PAPER

Overview of National and State Standards in Science

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ABSTRACT

Standards in science and other subjects are a recent phenomenon in education, with most having been developed within the past 15 years. Science content standards now exist in 49 of 50 states and the District of Columbia (Iowa has not developed its own standards). In some states a great deal of controversy surrounded initial adoption of content standards; in others controversy ensued when standards were revisited or revised (mandated by many states every 5-7 years). Here a brief history and overview of the science content standards movement in the United States are given along with insights into the forces that caused adoption to be contentious in some states, and the important part that professional scientists and engineers might play in shaping those standards. Roles for the ocean sciences in enhancing science learning and teaching through state standards are also considered.

A Brief History

Beginning with an historic conference of the National Governors' Association and continuing into the early 1990s, President George H.W. Bush and the nation's governors developed the National Education Goals (sometimes referred to as "Goals 2000"[2]). Eight Goals were articulated; Goal 4 declared that by the Year 2000, "U.S. Students will be first in the world in mathematics and science achievement." To achieve this goal, the governors decided that national standards for science and other subjects should be developed.[3] For science, the governors declared the following objectives:

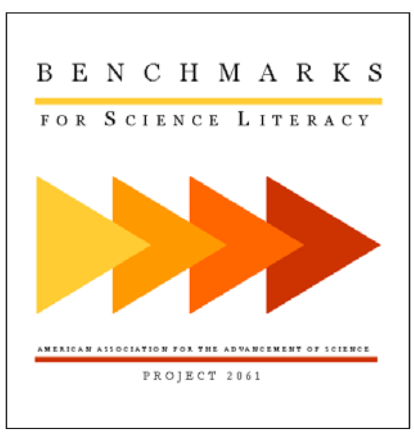
Students in Grades K-12 will

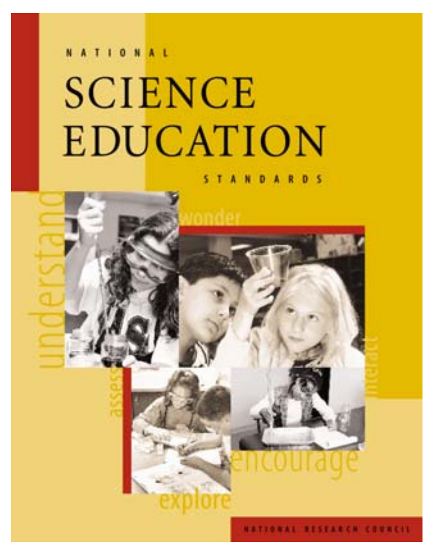
- Use scientific principles and processes appropriately in making personal decisions.
- Experience the richness and excitement of knowing about and understanding the natural world.
- Increase their economic productivity.
- Engage intelligently in public discourse and debate about matters of scientific and technological concern.
- Be aware of careers in science, technology, and the medical sciences.

These principles suggested science education that was very different from the prevailing teaching methods in several fundamental ways. First, instead of focusing almost exclusively on facts, these objectives also called for educating students to *understand* how science is relevant to their lives and their communities. Second, rather than providing science education primarily to those students who were most likely to pursue careers in science or engineering (as had been emphasized in the Post-Sputnik era), these objectives emphasized science education and scientific literacy for all students. Lastly, science was to be introduced to students much earlier in their academic preparation than was typical.

All of these changes had clear implications for the education and ongoing professional development of teachers, the numbers of teachers able to teach science, curriculum development and implementation, assessment, and even the physical space in which science would be taught. Clearly, some guidance was needed to help state education departments, as well as local school districts and school personnel implement such sweeping changes in pre-college science education.

This new perspective on science education also was influenced greatly by the publication of *Science for All Americans* (Rutherford and Ahlgren, 1990) by the American Association for the Advancement of Science





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[2] For additional information on Goals 2000, see http://www.ed.gov/G2K/index.html.

[3] Standards for mathematics had already been developed by the National Council of Teachers of Mathematics and released in 1989. These mathematics standards were revised and updated in 2000. For more information, see National Council of Teachers of Mathematics (1989, 2000).

(AAAS). In response to both this publication and the directives of the National Governors Association, both AAAS and the National Research Council (NRC) began work on producing national standards for science. AAAS' *Benchmarks for Science Literacy* were published in 1993 and focused on content standards.

The NRC released the *National Science Education Standards* (*NSES*) in 1996. These standards deliberately embedded science content standards within the *system* of science education so it was clear that improvements in student performance are dependent upon improvements in the *entire* system of science education and not solely on enhancements in the student content standards. Consequently, the *National Science Education Standards* focused on changes in six sectors of the education system required to realize sustained improvements in student performance:

- Science Teaching Standards
- Standards for Professional Development for Teachers of Science
- Assessment in Science Education
- Science Content Standards
- Science Education Program Standards
- Science Education System Standards

Both the *Benchmarks* and the *NSES* offer their content standards by grade bands rather than by individual grade levels; this enables schools, districts, and states flexibility in deciding when specific topics might be taught. Although the content standards in the *Benchmarks* and the *NSES* differ to some degree in emphasis (see Table 1), an analysis by AAAS suggests the *Benchmarks* and the *NSES* content standards are approximately 90-95% congruent in their focus and subject matter (AAAS, 1997). Thus, as individual states have adopted or adapted these national guidelines for their own, some states have based their standards on one of these sets of national standards guidelines while others have utilized aspects of both.

The *NSES* call for a very different way of presenting content and assessing students' knowledge of science (Table 2, Table 3). The *NSES* view science education as something that students *do*, rather than something that is done to them. There is greater emphasis on teaching and learning the processes and nature of science, along with content knowledge in scientific disciplines and the integration of this disci-

TABLE 1

Content Topics in the *Benchmarks for Science Literacy* and the Content Standards of the *National Science Education Standards**

AAAS BENCHMARKS:	NATIONAL SCIENCE EDUCATION STANDARDS:
The Nature of Science	
The Nature of Mathematics	
The Nature of Technology	Science and Technology
The Physical Setting	Physical/Earth/Space Sciences
The Living Environment	Life Sciences
The Human Organism	Science in Personal/Social Perspectives
Human Society	
The Designed World	
The Mathematical World	
Historical Perspectives	History and Nature of Science
Common Themes	Unifying Concepts and Processes
Habits of Mind	Science as Inquiry

**Topics are organized such that similar topics in each column are displayed on the same row.*

TABLE 2

The *NSES* Stress a Changing Emphasis on Scientific Content

LESS EMPHASIS ON:	MORE EMPHASIS ON:
Knowing scientific facts and information.	Understanding science processes and developing abilities of inquiry.
Studying subject matter disciplines (e.g., physics, earth sciences) for their own sake.	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science.
Separating science knowledge and science process.	Integrating all aspects of science content.
Covering many science topics.	Studying a few fundamental science concepts.
Implementing inquiry as a set of processes.	Implementing inquiry as instructional strategies, abilities, and ideas to be learned.

NRC (1996, page 113)

TABLE 3

The *NSES* Stress a Changing Emphasis on Assessment of Scientific Knowledge and Understanding

LESS EMPHASIS ON:	MORE EMPHASIS ON:
Assessing discrete knowledge.	Assessing what is most highly valued.
Assessing scientific knowledge.	Assessing rich, well-structured knowledge.
Assessing to learn what students do not know.	Assessing scientific understanding and reasoning.
Assessing what is easily measured.	Assessing to learn what students do understand.
Assessing only achievement.	Assessing achievement and opportunity to learn.
End-of-term assessments by teachers.	Students engaged in ongoing assessment of their work and that of others.
Development of external assessments by measurement experts alone.	Teachers involved in the development of external assessments.

NRC (1996, page 100)

plinary knowledge, using these processes as a student progresses from elementary through the secondary grades.

Not all content is equal. Consequently, both standards guidelines stress students will gain a deeper understanding and appreciation of science if they *cover* fewer topics but do so in greater depth, i.e., "less is more."

The *NSES,* as part of the six pronged systems approach, also call for fundamental changes in what teachers should know and be able to do (Table 4), especially for elementary and middle school teachers who are increasingly teachers of science. These recommendations suggest that new and very different approaches for teacher preparation and ongoing professional development are needed.

Since the publication of the *Benchmarks* and the *NSES*, both the AAAS and the NRC have published supplements to these original documents. AAAS has released several publications that focus on how to use the *Benchmarks* and implications for their use in schools. An especially useful supplement is AAAS' *Atlas of Science Literacy* (2001) that helps educators identify prerequisite knowledge and understandings in science that students need to study grade level appropriate material and to be prepared to progress to more advanced materials. The *Benchmarks* and all of these supplemental publications are available at http://www.project2061.org/. Supplements to the *NSES*, on the other hand, have focused on broader systems issues including helping teachers understand the nature of inquiry (NRC, 2000), classroom assessment (NRC, 2001a), designing standards-based mathematics or science curricula (NRC, 1999), a framework for research efforts to investigate the efficacy of standards (NRC, 2001b), and a publication to help the public understand the changes being promoted by the *NSES* (NRC, 1997).

State Based Implementation of National Standards

National Standards are not federal standards. There are no mandated national standards for any subject in Grades K-12 in the United States. The responsibility for pre-college education is vested constitutionally with state and local authorities. The federal government contributes approximately 8% of the total budget for K-12 education. Thus, the *Benchmarks*, *NSES*, and other national standards documents that were produced at the same time as, and subsequent to, science standards[4] are intended to serve as guides that states can use to voluntarily develop and implement their own standards. However, the *NSES* do represent a national *consensus* of what constitutes quality science education and the educational systems needed to support that education. They were reviewed by thousands of scientists and science educators and by dozens of professional societies prior to their release.

State standards are now the predominant influence on K-12 education. Consequently, there is considerable variation from state to state in their use of the *NSES* and the *Benchmarks*. For example, evolution is a subject that received considerable attention in both national standards documents. Some states have adopted these recommended standards faithfully while others have eliminated selected components or do not mention evolution at all (Lerner, 2000; Gross et al., 2005). In other cases, there has been great controversy about the amount of content that students should be required to know and at what grade levels they are expected to know it. Political and other influences continue to shape the state-based adoption process as individual states revise their standards every five to seven years.[5]

The proliferation of state standards has resulted in some unintended consequences. For example, science textbook publishers and curriculum developers who previously only had to show that their products were consistent with one or both national standards documents to be adopted, now have to tailor their products to the many different state standards to be considered. Such pressures can lead to fragmentation of content or producing textbooks that respond to the "lowest common denominator." Other efforts, including the Ocean Literacy framework (see Walker & Keener-Chavis article in this publication), that are attempting to introduce ocean concepts into K-12 science curricula may not be successful if they focus solely on how these concepts correspond to the national standards.[6] Additional attention also must be paid to variations in content and emphasis in the various state standards.

During the past few years, state standards also have taken on increasing prominence because of the federal No Child Left Behind Act (NCLB). NCLB mandates that students be tested on content that is tied to a state's stan-

TABLE 4

Excerpts from the NSES of Standards for the Professional Development of Teachers of Science

- **STANDARD A:** The professional development of teachers of science requires learning science content through the perspectives and methods of inquiry
- **STANDARD B:** Professional development of teachers of science requires integrating knowledge of science, learning, pedagogy, and students applying that understanding to science teaching
- **STANDARD C:** The professional development of teachers of science enables them to build the knowledge, skills, and attitudes needed to engage in lifelong learning
- **STANDARD D:** Pre-service and in-service professional development programs for teachers are coherent and integrated…Excerpted and modified from NRC (1996)

[4] For example, in 2000 the International Technology Education Association published standards for technological literacy (ITEA, 2000).

[5] See, for example, the controversy that has arisen in California: http://www.sci-ed-ga.org/standards/analysis.html.

[6] A matrix showing the correlation of ocean literacy concepts with the *NSES* can be found at; http://www.coexploration.org/oceanliteracy/documents/cean_Lit_Matrix_08.05.xls. This matrix is the first step in an effort to provide coordinated ocean literacy learning opportunities for K-12 students and the professional development of their teachers that is aligned with the *NSES*.

dards in a particular discipline and each state must administer tests aligned to those standards. However, since the law's inception, schools have only been held accountable for testing and demonstrating Adequate Yearly Progress[7] in reading and mathematics and only for Grades 3-8. Science will not be tested until the 2007-2008 school year and then only in each grade band corresponding to the elementary, middle, and secondary grades. There are three important consequences of this process that should concern scientists, engineers and technologists, and those who rely on science or technology innovations for their livelihood:

- In some districts teachers, especially in the elementary grades, recently have been asked to minimize or eliminate science from their classrooms to allow more time for preparation in reading and mathematics. Districts often do not embrace the concept that science also can serve as an effective vehicle for learning of mathematics and developing of reading skills, since both are essential for successful performance in science. Consequently reduction in class time doing science may result in a cohort of students who are ill-prepared to appreciate and succeed in science when testing does begin.
- When science is finally tested in 2007-2008, or when districts recognize that they have to begin preparing students for the science examinations, they will rely heavily, if not exclusively, on their state science standards which in some states may focus more heavily on fact based content standards, rather than the more systemic approach emphasized in the *NSES*. Unless state standards both require and emphasize that quality science education also includes exploration, data analysis, and developing deep conceptual understanding of topics in the state standards, teachers will be under pressure to focus primarily on factual information, lower level thinking skills (e.g., memorization) and limited conceptual understanding. Moreover, these conditions suggest that teachers and school administrators will tend to emphasize the specific content and examples that are planned for the assessment.

Thus, using the ocean sciences to address existing science content requirements may be difficult because learning in many school districts and states will correspond more closely with specific examples rather than with concepts that can be learned through a variety of examples. The report, *Ocean Literacy Essential Principles of Ocean Sciences* shows how concepts in the ocean sciences can be integrated into more general science curricula. If the ocean sciences community also can demonstrate that teaching and learning concepts and curricular materials in the ocean sciences can enhance students' learning and academic achievement in science, then teachers and school administrators may be more likely to use these tools. The engineering community is actively engaged in this kind of research to demonstrate a similar relationship between engineering and design concepts and the improvement of science learning.

- NCLB permits individual states to employ any assessment instruments they wish as long as they align with that state's content standards. Because assessments that authentically measure deep conceptual understanding, and demonstrate skill and ability to explore, transfer knowledge from one topic to another, and to synthesize and draw conclusions from data are more expensive to develop, administer, and score than tests that focus on factual knowledge, there will be strong financial pressure to employ the less expensive, less rigorous instruments. These kinds of assessments would send strong messages about the kind of science education that is valued and could reverse some of the gains that are beginning to be reported around the country. The National Research Council has published several reports that focus on these issues (NRC, 2001c, 2003, 2005).

Science education is at a crossroads and will continue to be over the next several years. Whether our nation will finally realize the kind of quality science education that was envisioned in the national standards documents and is required for the United States to continue to lead the world in science and technology innovations and in the practical application of those innovations (e.g. National Academy of Sciences et al., 2005) remains to be seen. It is incumbent upon today's science and technology practitioners to become more knowledgeable about the vision, the emphases of the national standards and their reflection in the standards of the state in which they live and work, and the influential role they can play in shaping development and revisions in those standards and assessments.[8]

Scientists and technologists can be engaged and influential in science education in many ways. Opportunities are sufficiently diverse to suit the particular interest and personality of every scientist and technologist. A few examples are given here:

- You can work with your state board of education to review science standards in your specific discipline or more broadly when standards are being revised.
- You can work locally with the school district where you live. One of many things you could do is to sit on the selection committee for adoption of new textbooks and other science education resources. In this way you will help district leaders and administrators identify those resources that contain up-to-date high quality material and also conform to state standards.
- As a parent, grandparent, and citizen you can play an important role in your schools and community as an advocate for high quality science teaching and learning for *all* students.

With at least three major national reports calling for action to improve ocean science literacy of this country's citizenry, we can no longer ignore educating our teachers and our students about the oceans and all of the sciences disciplines connected to it, and need to strive for system-based approaches in all of our teachings. For all the reasons outlined above, the time to do so is *now*.

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[7] For more information from the U.S. Department of Education about this component of the law, see http://www.ed.gov/nclb/accountability/ayp/yearly.html.

[8] Access to individual state standards is available through the state's Department of Education or through http://www.education-world.com/standards/state/index.shtml.

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