculum projects sponsored by NSF; science instruction became investigation- and inquiry-based; “hands-on” became the mantra; kits became the instructional format in K-8 science programs; and teaching the processes of science to get students to think like scientists became the goal.

The standards movement arrived in the mid-1980s and new curriculum frameworks of instruction were crafted for the reform of science and mathematics curriculum, instruction, assessment, and professional development for teachers.

Today, the clarion warning calls about science and mathematics education, the fading STEM (science, technology, engineering, and math) work force, and equipping U.S. students with 21st century skills can be heard, respectively, in the 2006 National Research Council report, “Rising Above the Gathering Storm” (RAGS) and the 2007 National Center on Education and the Economy report, “Tough Choices or Tough Times” (TCTT). Each makes recommendations for changing the landscape of schools and schooling. The RAGS report emphasizes attracting and retaining students and teachers in STEM education with an emphasis on Advanced Placement instruction. The TCTT report emphasizes preparing a work force for the 21st century that must engage more and more in creative work and less and less in routine work.
The TCTT report recommends that we “develop standards, assessments, and curriculum that reflect today’s needs and tomorrow’s requirements,” while a core RAGS issue is “attracting and retaining students in STEM education.” In this article, we apply K-8 science to these two positions and share research-based recommendations from the 2007 National Research Council report “Taking Science to School: Learning and Teaching Science in Grades K-8” (TSTS).

New Views About Learning Science

In addition to the dynamic reform efforts in science education, during the 50-year period from 1950 to 2000 there has been major research guiding our understandings of cognition, learning, and the brain. There have also been significant developments in our understandings of what science is in a world aided and guided by new tools, new technologies, and new theories. The agenda for science education has broadened in ways that demand, as the TSTS report suggests, a rethinking of approaches to K-8 science curriculum, instruction, and assessment.

We live in a time when there is rapid growth of scientific knowledge, tools, and theories. Like the first science education reformers in the 1950s and 1960s, we are today faced with the challenge of making important decisions about what and how to teach. We now have a deeper understanding of how and under what conditions learning occurs. We also have a richer understanding of the dynamics occurring in the growth of or advancements in scientific knowledge. Essentially, as presented in the TSTS report, we have learned about science learning through advancements in two overlapping scholarly domains that guided the National Research Council committee in thinking about how to reform K-8 science education:

- **Learning sciences** research focuses on understanding teaching, learning, and learning environments, and is conducted through interdisciplinary efforts by individuals from such disciplines as cognitive, developmental and social psychology; anthropology; linguistics; philosophy of mind; artificial intelligence; and educational research.
- **Science studies** research focuses on understanding, inquiring, and knowing, and is conducted by individuals from such disciplines as history, philosophy, anthropology, and sociology of science, as well as cognitive psychology, computer science, and artificial intelligence.

In order to arrive at recommendations regarding the learning and teaching of science, the TSTS committee members felt it important to first address the question “What is science?” There are many competing perspectives about science, but none more pernicious than “the scientific method” as represented in school science. We recognize and appreciate today that we need to see science as a set of processes that involve logical reasoning about evidence, theory change, and participation in the culture of scientific practices. The hypotheses-testing practices of science are a critical component of what it means to be doing science. But such practices are conducted in service to other equally important dynamic elements of what it means to be doing science:

- Building theories and models;
- Collecting and analyzing data from observations or experiments;
- Constructing arguments; and
- Using specialized ways of talking, writing, and representing phenomenon.

The recommendation of the TSTS committee is that K-8 science instruction should be coordinated around those doing science elements or practices. Furthermore, science learning environments should be designed to support the development of four strands of scientific proficiency for all K-8 students. Students who understand science:

1. Know, use, and interpret scientific explanations of the natural world;
2. Generate and evaluate scientific evidence and explanations;
3. Understand the nature and development of scientific knowledge; and
4. Participate productively in scientific practices and discourse.

The four strands reflect an important change in focus for science education. One important change is recognizing that young children are more competent than we think. They can think abstractly early on and do not go through universal, well-defined stages of development. Another important change is a shift in emphasis from teaching that focuses on what we know (e.g., facts and skills) to teaching that focuses on how we came to know and develop scientific knowledge and why we believe what we know.

The emphasis on how and why reflects the TSTS committee recommendation that science learning must be strongly tied to the use and consideration of evidence. This, in turn, leads to the recommendation that science learning be connected through “learning progressions” that function across modules, units, and years of instruction. The rationale is to facilitate the learning of core science knowledge and practices that are critical for the development of scientific knowledge and of the reasoning inherent in the four strands of proficiency. Developing rich, conceptual knowledge takes time and requires instructional support via sound assessment practices.
What you learn here and how you learn it will not only transform your life, but the lives of everyone around you. When we opened our doors more than 35 years ago, we shattered the barriers of traditional learning, causing a ripple effect that can still be felt today. We’re the Fischler School of Education and Human Services. Our ideas, our approach, and our programs inspire educational leaders to inspire the people around them to move the world.

cause an effect › www.FischlerSchool.nova.edu 800-986-3223
Tensions with Established Practices

We face challenges implementing the TSTS recommendations because some established school and classroom practices create tensions. One tension is that the current state of affairs finds science instruction disconnected and frequently separating the teaching of concepts from the teaching of processes, skills, and practices. For example, in many K-8 science inquiry programs the emphasis is on domain-general skills (e.g., distinguish observations from inferences) without any attention being given to how these skills relate to the disciplinary knowledge under study—processes learning goals are separated from the conceptual learning goals.

Then there is the tension of far too many objectives, benchmarks, and standards at individual grade levels and grade bands. This is the recognized problem of U.S. science curricula being a “mile wide and an inch deep.” Many existing curricula, standards, and assessments in the U.S. comprise too many disconnected topics given equal priority. The important unifying themes and principles of science are getting lost in favor of concept coverage. Core knowledge (e.g., properties of matter), science practices (e.g., building and refining models that account for evidence), and scientific discourses (e.g., collecting, analyzing, and representing data from observations and experiments) are not being carried over from one school year to the next, nor even from one module to the next within a school year. Core knowledge and practices should be central to science curriculum content, accessible to students in kindergarten, and have potential for sustained exploration across K-8.

Conceptual knowledge, scientific reasoning, understanding how scientific knowledge is produced, and participating in science all represent elements that are intimately intertwined in the doing of science. Another tension for implementing the TSTS recommendations is too much sequencing variation in the implementation of the standards. The use of modular units shared across classrooms, and that jump from one topic to another, work against the development of coherent learning progressions. Modules do provide flexibility for sharing materials and textbooks among teachers and across classrooms, but without careful consideration the enacted sequence can confuse rather than enlighten young science learners.

The research on young children’s thinking suggests that children are capable of abstract reasoning and theory building from very early ages in select domains. The research on infants and pre-K children, and research on children’s alternative conceptions, demonstrates that students do arrive at school with core knowledge, and as they experience the world around them they do develop explanations—albeit naïve ones at times.
Sequence variation can lead to teachers having too strong a focus on “fixing” students’ misconceptions that can, in turn, lead teachers to overlook the productive “half-baked” ideas and intuitions that can be leverage points for learning across coordinated sequences.

Research on early childhood learning reported in TSTS shows that some areas of knowledge provide more robust foundations to build on than others when thinking about the sequencing of curriculum. Promising core knowledge domains for the early development (pre-K-2) of reasoning include:

- Physical mechanics (locating patterns based on property size, shape, and weight; describing and representing mechanisms for the causes);
- Biology (differentiating between animate and inanimate; describing and representing biological processes such as digestion, growth, reproduction, and sickness);
- Matter and substance (measurement and representation of macroscopic properties and attributes); and
- Naïve psychology (engaging in meaning-making with others, recognizing that beliefs of others may be different from your own and for good reasons).

Another tension recognized in the TSTS report is that scientific argument is rare in science classrooms, although central to science. We find that teaching focuses on recall rather than model-based reasoning. The classroom norms of teachers and textbooks providing answers do not facilitate the building of scientific models from evidence. Scientific argumentation, when carefully supported and mediated by classroom teachers, can effectively engage K-8 students in examining the following:

- What are the measurements/observations one needs to take to get data for the question or problem at hand?
- What are the data worth keeping and using as evidence?
- How can the evidence be examined and analyzed to locate patterns and trends?
- How can models be built to construct explanations and devise further tests to refine the models and/or compare models with alternative and established scientific theories?

Recommendations for Policy, Practice, and Research

With respect to standards, curricula, and assessments, the TSTS report recommends:

- Revising standards, curricula, and assessments to reflect a new understanding of children’s thinking;
- Structuring the next generation of standards and curricula to identify a few core ideas in a discipline and articulate how these ideas can be grown in a cumulative manner over grades K-8; and
- Presenting science as a process of building theories and models using
evidence, checking them for internal consistency and coherence, and testing them empirically.

Regarding instruction and how to teach, the TSTS report recommends that:

- Science instruction should provide opportunities for students to engage in all four strands of proficiency;
- State and local leaders in education should provide teachers with models of classroom instruction that incorporate the four strands of proficiency; and
- Policymakers, educational leaders, and administrators need to ensure that adequate time and resources are provided, teachers have adequate knowledge of science content, and adequate professional development is provided.

Professional development is needed for supporting effective science instruction and the TSTS report recommends that:

- State and local systems should ensure that all K-8 teachers experience science-specific professional development in preparation and induction programs and while in service;
- University-based courses for teacher candidates and teachers’ ongoing opportunities to learn science in service should mirror the opportunities they will need to provide for their students; and
- Federal and state agencies that fund providers for professional development should design funding programs that require applicants to incorporate models of instruction that combine the four strands of proficiency, focus on core ideas in science, and enhance teachers’ knowledge.

The TSTS executive summary and full report includes 14 conclusions across the categories of learning and learners, curriculum and instruction, and teachers and schools. Implementation of the recommendations listed above will help address concerns about attracting and retaining students to STEM disciplines. Focusing on the TSTS research conclusions will facilitate a reform of K-8 science curricula, standards, and assessments.

Richard A. Duschl is chair of the Committee on Science Learning, Kindergarten Through Eighth Grade, and professor of science education at Rutgers University. His e-mail address is r duschl@rci.rutgers.edu.

Andrew W. Shouse and Heidi A. Schweingruber are co-study directors of the Committee on Science Learning, Kindergarten Through Eighth Grade, and senior program officers with the Board on Science Education at the National Research Council. Their e-mail addresses are ashouse@nas.edu and aschweingruber@nas.edu.

**WEB RESOURCES**

Interested individuals can order or download the “Taking Science to School: Learning and Teaching Science in Grades K-8” report and executive summary.

http://newton.nap.edu/catalog/11625.html

Ready, Set, Science: Putting Research to Work in the K-8 Science Classroom is an account of the groundbreaking and comprehensive synthesis of research into teaching and learning K-8 science. The book is scheduled for release in October 2007 and will be downloadable.

http://books.nap.edu/catalog.php?record_id=11882

The U.S. Department of Education’s FREE (Federal Resources for Educational Resources) site offers numerous science resources.

www.free.ed.gov/subjects.cfm?subject_id=41

**References**


School Furniture

In Stock and Ready to Ship!

When you need furniture for your school, Virco is ready to respond. From student chairs and desks to cafeteria tables, Virco has the industry’s largest selection of ready-to-ship education solutions to start the year off right. And ordering Virco furniture is easy. You can use our U.S. Communities contract, which gives you quick access to great Virco furniture prices without the hassles of the bidding process.

Hundreds of Virco furniture models are now certified according to the stringent GREENGUARD® indoor air quality standard for children and schools, including all ZUMA® chairs and desks.

For more information, call us today at 800-448-4726, or visit our website at www.virco.com. Registered customers can now BUY ONLINE at www.virco.com. Register today by calling 800-448-4726.

Virco is a proud sponsor of:

- equipment for educators™