NATIONAL

SCIENCE EDUCATION

STANDARDS

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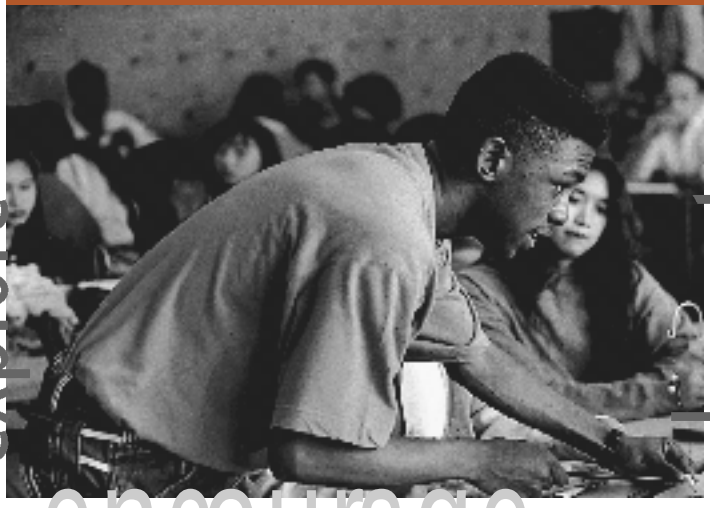
observe



explore

encourage

understand

Contents

The world looks so different after learning science.

For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree. [A]nd in the ash is the small remnant of the part which did not come from air, that came from the solid earth, instead.

These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others.

Richard Feynman

Call to Action

This nation has established as a goal that all students should achieve scientific literacy. The *National Science Education Standards* are designed to enable the nation to achieve that goal. They spell out a vision of science education that will make scientific literacy for all a reality in the 21st century. They point toward a destination and provide a roadmap for how to get there.

All of us have a stake, as individuals and as a society, in scientific literacy. An understanding of science makes it possible for everyone to share in the richness and excitement of comprehending the natural world. Scientific literacy enables people to use scientific principles and processes in making personal decisions and to participate in discussions of scientific issues that affect society. A sound grounding in science strengthens many of the skills that people use every day, like solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning. And the economic productivity of our society is tightly linked to the scientific and technological skills of our work force.

Many types of individuals will play a critical role in improving science education: teachers; science supervisors; curriculum developers; publishers; those who work in museums, zoos, and science centers; science educators; scientists and engineers across the nation; school administrators; school board members; parents; members of business and industry; and legislators and other public officials.

Individuals from all of these groups were involved in the development of the *National Science Education Standards*, and now all must act together in the national interest. Achieving scientific literacy will take time because the *Standards* call for dramatic changes throughout school systems. They emphasize a new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world. They also invoke changes in what students are taught,in how their performance is assessed, in how teachers are educated and keep pace, and in the relationship between schools and the rest of the community—including the nation's scientists and engineers. The *Standards* make acquiring scientific knowledge,understanding, and abilities a central aspect of education, just as science has become a central aspect of our society.

The *National Science Education Standards* are premised on a conviction that all students deserve and must have the opportunity to become scientifically literate. The *Standards* look toward a future in which all Americans, familiar with basic scientific ideas and processes, can have fuller and more productive lives. This is a vision of great hope and optimism for America, one that can act as a powerful unifying force in our society. We are excited and hopeful about the difference that the *Standards* will make in the lives of individuals and the vitality of the nation.

Richard Klausner, Chairman
National Committee on Science Education Standards and Assessment

Bruce Alberts, President
National Academy of Sciences

observe

Learn

Interact

Change

Children on the Einstein statue at the National Academy of Sciences in Washington,DC, remind us that there is no more important task before us as a nation.

National Science Education Standards: An Overview

In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise everyday. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world.

Scientific literacy also is of increasing importance in the workplace. More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions, and solve problems. An understanding of science and the processes of science contributes in an essential way to these skills. Other countries are investing heavily to create scientifically and technically literate work forces. To keep pace in global

markets, the United States needs to have an equally capable citizenry.

The *National Science Education Standards* present a vision of a scientifically literate populace. They outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels. They describe an educational system in which all students demonstrate high levels of performance, in which teachers are empowered to make the decisions essential for effective learning, in which interlocking communities of teachers and students are focused on learning science, and in which supportive educational programs and systems nurture achievement. The *Standards* point toward a future that is challenging but attainable—which is why they are written in the present tense.

The intent of the *Standards* can be expressed in a single phrase: Science standards for all students. The phrase embodies both excellence and equity. The *Standards* apply to all students, regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science. Different students will achieve understanding in different ways, and different students will achieve different degrees of depth and breadth of understanding depending on interest, ability, and context. But all students can develop the knowledge and skills described in the *Standards*, even as some students go well beyond these levels.

By emphasizing both excellence and equity, the *Standards* also highlight the need to give students the opportunity to learn science. Students cannot achieve high levels of performance without access to skilled professional teachers, adequate classroom time, a rich array of learning materials, accommodating work spaces, and the resources of the communities surrounding their schools. Responsibility for providing this support falls on all those involved with the science education system.

Implementing the *Standards* will require major changes in much of this country's science education. The *Standards* rest on the premise that science is an active process. Learning science is something that students do, not something that is done to them. "Hands-on" activities, while essential, are not enough. Students must have "minds-on" experiences as well.

The *Standards* call for more than "science as process," in which students learn such skills as observing, inferring, and experimenting. Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills.

The importance of inquiry does not imply that all teachers should pursue a single approach to teaching science. Just as inquiry has many different facets, so teachers need to use many different strategies to develop the understandings and abilities described in the *Standards*.

Nor should the *Standards* be seen as requiring a specific curriculum. A curriculum is the way content is organized and pre-

sented in the classroom. The content embodied in the *Standards* can be organized and presented with many different emphases and perspectives in many different curricula.

Instead, the *Standards* provide criteria that people at the local, state, and national levels can use to judge whether particular actions will serve the vision of a scientifically literate society. They bring coordination, consistency, and coherence to the improvement of science education. If people take risks in the name of improving science education, they know they will be supported by policies and procedures throughout the system. By moving the practices of extraordinary teachers and administrators to the forefront of science education, the *Standards* take science education beyond the constraints of the present and toward a shared vision of the future.

Hundreds of people cooperated in developing the *Standards*, including teachers, school administrators, parents, curriculum developers, college faculty and administrators, scientists, engineers, and government officials. These individuals drew heavily upon earlier reform efforts, research into teaching and learning, accounts of exemplary practice, and their own personal experience and insights. In turn, thousands of people reviewed various drafts of the standards. That open, iterative process produced a broad consensus about the elements of science education needed to permit all students to achieve excellence.

Continuing dialogues between those who set and implement standards at the national, state, and local levels will ensure that the *Standards* evolve to meet the needs of students, educators, and society at large. The *National Science Education Standards* should be seen as a dynamic understanding that is always open to review and revision.

Organization of the *Standards*

After an introductory chapter and a chapter giving broad principles and definitions of terms, the *National Science Education Standards* are presented in six chapters:

- **Standards for science teaching (Chapter 3).**
- **Standards for professional development for teachers of science (Chapter 4).**
- **Standards for assessment in science education (Chapter 5).**
- **Standards for science content (Chapter 6).**
- **Standards for science education programs (Chapter 7).**
- **Standards for science education systems (Chapter 8).**

For the vision of science education described in the *Standards* to be attained, the standards contained in all six chapters need to be implemented. But the *Standards* document has been designed so that different people can read the standards in different ways. Teachers, for example, might want to read the teaching, content, and program standards before turning to the professional development, assessment, and systems standards. Policy makers might want to read the system and program standards first, while faculty of higher education might want to read the professional development and

teaching standards first, before turning to the remaining standards.

Science Teaching Standards

The science teaching standards describe what teachers of science at all grade levels should know and be able to do. They are divided into six areas:

- **The planning of inquiry-based science programs.**
- **The actions taken to guide and facilitate student learning.**
- **The assessments made of teaching and student learning.**
- **The development of environments that enable students to learn science.**
- **The creation of communities of science learners.**
- **The planning and development of the school science program.**

Effective teaching is at the heart of science education, which is why the science teaching standards are presented first. Good teachers of science create environments in which they and their students work together as active learners. They have continually expanding theoretical and practical knowledge about science, learning, and science teaching. They use assessments of students and of their own teaching to plan and conduct their teaching. They build strong, sustained relationships with students that are grounded in their knowledge of students' similarities and differences. And they are active as members of science-learning communities.

In each of these areas, teachers need support from the rest of the educational system if they are to achieve the objectives embodied in the *Standards*. Schools, districts, local communities, and states need to provide teachers with the necessary resources—including time, appropriate numbers of students per teacher, materials, and schedules. For teachers to design and implement new ways of teaching and learning science, the practices, policies, and overall culture of most schools must change. Such reforms cannot be accomplished on a piecemeal or ad hoc basis.

Considerations of equity are critical in the science teaching standards. All students are capable of full participation and of making meaningful contributions in science classes. The diversity of students' needs, experiences, and backgrounds requires that teachers and schools support varied, high-quality opportunities for all students to learn science.

Professional Development Standards

The professional development standards present a vision for the development of professional knowledge and skill among teachers. They focus on four areas:

- **The learning of science content through inquiry.**
- **The integration of knowledge about science with knowledge about learning, pedagogy, and students.**
- **The development of the understanding and ability for lifelong learning.**

- **The coherence and integration of professional development programs.**

As envisioned by the standards, teachers partake in development experiences appropriate to their status as professionals. Beginning with preservice experiences and continuing as an integral part of teachers' professional practice, teachers have opportunities to work with master educators and reflect on teaching practice. They learn how students with diverse interests, abilities, and experiences make sense of scientific ideas and what a teacher does to support and guide all students. They study and engage in research on science teaching and learning, regularly sharing with colleagues what they have learned. They become students of the discipline of teaching.

Reforming science education requires substantive changes in how science is taught, which requires equally substantive change in professional development practices at all levels. Prospective and practicing teachers need opportunities to become both sources of their own growth and supporters of the growth of others. They should be provided with opportunities to develop theoretical and practical understanding and ability, not just technical proficiencies. Professional development activities need to be clearly and appropriately connected to teachers' work in the context of the school. In this way, teachers gain the knowledge, understanding, and ability to implement the *Standards*.

Assessment Standards

The assessment standards provide criteria against which to judge the quality of assessment practices. They cover five areas:

- **The consistency of assessments with the decisions they are designed to inform.**
- **The assessment of both achievement and opportunity to learn science.**
- **The match between the technical quality of the data collected and the consequences of the actions taken on the basis of those data.**
- **The fairness of assessment practices.**
- **The soundness of inferences made from assessments about student achievement and opportunity to learn.**

In the vision described by the *Standards*, assessments are the primary feedback mechanism in the science education system. They provide students with feedback on how well they are meeting expectations, teachers with feedback on how well their students are learning, school districts with feedback on the effectiveness of their teachers and programs, and policy makers with feedback on how well policies are working. This feedback in turn stimulates changes in policy, guides the professional development of teachers, and encourages students to improve their understanding of science.

Ideas about assessments have undergone important changes in recent years. In the new view, assessment and learning are two sides of the same coin. Assessments provide an operational definition of standards, in that they define in measurable terms what

teachers should teach and students should learn. When students engage in assessments, they should learn from those assessments.

Furthermore, assessments have become more sophisticated and varied as they have focused on higher-order skills. Rather than simply checking whether students have memorized certain items of information, new assessments probe for students understanding, reasoning, and use of that knowledge—the skills that are developed through inquiry. A particular challenge to teachers is to communicate to parents and policy makers the advantages of new assessment methods.

Assessments can be done in many different ways. Besides conventional paper and pencil tests, assessments might include performances, portfolios, interviews, investigative reports, or written essays. They need to be developmentally appropriate, set in contexts familiar to students, and as free from bias as possible. At the district, state, and national levels, assessments need to involve teachers in their design and administration, have well-thought-out goals, and reach representative groups to avoid sampling bias.

Assessments also need to measure the opportunity of students to learn science. Such assessments might measure teachers' professional knowledge, the time available to teach science, and the resources available to students. Although difficult, such evaluations are a critical part of the *Standards*.

Science Content Standards

The science content standards outline what students should know, understand, and be able to do in the natural sciences over the course of K-12 education. They are divided into eight categories:

- **Unifying concepts and processes in science.**
- **Science as inquiry.**
- **Physical science.**
- **Life science.**
- **Earth and space science.**
- **Science and technology.**
- **Science in personal and social perspective.**
- **History and nature of science.**

The first category is presented for all grade levels, because the understandings and abilities associated with these concepts need to be developed throughout a student's educational experiences. The other seven categories are clustered for grade levels K-4, 5-8, and 9-12.

Each content standard states that as a result of activities provided for all students in those grade levels, the content of the standard is to be understood or certain abilities are to be developed. The standards refer to broad areas of content, such as objects in the sky, the interdependence of organisms, or the nature of scientific knowledge. Following each standard is a discussion of how students can learn that material, but these discussions are illustrative, not proscriptive. Similarly, the discussion of each standard concludes with a guide to the fundamental

ideas that underlie that standard, but these ideas are designed to be illustrative of the standard, not part of the standard itself.

Because each content standard subsumes the knowledge and skills of other standards, they are designed to be used as a whole. Although material can be added to the content standards,using only a subset of the standards will leave gaps in the scientific literacy expected of students.

Science Education Program Standards

The science education program standards describe the conditions necessary for quality school science programs. They focus on six areas:

- **The consistency of the science program with the other standards and across grade levels.**
- **The inclusion of all content standards in a variety of curricula that are developmentally appropriate, interesting, relevant to student's lives, organized around inquiry, and connected with other school subjects.**
- **The coordination of the science program with mathematics education.**
- **The provision of appropriate and sufficient resources to all students.**
- **The provision of equitable opportunities for all students to learn the standards.**
- **The development of communities that encourage, support, and sustain teachers.**

Program standards deal with issues at the school and district level that relate to opportunities for students to learn and opportunities for teachers to teach science. The first three standards address individuals and groups responsible for the design, development, selection, and adaptation of science programs—including teachers, curriculum directors, administrators,publishers, and school committees. The last three standards describe the conditions necessary if science programs are to provide appropriate opportunities for all students to learn science.

Each school and district must translate the *National Science Education Standards* into a program that reflects local contexts and policies. The program standards discuss the planning and actions needed to provide comprehensive and coordinated experiences for all students across all grade levels. This can be done in many ways, because the *Standards* do not dictate the order, organization, or framework for science programs.

Science Education System Standards

The science education system standards consist of criteria for judging the performance of the overall science education system. They consider seven areas:

- **The congruency of policies that influence science education with the teaching, professional development, assessment, content, and program standards.**
- **The coordination of science education policies within and across agencies, institutions, and organizations.**
- **The continuity of science education policies over time.**
- **The provision of resources to support science education policies.**
- **The equity embodied in science education policies.**
- **The possible unanticipated effects of policies on science education.**
- **The responsibility of individuals to achieve the new vision of science education portrayed in the standards.**

Schools are part of hierarchical systems that include school districts, state school systems, and the national education system. Schools also are part of communities that contain organizations that influence science education, including colleges and universities, nature centers, parks and museums, businesses, laboratories, community organizations, and various media.

Although the school is the central institution for public education,all parts of the extended system have a responsibility for improving science literacy. For example, functions generally decided at the state (but sometimes at the local) level include the content of the school science curriculum, the characteristics of the science program, the nature of science teaching, and assessment practices. These policies need to be consistent with the vision of science education described in the *Standards* for the vision as a whole to be realized.

Today, different parts of the education system often work at cross purposes, resulting in waste and conflict.Only when most individuals and organizations share a common vision can we expect true excellence in science education to be achieved.

Toward the Future

Implementing the *National Science Education Standards* is a large and significant process that will extend over many years. But through the combined and continued support of all Americans, it can be achieved. Change will occur locally, and differences in individuals, schools, and communities will produce different pathways to reform, different rates of progress, and different final emphases. Nevertheless, with the common vision of the *Standards*, we can expect deliberate movement over time, leading to reform that is pervasive and permanent.

No one group can implement the *Standards*. The challenge extends to everyone within the education system, including teachers, administrators, science teacher educators, curriculum designers, assessment specialists, local school boards, state departments of education, and the federal government. It also extends to all those outside the system who have an influence on science education, including students, parents, scientists, engineers, businesspeople, taxpayers, legislators, and other public officials. All of these individuals have unique and complementary roles to play in improving the education that we provide to our children.

Efforts to achieve the vision of science education set forth in the *Standards* will be time-consuming, expensive, and sometimes uncomfortable. They also will be exhilarating and deeply rewarding. Above all, the great potential benefit to students requires that we act now. There is no more important task before us as a nation.