CHAPTER 2

HISTORY OF THE SCIENCE STANDARDS MOVEMENT IN THE UNITED STATES

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In science, as in other areas of K-12 education, the development of standards has played a significant role in efforts to reform teaching and learning. In this chapter, the author explores the differences between two interrelated *standards movements* in the United States, their impact on science education reform efforts, and what remains to be done to promote further progress toward achieving widespread science literacy. Starting with the 1983 release of *A Nation At Risk*, the author traces the parallel development of standards that require accountability at every level of the education system and standards that describe the content that students need to learn and how best to teach it. While acknowledging the contributions of seminal standards documents such as *Benchmarks for Science Literacy* and *National Science Education Standards*, the author also recognizes the complex and change-resistant contexts—colleges and universities, the textbook publishing industry, classrooms and schools, and state bureaucracies—within which education reform must take place. The author concludes that standards aimed at accountability, such as those embodied in the current No Child Left Behind Act legislation, may be effective in moving people to action, but real and lasting change requires carefully developed content standards that provide

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the vision and the tools that can guide the ongoing reform of science curriculum, instruction, and assessment.

INTRODUCTION

Raymond Williams, in *Keywords*, distinguishes between three uses of the word *standard:* standard past, standard present, and standard future. About standard future, he says: "It is a very interesting use. Instead of referring back to a source of authority, or taking a current measurable state, a standard is set, projected, from ideas about conditions which we have not yet realized but which we think should be realized" (Williams, 1983, p. 299). The distinction nicely summarizes the differences between two closely interconnected standards movements in the United States today. Standards present and past are about accountability measured with respect to a level of achievement determined by authority, whereas standard future is about a vision of what could be. Standard future is squarely in the camp of efforts to improve science education that have taken place continuously throughout the past century and more, culminating in the present focus on science literacy for all. Standards-as-accountability, focusing as it does on a fixed authoritative statement of correctness and competence, is something different. It is something that has the potential to catalyze efforts for good in the ongoing struggle to improve science education, but also something that has the potential to undermine those efforts. The themes of this chapter are the way these two standards movements interact and what still needs to be done to ensure continued progress toward furthering a deeper and more widespread understanding of science through our educational efforts.

REFORM OF SCIENCE EDUCATION IN THE UNITED STATES

It is not possible here to examine in depth the historical roots of the current reform efforts in the United States, but a few historical notes will be helpful in understanding why we are where we are today. First, it is important to recognize that most of what we are tying to do is not new. Many current ideas can be found in an earlier time. The idea that there should be a common curriculum for all, whether the students were bound for college or the world of work, was put forward in the report of the Committee of Ten during the 1890s (National Education Association, NEA, 1893). The idea of *inquiry teaching* can be seen in Herbert Spencer's statement that: "Children should be led to make their own investigations, and to draw their own inferences" (Spencer, 1864, p. 124). The value of teaching

for understanding is evident in the warning made by the *Geography Conference of the Committee of Ten* (NEA, 1893) against educational practices that led to memorization without understanding and in Herbart's (1901) theory of instruction that focused on the development of conceptual understanding. The use of standardized testing to measure educational outcomes began in the second decade of the twentieth century (see DeBoer, 1991, pp. 121-124).

A second historical point to note is that curriculum and pedagogy have become "contested terrain" in our society "where warring parties contend for a kind of official sanctification of their deeply held beliefs" (Kliebard, 1995, p. 63). The tension has often been between ideas that are characterized as progressive on the one hand and traditional on the other, focusing respectively on the child or the content. Traditionalists think of themselves as rigorous, concerned about high standards, and valuing the authority of the past while progressives think of themselves as being sympathetic to how children think, how they interact with the world, and with preparing them for an ever-changing world. John Dewey (1938) laid out the parameters of the debate between traditionalists and progressives in the early part of the twentieth century and little has changed since then. Arguments over what standards and rigor mean, what our educational goals should be, or how to implement those goals continue today often in terms of that progressive versus traditionalist debate. If there has been one change that has occurred over the past 100 years it may be the efforts, in true Deweyan spirit, to accommodate the child and the curriculum, to find ways to connect the interests, experiences, and capacities of the child to the subject matter that has been organized by adult minds (Dewey, 1902, 1916). This does not mean that the progressive-traditionalist debate has ended. In fact, that debate is present in education as in all parts of our society. It is that some of the more thoughtful efforts to solve the seemingly impenetrable and intractable problems in science education are now focused on finding a new synthesis out of those opposing ideologies.

A third point to note is that rather than there being a clear trend in thinking throughout the last century, the attractiveness of ideas has tended to ebb and flow, more popular at one point in time and less popular at another (DeBoer, 1991). Typically what has happened is that in reaction to the perceived excesses of one era the emphasis shifts back toward what it had previously been. For example, the 1970s was, as some have described it, an era of "new progressivism" (Ravitch, 1983). Many of the child-centered approaches advocated by progressive educators during the first half of the twentieth century were reshaped in the form of open classrooms, elective courses for students, and other student-centered approaches. That revival of progressive ideas followed closely on the heels

of the more content-centered reforms of the 1960s. Then, largely in response to the perceived laxness of the educational system in the 1970s and declining student test scores, there was a renewed call for more rigor in the educational system. T. H. Bell, U.S. Secretary of Education during the Reagan administration, established a National Commission on Excellence in Education (NCEE) to help "define the problems afflicting American education and to provide solutions" (NCEE, 1983, p. iii).

A fourth point relates to the issue of excellence and equity in education, which is at the center of current reform efforts and has a long history as well. There has always been a question of how to deal with the enormous diversity of students who attend public schools. The American high school was established to accommodate that diversity through a variety of academic and vocational curricular tracks and varied opportunities for students to select programs most suited to their interests and projected life work. That system has come under close scrutiny at various times for its apparent unfair allocation of resources toward the most advantaged students (Kozol, 1992). In the early 1980s Mortimer Adler, Chairman of the Board of Editors of the Encyclopedia Britannica and Director of the Institute for Philosophical Research in Chicago, published *The Paideia Proposal: An Education Manifesto* (Adler, 1982). Adler, in the spirit of Robert Maynard Hutchins, activist President of the University of Chicago between 1929 and 1951, called for a required common academic curriculum for all students—with no electives or specialized courses—as a way of ensuring that all citizens would receive the education needed to become capable thinkers and to participate fully in a democratic society. Doing away with a multitrack educational system would prevent students from downgrading their education by their own choice or having others downgrade it for them. According to the *Paideia Proposal*, all people, because of their common humanity, deserve an education that offers a prospect of personal growth and self-improvement, effective citizenship, and the ability to earn a living in our society.

Adler identified three categories of student learning. They are the acquisition of organized knowledge by means of didactic instruction and demonstration, the development of intellectual skills through supervised practice, and an enlarged understanding of ideas and values through Socratic questioning and discussion. Consistent with the ideas of other educators in the early 1980s, Adler emphasized that learning is an active process. "All genuine learning is active, not passive. It involves the use of the mind, not just the memory. It is a process of discovery, in which the student is the main agent, not the teacher" (Adler, 1982, p. 50). The teacher aids discovery and elicits the activity of the student's mind by "inviting and entertaining questions, by encouraging and sustaining inquiry, by supervising helpfully a wide variety of exercises and drills, by

leading discussions" (p. 50). Adler was recommending this program for all students, not just the academically inclined or the college bound. The idea was summed up in a phrase attributed to Hutchins: "the best education for the best is the best education for all" (p. 6). Although this idea of a liberal arts type of academic education for all was not new, having been introduced in much the same form by the Committee of Ten in 1893, the idea lost ground in the early twentieth century because of a perceived need to concentrate on vocational education for many of the students. Although sometimes associated with a conservative and elitist approach to education, the idea of a common core of academic learning was resurrected in the 1980s and become one of the cornerstones of the late twentieth century reform movement.

A Nation at Risk

NCEE was established on August 26, 1981, in an environment of low and declining test scores, and in an environment in which the United States was experiencing difficult times economically when compared with other nations that were thriving, especially Germany and Japan. The report of the commission, *A Nation at Risk*, was presented on April 26, 1983. The report was a call to mobilize the efforts of the federal government along with states and local school districts to raise the level of competence of American students in all academic areas but with special emphasis on science and mathematics. This was not the first time that the United States government had intervened so vigorously in American education. There were significant efforts by the federal government—in 1917 with the Smith-Hughes Act on vocational education, and in 1958 with the National Defense Education Act, following the Soviet Union's launch of the earth-orbiting satellite Sputnik—to influence education policy in response to problems that were perceived to be serious enough to require national solutions. The NCEE concluded that we had lost sight of our true educational mission and the need for high expectations for students. They recommended a return to a more academic educational focus and more disciplined effort on the part of students. They said that our international competitors were well-educated and highly motivated and that the United States needed to be as well if it were to compete successfully. The new raw materials of international commerce were knowledge, learning, information, and skilled intelligence. The argument that the federal government had to intervene in order to develop human capital for reasons of international economic competition was the same argument that had been used to support the 1917 Smith-Hughes vocational education act, although the means of accomplishing the goal (academic study vs.

vocational education) was very different. The federal government's intervention in 1958, in contrast, was about national defense and Cold War competition with the Soviet Union.

The NCEE pointed to the importance of a high level of common understanding in a free and diverse democratic society. The concern was not just for competitive success in industry and commerce. It was also for the intellectual, moral, and spiritual strength of the people who form the society. The educational system should contribute to the development of a common culture to help achieve a shared understanding of complex societal issues. The commission pointed to the value of an education where comprehension, analysis, and problem solving were fostered rather than rudimentary knowledge or technical and occupational skills. Schools also should develop a commitment to lifelong learning because education adds value to the quality of life throughout one's life. Schooling provides the foundation, but without lifelong learning the knowledge and skills learned in school will soon become outdated.

The commission argued for genuinely high standards for all. Neither mediocrity nor elitism was acceptable, although the commission did grant the possibility that the curriculum might vary for students of differing capabilities and interests. However, all should be expected to work to their capacity and develop their talents to the fullest. In high school, all students would learn the *new basics*, including English, mathematics, science, social studies, computer science, and, for the college-bound students, 2 years of foreign language.

The commission recommended that schools, colleges, and universities adopt more rigorous and measurable academic standards and that they raise expectations for academic performance and student conduct. Textbooks should be upgraded and updated to assure more rigorous content, and university scientists should be called on to help in this task. In science, students should be introduced to: "(a) the concepts, laws, and processes of the physical sciences; (b) the methods of scientific inquiry and reasoning; (c) the applications of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development" (NCEE, 1983, p. 25). Textbooks should be chosen by states and school districts on the basis of their ability to present rigorous and challenging material clearly, and textbook publishers should be required to furnish evaluation data on the material's effectiveness. The commission recommended more homework, longer school days and longer school years, better attendance policies, and placement and promotion of students on the basis of academic progress. Higher standards and expectations were needed as well to give students themselves a deep respect for intelligence, achievement, learning, and for self-disciplined effort.

The vision was of an academically educated society, a common culture, rigorous academic standards, and accountability through standardized tests of achievement to be administered at major transition points from one level of schooling to the next, especially from high school to college or the work world. The commission recommended that the tests be administered as part of a national (but not federal) system of state and local standardized tests.

Educating Americans for the 21st Century

Just five months later, on September 12, 1983, the Commission on Precollege Education in Mathematics, Science and Technology of the National Science Board, which acts as an advisory board to the National Science Foundation, issued its report, *Educating Americans for the 21st Century* (National Science Board, 1983). The report echoed many of the ideas in *A Nation at Risk* and provided additional detail on how the vision of improved science education for all could be realized. The problem they identified was the same as that identified by the NCEE. The educational system had undergone a period of neglect, resulting in unacceptably low performance levels in science and mathematics. Unites States national security and economic health depended on its human resource development. And for reasons of national pride and international prestige, a world leader with the stature of the United States should have an educational system that was the finest in the world. Finally, a commitment to academic excellence would put the United States on a firm economic footing in its competition with other countries.

The recommended strategy to accomplish these priorities involved the development of national goals and curricular frameworks, strong national leadership for monitoring the quality of efforts, local responsibility for meeting the goals, and local variation in how they would be implemented. The commission recommended increased student exposure to science; higher standards of participation and achievement (noting comparisons to Japan's system where students spent more time in school), and a system of objective measurement to monitor progress. The belief was that our diverse educational system could be improved by establishing national goals and a system to measure local accomplishment of those goals.

The Commission on Precollege Education in Mathematics, Science, and Engineering provided more detail than the NCEE in its recommendations regarding the content of the science, mathematics, and technology curriculum. They recommended drastically reducing the number of topics that students would study, in part by integrating topics within subject areas and by making connections between subject areas, especially

between mathematics, science, and technology. Courses should focus on thinking, communication, and problem solving skills. Students should have early hands-on experiences and formulate questions and seek answers from their observations of natural phenomena. The study of science should provide knowledge that would lead to civic responsibility and the ability to cope in a technological world. The commission recommended that the courses be oriented toward practical problems that "require the collection of data, the communication of results and ideas and the formulation and testing of solutions" (p. 45). Content recommendations were given for each subject area and organized into three grade bands within subject areas. These content recommendations were at the topic level of detail. For example, at the high school level they recommended that biology should emphasize concepts and principles such as "genetics, nutrition, evolution, reproduction of various life forms, structure/function, disease, diversity, integration of life systems, life cycles, and energetics" (p. 98). Specific ideas within these topic areas were not identified.

There was concern within the commission that by emphasizing academic rigor, its recommendations would seem to be intended only for those students who would pursue careers in science, mathematics, and technology and would seem to advocate intellectual elitism. The commission addressed the excellence-equity distinction by saying: "these new basics are needed by *all* students—not only tomorrow's scientists—not only the talented and fortunate" (p. v). "While increasing our concern for the most talented, we must now also attend to the need for early and sustained stimulation and preparation for all students so that we do not unwittingly exclude potential talent" (p. x).

The commission was also careful, as they recommended the development of standards written at the national level, to leave room for variation in the way states and local school districts would implement those standards. "This should not be construed as a suggestion for the establishment of a national curriculum; rather these are guides that state and local officials might use in developing curricula for local use" (p. 41).

> No one course of study is appropriate for all students and all teachers in all schools in all parts of the country. Nor is there just one good curriculum. Various parts of the Nation must develop their total curriculum and revise it repeatedly to keep it suitable for students and teachers. (p. 92)

Reports such as those of the NCEE (*A Nation at Risk*) and the Commission on Precollege Education in Mathematics, Science, and Technology (*Educating Americans for the 21st Century*) set the stage for hundreds of additional reports to be published on education during the 1980s. These two

documents, however, aptly summarize a vision and strategy for reform. The vision included an intellectually rigorous common core of science knowledge for all, which would lead to an understanding of science ideas that are personally fulfilling and that can help build a knowledgeable and competent citizenry that is well prepared for life in a free society. The strategy involved national goals, local implementation, and accountability through student testing. Details of the vision and the strategy were to be worked out over time with the help of scientists and professional educators.

Many of the reports that followed, however, simply lamented the poor performance of United States students on national and international tests, especially in mathematics and science, and continued to link the nation's economic problems to the poor quality of the educational system. In response, many of the changes that were initiated by state legislatures and state departments of education during the 1980s were structural in nature. They often did not pay attention to the broader goals of the educational reformers. As Hurd said toward the end of the 1980s: "changes implemented ... include lengthening the school day and year, requiring more science courses, intensifying course rigor, increasing student testing and school assessments, and raising graduation requirements; but, to what ends" (1989, p. 16)?

Science for All Americans

The first detailed and substantive response to the call for a comprehensive statement of what all students should know and be able to do in science came from the American Association for the Advancement of Science (AAAS) through the establishment of Project 2061, a long-term reform effort to define and promote science literacy. Their work began with the publication of *Science for All Americans* (AAAS, 1990) and continued with the development of tools and resources to bring the vision of science for all to full realization.

In 1985, Project 2061 began work on producing a coherent statement of what all adults should know in order to be considered science literate. Science literacy is a term that became popular in the 1970s and 1980s to describe the knowledge people needed to live successfully in a world where science played such a large part. (For a discussion of the multiple meanings of science literacy, see DeBoer, 2000.) The AAAS statement that resulted consolidated reform ideas that had been promoted by science educators during the previous decades, many of which could also be found in *A Nation at Risk* and *Educating Americans for the 21st Century*. The 1989 publication of *Science for All Americans* brought these ideas together

in one bold statement. Project 2061 was so named because it was the year that Halley's Comet was to be visible again on earth, 76 years after its appearance in 1985, and the year the project originated. Most of those born in 1985, it was said, would live to see the comet's return in 2061. Enacted reforms could very well touch their entire lives.

Science for All Americans was a vision of adult science literacy, what everyone should know to be able to participate fully in society. That core knowledge included concepts and skills in science, mathematics, technology, and the social sciences. It included knowing about the nature of science, the nature of mathematics, and the nature of the designed world. It also included an understanding of historical perspectives, common themes having to do with systems, models, constancy and change, and issues of scale. It included information on scientific habits of mind and effective teaching and learning. *Science for All Americans* was not, however, a prescription for what students should know at various grade levels. Although it provided much more detail on what students should know and be able to do than had been provided by the National Commission on Precollege Education, this was not a list of content standards.

The language of *Science for All Americans* is inspiring and stresses both personal development and responsible citizenship:

> Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education—meaning education in science, mathematics, and technology—should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. America's future—its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities—depends more than ever on the character and quality of the education that the nation provides for all of its children. (AAAS, 1990, p. xiii)

In contrast to many of the reports produced during the 1980s, *Science for All Americans* did not propose a get-tough approach or that schools should teach *more* science content. Instead, it suggested that schools should focus on what is essential for science literacy—a common core of ideas and skills that have the greatest scientific, educational, and personal significance—and should teach that science better and for deeper understanding. The recommendations for content and for pedagogy were meant for all students regardless of social circumstances or career ambitions. Criteria for content selection included: (1) the utility of the content for employment, personal decision making, and intelligent participation in society; (2) the intrinsic historical or cultural significance of the knowledge; (3) the potential to inform one's thinking about the enduring questions of human meaning; and (4) the value of the content for the child's life at the present time and not just for the future. Within these parameters, the recommended content in *Science for All Americans* represented a consensus view of what the scientific community thought was important for everyone to know.

There were also recommendations regarding pedagogy. *Science for All Americans* said that in order to teach for understanding "people have to construct their own meaning regardless of how clearly teachers or books tell them things" (AAAS, 1990, p. 198). The student does this by connecting new information to what he or she already knows. Knowledge is remembered best if it is connected with other ideas and encountered in a variety of contexts. When new ideas do not fit within a student's existing knowledge framework, restructuring of existing ideas becomes necessary. This is done by providing students with experiences where they can see how the new information helps them make better sense of the world.

Science for All Americans also suggested that: "Young people learn most readily about things that are tangible and directly accessible to their senses—visual, auditory, tactile, and kinesthetic" (AAAS, 1990, p. 199). Although the ability to think abstractly, to reason logically, and to manipulate symbols develops throughout schooling, most people continue to rely on concrete examples of new ideas throughout their lifetimes. Other pedagogical approaches that would support conceptual understanding include applying ideas in novel situations and giving students practice in doing so themselves, having students express ideas publicly and obtaining feedback from their peers, allowing time to reflect on the feedback they receive, and having the chance to make adjustments and try again. Also noted were the values of self-confidence and the importance of the expectations that others have on one's self-confidence.

In addition to these general pedagogical principles, *Science for All Americans* also made recommendations specifically for the teaching of science, mathematics, and technology. There, too, the recommendations were not new but rather a reaffirmation of many of the ideas that were being suggested by science educators. According to *Science for All Americans*, to appreciate the special modes of thought of science, mathematics, and technology, students should experience the kind of thinking that characterize those fields: "To understand [science, mathematics, and technology] as ways of thinking and doing, as well as bodies of knowledge, requires that students have some experience with the kinds of thought and action that are typical of those fields" (AAAS, 1990, p. 200). *Science for All Americans* also pointed out the value of beginning instruction within the range of concrete experiences that students have already had:

> Sound teaching usually begins with questions and phenomena that are interesting and familiar to students, not with abstractions or phenomena outside their range of perception, understanding, or knowledge. Students need to get acquainted with the things around them—including devices, organisms, materials, shapes, and numbers—and to observe them, collect them, handle them, describe them, become puzzled by them, ask questions about them, argue about them, and then to try to find answers to their questions. (p. 201)

It was also recommended that the content and methods of science be taught together:

> In science, conclusions and the methods that lead to them are tightly coupled. Science teaching that attempts solely to impart to students the accumulated knowledge of a field leads to very little understanding and certainly not to the development of intellectual independence and facility.... Science teachers should help students to acquire both scientific knowledge of the world and scientific habits of mind at the same time. (AAAS, 1990, pp. 201-203)

The suggestion that because content and method are coupled in the doing of science they should also be coupled in the teaching of science presents a significant challenge to educators, one that has historically been easier to state in the abstract than to implement in actual practice.

Science for All Americans also recognized that doing science was a social activity that incorporates a number of human values, and these too should be part of the science curriculum. For example, curiosity, creativity, imagination, skepticism, and the absence of dogmatism should all be acknowledged as important in the conduct of science. Science teaching should encourage students to raise questions about what is being studied, help them frame their questions clearly enough to begin to look for answers to those questions, and support the creative use of imagination. It should promote the idea that one's evidence, logic, and claims will be questioned, and experiments will be subjected to replication. Students should be encouraged to ask: How do we know? What is the evidence? Are there alternative explanations? *Science for All Americans* makes clear that science is a way of extending understanding and not a body of unalterable truth. It also suggests that teachers and textbooks should not be viewed primarily as purveyors of truth. Because science ideas are often modified, an open mind is needed when considering scientific claims.

Originally Project 2061 was designed in three phases. In Phase II, teams of educators and scientists were charged with transforming *Science for All Americans* into blueprints for action. Six school-based teams would produce curriculum models that other school districts and states could use as they undertook the reform of science, mathematics, and technology education. Phase II would also specify the changes needed in research, teacher education, testing, educational technologies as well as the organization of schooling, and state and local policies for the vision to succeed. The idea that local sites could interpret general frameworks and provide the implementation suitable to their own communities was consistent with the general belief in the importance of local control that was reflected in the reports of the early 1980s. That approach called for a centralized vision and decentralized implementation.

In Phase III, there was to be collaboration with scientific societies, educational organizations and institutions, and other groups involved in the reform of science, mathematics, and technology education to turn the Phase II models into educational practice (AAAS, 1990, p. 221). Project 2061 was hopeful that *Science for All Americans* would be part of the policy discussions that would ultimately lead to a specification of the science content that needed to be taught to achieve science literacy for all. Project 2061 recommended that the President, the U.S. Secretary of Education, Congress, state governors, business and labor leaders, and the news media use the *Science for All Americans* report along with other reports to stimulate discussion and debate on the goal of scientific literacy for all. As noted earlier, *Science for All Americans* did not, however, lay out grade-by-grade learning expectations for students.

The first organization that did produce such grade-by-grade learning expectations for students in the form of content standards was the National Council of Teachers of Mathematics (NCTM). In 1986, the NCTM board of directors created a Commission on Standards for School Mathematics to "create a coherent vision of what it means to be mathematically literate" and to "create a set of standards to guide the revision of the school mathematics curriculum" (NCTM, 1989, p. 7). In 1989, NCTM produced a document specifying content standards for students in school mathematics at four grade bands (K-2, 3-5, 6-8, and 9-12). The standards were offered as "statements of what is valued." The standards were to serve: "(1) to ensure quality, (2) to indicate goals, and (3) to promote change" (NCTM, 1989, p. 2). The NCTM report was well received by the education community as a model for standards-based reform. Kirst and Bird (cited in Collins, 1998, p. 713) listed four reasons for the positive reception that the NCTM standards received: (1) the preparation time taken to develop the intellectual groundwork for mathematics reform, (2) broad involvement in the development process including significant roles for educators and subject-matter specialists, (3) a far-reaching review and feedback process, and (4) continued robust efforts to establish consensus and build capacity.

The National Governors' Conference

In September 1989, President George H. W. Bush met with the state governors in Charlottesville, Virginia, to discuss a national agenda for education. At this meeting the president and the governors agreed to establish clear national performance goals and strategies to ensure United States international competitiveness. They also agreed that there should be annual reporting on progress toward meeting those goals and that in return the states would be given greater flexibility in the use of federal resources to meet the goals. The goals themselves were to be announced in early 1990. Structural changes that would be needed to implement the goals would include

> a system of accountability that focuses on results ... and decentralization of authority and decision-making responsibility to the school site, so that educators are empowered to determine the means for achieving the goals and to be held accountable for accomplishing them. (U.S. Department of Education, 1991, p. 79)

The strategy of centralized goal setting and decentralized implementation that had been introduced in the early 1980s was finding favor across the country.

On April 18, 1991, President Bush released *AMERICA 2000: An education strategy* (U.S. Department of Education, 1991) which described a plan for moving the nation toward the national goals adopted the previous year. In his opening remarks, the President said: "If we want to keep America competitive in the coming century, we must stop convening panels to report on ourselves.... We must accept responsibility for educating everyone among us, regardless of background or disability" (p. 2). "It's time to turn things around—to focus on students, to set standards for our schools—and let teachers and principals figure out how best to meet them" (p. 4). President Bush spoke also of the importance of character education, school choice, lifelong learning, and the cultivation of communities where learning was valued and available throughout one's lifetime. Forged in cooperation with the nation's governors, six goals were identified that would be accomplished by the year 2000: (1) ensure that every child starts school ready to learn, (2) raise the high school graduation rate to 90%; (3) ensure that each American student leaving the fourth, eighth, and 12th grades can demonstrate competence in core subjects; (4) make United States students first in the world in math and science achievement; (5) ensure that every American adult is literate and has the skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship; and (6) liberate every American school from drugs and violence so that schools can encourage learning (p. 4).

This was to be a national program but it would not be dictated by the federal government. According to President Bush,

> America 2000 is a national strategy, not a federal program. It honors local control, relies on local initiative, affirms states and localities as the senior partners in paying for education... It recognizes that real education reform happens community by community, school by school, and only when people come to understand what they must do for themselves and their children and set about to do it. The federal government's role in this strategy is limited.... But that role will be played vigorously. Washington can help by setting standards, highlighting examples, contributing some funds, providing flexibility in exchange for accountability and pushing and prodding. (pp. 11-12)

The strategy for accomplishing the national goals was to include a 15-point accountability package that would encourage schools and communities to measure and compare results, and insist on change when the results were not good enough. The package included national standards, national tests, reporting mechanisms, and various incentives. Content standards in each of five core subject areas would be developed in conjunction with a national education goals panel. "These standards will incorporate both knowledge and skills, to ensure that, when they leave school, young Americans are prepared for further study and the work force" (p. 21). Tests to measure achievement of that content would also be developed in conjunction with the national education goals panel. These tests would be national but voluntary and tied to the national standards. Colleges would be encouraged to use the tests in admissions, and employers would be encouraged to use them in hiring. To ensure accountability to the public, school districts would issue report cards on results to provide clear (and comparable) information on how they were doing. The President's proposals called for Congress to authorize the National Assessment of Educational Progress

> regularly to collect state-level data in grades four, eight and twelve in all five core subjects, beginning in 1994. Congress will also be asked to permit the use of National Assessment tests at district and school levels by states that wish to do so. (p. 22)

Finally, the President argued for a decentralization of authority and decision making in which the local school was identified as the site of reform.

> Because real education improvement happens school by school, the teachers, principals and parents in each school must be given the authority—and the responsibility—to make important decisions about how the school will

> operate. Federal and state red tape that gets in the way needs to be cut. (p. 23).

Recognizing that in 1991 national content goals in the subject areas were not yet available, the President said:

> First, what students need to know must be defined. In some cases, there is a solid basis on which to build. For example, the National Council of Teachers of Mathematics and the Mathematical Sciences Education Board have done important work in defining what all students must know and be able to do in order to be mathematically competent. A major effort for science has been initiated by the American Association for the Advancement of Science. These efforts must be expanded and extended to other subject areas. (p. 70)

Benchmarks for Science Literacy

In 1991, Project 2061 was engaged in Phase II of its reform efforts, the development of curriculum models in six school districts around the country. Over the course of four summer workshops between 1989 and 1992 and 40 days of release time during each school year, teams from each location worked on developing these curriculum models. During the first summer, a number of cross-team working groups were formed as well. One was a *strand* group, whose purpose was to begin the process of determining what knowledge and experiences a student had to have in grades K-12 in order to achieve the goals in *Science for All Americans*. It had become clear to everyone that it would not be possible to directly translate the content described in *Science for All Americans* into a K-12 curriculum without intermediate learning goals. The intent was that the product of the efforts of this strand group would be an internal document that would aid the curriculum development teams in their work. The process was called *backmapping* and the products were called *maps* or *strand maps*. These maps showed the progression of ideas through four grade bands. They were based on (1) the logical development of the science ideas and (2) the age at which students would be expected to understand each idea. During the second summer workshop in 1990, all of the teams were assigned to work on these maps because the maps were proving to be so useful to the schools.

With President Bush's declaration in his *America 2000* report in the spring of 1991 that standards "will be developed ... for each of the five core subjects," and his explicit mention of the work of AAAS, the focus at Project 2061 shifted from the further development of school-based curriculum models to the transformation of back-mapped ideas into "benchmarks." By 1993 that work was complete and in print, and *Benchmarks for Science Literacy* (AAAS, 1993) was hailed by many as the long-awaited national content standards in science (Atkin, 1997, p. 168). Although the

original intent of the back-mapping was not to produce content standards, but rather to produce an ordering of ideas that could be used in the development of curriculum models, Project 2061 decided to use the work they had already done in creating the benchmarks to more directly impact the national debate on science literacy and ultimately to influence what became the *National Science Education Standards*.

The decision to produce and publish *Benchmarks* thrust Project 2061 into the center of the standards movement. But according to an external evaluation of Project 2061 prepared by SRI International in 1996, even before *Benchmarks* was published in 1993 "both the National Science Foundation and the U.S. Department of Education urged states and local districts to incorporate or demonstrate consistency with Project 2061's vision of science literacy in their proposals for important federal initiatives" (SRI International, 1996a, pp. 10-11). For example, the statewide systemic initiatives (SSI) program, a National Science Foundation program begun in 1990, was based on the idea of state-level, systemic, standards-based reform. According to the SRI report, *Science for All Americans* was explicitly named as a useful model for supporting a systemic initiative in elementary and secondary science education. The U.S. Department of Education also referred to Project 2061 as a model to support standards-based or systemic reform. In the national portion of the Department of Education's Eisenhower National Mathematics and Science Program that began in 1992 to promote the development and implementation of state curriculum frameworks in mathematics and science, "*Science for All Americans* [was] noted as one of a very small number of documents that could serve as a foundation on which the states applying for federal funds could build their frameworks" (SRI International, 1996a, p. 11).

Especially after *Benchmarks* was published, Project 2061, which was meant to be part of a long-term reform effort bringing together many of the values and ideals of enlightened science educators, soon became identified with the standards movement. *Benchmarks* became a *standards* document in the minds of most people, in part because the nation was poised to receive national standards. By the early 1990s, the idea of national goals (along with local implementation) that had been discussed throughout the 1980s had become a widely accepted approach to reform throughout the country.

At the same time that work was progressing at Project 2061 to create benchmarks for science literacy, the national education goals panel was established in 1991 to measure progress toward the broad national goals that had been established by the Bush administration. Also that year, consistent with the charge from the goals panel to establish national content standards in five content areas, the U.S. Department of Education and the National Science Foundation made a decision to fund the National

Research Council (NRC) to create national standards in science. According to Collins (1998), in receiving the award "the NRC was encouraged to draw on expertise and experience from both the AAAS and NSTA [National Science Teachers Association]" (Collins, 1998, p. 715), and the advisory board for the project included representatives of both NSTA and AAAS. In the fall 1991 issue of its newsletter, *Project 2061 Today*, the response of Project 2061 to this decision was clear:

> [*Science for All Americans* and *Benchmarks*] will contribute to the formulation of national standards for science education, an enterprise to be orchestrated by the National Research Council and funded by the U.S. Department of Education. This welcome opportunity for working together will produce a much-needed resource for the nation. ("Developing Standards," 1991, p. 3)

National Science Education Standards

National Science Education Standards was written in direct response to a call from the federal government to establish content standards in each of five disciplinary areas that could be used to measure progress toward the national goals. (In addition to writing content standards, the NRC also wrote standards for teaching, professional development, assessment, science education programs, and science education systems.) The national standards in each disciplinary area were to offer a means to judge the quality of student learning and educational programs. In the words of the NRC: "Science education standards provide criteria to judge progress toward a national vision of learning and teaching science" (p. 12). As that statement makes clear, however, the *National Science Education Standards* represents a vision as well as a set of criteria for making judgments. *Standards* are forward looking even as they provide a means for measuring progress toward attaining that vision. In fact, from the beginning to the end of the document, it is the forward-looking vision of science literacy that comes through most strongly in the *Standards*.

The tension between a statement that represents a fixed standard that can be used for accountability purposes and one that represents a flexible and ever-evolving vision of reform is difficult to resolve. That tension is evident in Collins' (1998) discussion of the political nature of the process of developing the *Standards*. One place this is particularly apparent is in how *standard* is defined. In the NRC *Standards*, there are seven content areas at each grade band, each divided into several bulleted topics, which in turn are elaborated into a small number of more detailed fundamental abilities and concepts. For example, for grades 5-8, Content Standard B (Physical Science) says: "As a result of their activities in grades 5-8, all students should develop an understanding of (1) properties and changes of properties of matter, (2) motions and forces, and (3) transfer of energy"

(NRC, 1996, p. 149). There are then six "fundamental concepts and principles" that underlie the "transfer of energy" part of this standard, one of which that states: "Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature" (NRC, p. 155). Clearly, when considered at the topic level (transfer of energy) there is a lot of discretion granted for making decisions about content, instructional activities, and assessment, and not much guidance regarding exactly what to teach or what to hold students accountable for. At the level of the detailed knowledge statements (heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature), there is more specificity and less flexibility. The position taken in the *Standards* is captured in the statement: "the discussion of each standard concludes with a guide to the fundamental ideas that underlie that standard, but these ideas are meant to be illustrative of the standard, not part of the standard itself" (pp. 6-7). This interpretation of what a standard is suggests that in the development of the *Standards*, accountability with respect to a fixed standard was not the first priority.

Additional evidence that the *Standards* was not attempting to be a present day accountability document is the strong position that the NRC took with respect to inquiry as pedagogy, even though such approaches had met with mixed success throughout the twentieth century, most notably in the reform efforts of the 1960s (Welch, Klopfer, Aikenhead, & Robinson, 1981, p. 40). In its "Call to Action," the NRC said that the *Standards* "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" (p. ix). Later, when recommending changing directions for science content, *inquiry* is the dominant theme, including the statement that there should be greater emphasis on "doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content" (p. 113). In its "Overview," the NRC said: "Implementing the *Standards* will require major changes in much of this country's science education.... Inquiry is central to science learning" (p. 2). Although these statements make it clear that the "importance of inquiry does not imply that all teachers should pursue a single approach to teaching science" (p. 23), nevertheless, inquiry pedagogy is so deeply imbedded in the NRC *Standards*, that many have come to equate standards-based science education with "inquiry-based" science education. The point is that given the historic difficulty of implementing inquiry-based pedagogies, inquiry could not reasonably be used as an accountability criterion at this time. It must be viewed as a vision for the future.

Goals 2000

The specific proposals in President Bush's *America 2000* report were never enacted into law during his presidency because in November 1992 President Bush was defeated in his reelection attempt by Bill Clinton, then governor of Arkansas. But because many of the ideas in *America 2000* had come from the governors at the education summit that Bush had convened shortly after he took office in 1989, including Clinton as governor of Arkansas, the general strategy for reforming education remained intact and the legislation that President Bush had proposed was resurrected by the Democrats as Goals 2000.

On March 31, 1994, President Clinton signed the Goals 2000: Educate America Act. The act retained the six goals from *America 2000* and added two new goals, one on teacher professional development and another on promoting the involvement of parents in their children's education. The rationale for the eight goals centered on educating workers for productive employment, with special reference to competition in international trade. Again, as throughout the 1980s, the 1960s, and earlier in the century, the government's primary interest in education was the development of human capital so that the U.S. could remain competitive internationally (Spring, 2001, p. 434). In addition to stating national goals, the Goals 2000 legislation also created the National Education Standards Council, which had the authority to approve or reject the states' content standards. This body subsequently dissolved following the 1994 midterm elections when the Republicans took control of Congress and voiced objections to the increasing intrusion of the federal government in education (National Conference of State Legislatures Report, 2004). Also in 1994, President Clinton signed the Improving America's Schools Act (IASA), which was a reauthorization of the original Elementary and Secondary Education Act of 1965, first enacted as part of President Johnson's War on Poverty and intended to improve education for disadvantaged children in poor areas. Under the IASA, states had to: (1) develop challenging content standards for what students should know in mathematics and language arts; (2) develop performance standards representing three levels of proficiency for each of those content standards—partially proficient, proficient, and advanced; (3) develop and implement assessments aligned with the content and performance standards in at least mathematics and language arts at the third through fifth, sixth through ninth and 10th through 12th grade spans; (4) use the same standards and assessment system to measure Title I students as the state uses to measure the performance of all other students; and (5) use performance standards to establish a benchmark for improvement referred to as *adequate yearly progress*. All schools were to show continuous progress or face possible consequences, such as having to offer supplemental services and school choice options to students or replacing the existing staff (National Conference of State Legislatures, n.d.).

The trend toward holding schools accountable for their students' performance through standards setting and assessments that began in the early 1980s was continued and strengthened with this legislation. It played a significant role in the development of the standards movement because it moved the emphasis away from national standards and voluntary national testing to a state-by-state system of standards setting and accountability. And as we will soon see, it provided the basis for the No Child Left Behind Act of 2001. But before moving forward to 2001, it is important to note that not everyone in the education community in the early 1990s was in favor of the standards-based accountability movement, especially when it spoke of national accountability and hinted at the possibility of a national curriculum. Although the movement was generating bipartisan support in Congress and in statehouses across the country, concerns persisted about the *nationalization* of education and were, in part, why attention shifted, particularly legislatively, from a focus on national goals and accountability to state-by-state accountability programs in the mid to late 1990s.

Reaction to the Idea of National Standards

In June 1993 the American Educational Research Association (AERA) sponsored an invitational conference to explore the implications of the new standards-based accountability movement. Papers were commissioned as part of the conference and published as the first in a series of AERA public service monographs in 1995. In general, the papers were critical of what was seen as a move toward a national curriculum and toward greater federal control over education. The fear was that aligning national tests (albeit voluntary) to national goals was a recipe for a mandated curriculum, and the country would inevitably move in the direction of a national curriculum. The proposal that there would be a national test was the most troubling aspect of the plan, for it was felt that a national test would create a de facto mandated curriculum (Zumwalt, 1995).

Although some felt there were likely to be advantages to having a national curriculum, there were many concerns that such centralization would take control away from local communities which, it was thought, had the best insights into what was important for their students to know. There were also concerns that common goals and accountability through testing would lead to a narrowing of the curriculum, a de-skilling of teachers, a focus on external academic knowledge, and a move toward direct instruction (Kellaghan & Madaus, 1995; McNeil, 1995). It was also

feared that these changes would threaten the "soul of the curriculum" (aesthetics, for example) and draw attention away from caring about children as individuals (Kellaghan & Madaus, 1995; McNeil, 1995; Zumwalt, 1995). Some questioned whether it was desirable to specify what all students should know and whether it was possible to validate such knowledge given the vast array of social and cultural contexts from which people have come and in which they now live. In his concluding statement, Asa Hilliard, said: "The problem is at its base one of curriculum validity.... Multiethnic, multinational, multidisciplinary scholars must be consulted to review every area of the curriculum to cleanse it of error and to enrich it with diverse perspectives" (1995, pp. 153-154). Others questioned the overall effectiveness of this approach to reform, especially if it was even possible to create unity out of such a diverse system.

No Child Left Behind

Consistent with a move toward state-level standard setting and accountability through testing, on January 8, 2002, President George W. Bush signed into law the No Child Left Behind Act of 2001 (NCLB), a bill to extend and revise the Elementary and Secondary Education Act of 1965. The changes in this legislation over the 1994 reauthorization are significant because the new law emphasizes even greater public accountability, with funding tied directly to meeting expectations. In the words of one observer: "This landmark event certainly punctuated the power of assessment in the lives of students, teachers, parents, and others with deep investments in the American educational system" (Jorgensen & Hoffmann, 2003).

NCLB requires states to build assessment systems to track the achievement of students in their state against a common set of state-derived standards. By the 2005-2006 school year, states are required to test students annually in reading and mathematics between grades 3 and 8 using statewide tests, and to test students at least once during grades 10 through 12. The tests must provide individual student scores. By the 2007-2008 school year, students must be tested in science at three grade bands. Every 2 years, states must also administer the mathematics and reading tests of the National Assessment of Educational Progress to a sample of students in grades 4 and 8. This allows the states to check the rigor of their own tests and to make national comparisons. The law also requires schools, school districts, and states to disaggregate the average test score results for major racial and ethnic groups, income groups, students with disabilities, and students with limited English proficiency. Starting in the 2001-2002 school year, states have 12 years to achieve the goal of having all groups of students meet their own state's benchmark for proficiency in reading and mathematics. As with the 1994 Improving America's Schools Act, the new legislation calls for states to define three levels of proficiency and to measure students with respect to those proficiency levels. The goal of NCLB is to raise reading and math proficiency to 100% for all students in the country by 2014. NCLB measures the performance of subgroups of students in reading and math and requires all groups—defined by race, ethnicity, income, and other characteristics—to keep improving until all groups reach the 100% goal. Failure to make *adequate yearly progress* toward meeting these goals results in various actions intended to help a school improve. In addition to technical assistance, staff changes, and the possibility of private or state takeover of the failing school, students in schools that do not meet their target goals are able to transfer to another school or use their Title I funds to pay for tutoring or other supplemental services.

NCLB continued a standards-based accountability movement that began in the early 1980s and that was strengthened with passage of the Improving America's Schools Act (1994) and the Goals 2000: Educate America Act (1994). The NCLB legislation of 2001, however, took the focus on standards-based accountability significantly farther through the specificity of its requirements and its sanctions. Standards present and past were now firmly entrenched in federal law.

IMPACT OF THE STANDARDS MOVEMENT

It is clear that the standards movement that began in the early 1980s represents one of the most significant changes in education policy in the United States to date. It is reasonable, then, to ask what the impact of that change in policy has been. Immediately, though, we are faced with the question: Which standards movement are we talking about? There are at least four ways to think about the *impact of standards*, depending on whether the standards movement is defined as (1) the general goal of raising the rigor of the educational experience for all, to be accomplished by requiring all students to take more science courses, offering students more academically challenging experiences, and increasing the length of the school day and the school year; (2) an accountability strategy involving testing and public reporting; (3) a detailed specification of what all students should know and be able to do; or (4) an elaboration of a vision of science literacy for all.

It is not my intent to provide a detailed discussion of each of these meanings or their implications here. A brief response to each of the questions below provides an overview of the widely acknowledged impact of standards before moving to a discussion of what next steps should be taken to move the standards-based reform agenda forward.

Question 1: What has been the effect of calls for more rigor? There is no question that the ideas presented in *A Nation at Risk* have resonated with many people in this country over the past two decades. States were quick to raise science course requirements, and some increased either the length of the school year or the school day. Between 1982 and 1994 the percentage of high school students taking science courses increased substantially from 77% to 93% in biology, from 31% to 56% in chemistry, and from 14% to 25% in physics (see Demarest, 2002, p. 332). During the 1980s and 1990s states and local school districts raised their requirements for the number of science courses students had to take. Some states also increased the length of the school day and the school year. There is no question that schools today are valued for the number of rigorous and challenging courses that they offer, especially honors and advanced placement courses. Holding students back when they do not perform at grade level is frequently seen as a way to maintain standards, and some states have officially ended the practice of "social promotion" (Neal & Poole, 2004). "Standards as rigor" is very much a part of the present educational environment.

Question 2: What has been the effect of the standards movement as an accountability strategy that uses high-stakes testing and external reporting? The conventional wisdom is that high-stakes tests concentrate energy and resources toward the things being tested. This is becoming particularly evident under NCLB legislation that uses test results in mathematics and reading as part of annual yearly progress reports, but does not include test results from any other subject areas (Perlstein, 2004). The power of the test to focus attention on what is being tested applies both at the school wide curriculum level and it applies at the level of the content of individual courses. Teachers are beginning to limit their instruction to those ideas that are going to be on the state's test. The issue of *teaching to the test* raises questions about whether such a practice is helpful or detrimental to good education.

Question 3: What has been the impact of defining—much more precisely than had been done in the past—what all students should know and be able to do? This is an extremely difficult question to answer by itself. Especially at the state level, specification is accompanied by accountability testing, so it is difficult to tell whether the effect, if any, is due to the testing or to the specification. Specification of content was intended to be a positive feature of reform. The specified content would represent the most important things for students to know, including ideas that were functional in students' lives and that taught them important aspects of the structure of science itself—a *less is more* approach. One place to look for the impact of content specification is textbooks. In general, there has been little if any effect on textbooks of the efforts to identify the most important content for students to study. Textbooks continue to cover as much content as possible. Another place to look for the effect of greater specification of content is student learning. Whether a sharper focus on important science ideas has affected either the depth or breadth of student understanding, we do not yet know. In fact, the assessment instruments that would provide an answer to that question do not exist.

Question 4: What has been the contribution of standards-based reform as presented in the *National Science Education Standards* and *Benchmarks for Science Literacy* to the on-going efforts to achieve science literacy for all? Where will these documents stand in the record of important efforts to improve science education in the United States? At one level their contribution has already been impressive. These national standards documents were used as models to write state curriculum frameworks to guide the development of the science curriculum in each state. This was the first time that the science content most worth knowing had been specified with such great precision. In the past, guidance had been given at a more general level of specification, and no one had provided a system of interconnected ideas at this level of detail. In addition, both national documents consolidated the best thinking about *how* science should be taught. There is no question that through their influence on the states, that they have had a major contribution to national attempts to achieve science literacy for all.

NEXT STEPS IN THE REFORM OF SCIENCE EDUCATION

It is this fourth category of impact concerning the vision of science literacy for all that I will address in the remainder of this paper. It is this vision that is the focus of standards future, and that is ultimately what reform today in science education should be about. Accountability through assessment is simply a strategy for motivating people to act. Reform, on the other hand, is a continuing process of change. The standards documents in science education embodied a vision for improvement; they were not authoritative pronouncements of a standard that all must meet. They were meant to inform and enliven reform efforts. Although established by means of broad-based authoritative consensus, it was anticipated that within certain boundaries consistent with that vision, the standards documents were expected to be used by people who would apply that vision of reform to their own practice, resulting in products that would be shaped by their own particular situations.

The goals of the reform movement that appear in the standards documents are: (1) decreased content coverage to increase student understanding of the ideas being taught, (2) science for all students, (3) the

integration of ideas within subject areas and across subject areas to increase meaning and aid in retention, (4) knowledge that is useful for personal growth and development, and (5) content that takes into account both the products of science and the way that knowledge was developed. These are noble goals worthy of pursuit.

In the early and mid1990s, the assumption was that it was possible for the educational system to take content standards and turn them into curriculum as long as important elements of the educational system were considered and brought into the process. Working through issues of school organization, curricular connections, equity, and finance seemed doable (AAAS, 1998). That idea began to change as it became clear that the content standards alone were not enough to guide reform. An entire coordinated and integrated system of clarified and elaborated content standards, more detailed guidance regarding effective classroom practices, curriculum materials aligned to the content standards that incorporate pedagogical support for teachers, and student assessment aligned to those content standards needed to be developed before significant numbers of people in state education departments, higher education, the business world, and family and community would be convinced of the soundness of the reform message. Without further elaboration of the intent of the reform movement and models of how to get there, it was unlikely that the desired changes would occur.

At a minimum, three additional steps of considerable magnitude still need to be taken if we are to build a standards-based educational system that works and that the educational community will embrace. The standards documents that we now have lay out a comprehensive vision for science literacy, but they do not adequately operationalize that vision in terms of teacher practice, curriculum materials, or assessment. A number of principles of effective instruction are included in the standards documents as well as some guidelines regarding assessment, but what we do not yet have is: (1) models of what textbooks actually look like that are at one with the vision of science literacy and that can be successfully used on a wide-scale basis; (2) a thorough and convincing statement, along with examples, regarding the range of research-based teaching practices or classroom activities that are consistent with the reform agenda; and (3) an assessment system that is aligned with the content standards that is laid out in the *Standards* and in *Benchmarks for Science Literacy.*

Fostering Implementation

In theory it is possible to construct an educational system made up of a set of interconnected parts each of which is aligned with the content standards. But even with clearly elaborated content standards in place, accompanied by curriculum materials aligned with those content standards, teaching that is consistent with the goals of reform, and student assessments aligned to the content standards, we still need to consider the contexts in which these parts will have to be implemented and the various players who can help or hinder progress. There is a real world of existing organizational structures, values, and practices that needs to be considered both during development and during implementation. In 2002, a NRC panel produced a report on the influence of standards on the educational system in the United States. The panel did not attempt to answer the question of what the influence of standards had been to date; rather, it created a framework for conducting future research on the impact of standards. (See chapter 2, A Framework for Investigating the Influence of Standards, for a detailed discussion of the panel report.) As part of that framework, the panel identified three "channels of influence" —assessment, professional development, and curriculum materials—that potentially can leverage change in the system.

These channels of influence can also be viewed as contexts for reform, that is, elements in the system whose preexisting interests and capacities need to be accommodated if change is to occur. Those who control these channels of influence, who have interests and capacities of their own, can provide support for reform, remain uninvolved and disinterested bystanders, or even counteract the efforts of reform. The point is that these are not necessarily freely flowing and readily available channels waiting to serve a new interest. They all represent well-established systems of their own, and may not be easily changed. Tradition and resistance to change has proved to be very powerful throughout our educational history.

In European countries that have a more centralized means of enacting and monitoring education, the channels of influence are very similar to those in the United States, but the way education is controlled is very different. According to Cohen and Spillane (1992), channels of influence in centralized systems can be used to direct what happens in classrooms by controlling instructional materials, preservice and in-service education of teachers, classroom instruction, and assessment of student achievement (cited in Kellaghan & Madaus, 1995, p. 88). In centralized systems

> there are definite procedures to reinforce the messages about content and pedagogy conveyed in curriculum documents unlike the practice in America, where the dispersed organization of education might have 'rendered the connections between policy and instruction inconsequential for most of our history.' (p. 87)

The decentralized nature of the U.S. educational system, both in its structural organization and its beliefs about local control, raises significant challenges to any national efforts of reform.

ELEMENTS IN AN EDUCATIONAL SYSTEM IMPORTANT IN IMPLEMENTING REFORM

In the following sections, I will discuss some parts of the educational system that need to be kept in mind when thinking about implementing a reform strategy, and I will offer suggestions as to what is needed to move the reform agenda forward.

State Education Departments and State Legislatures

At the present time, states are struggling with the requirements of NCLB. Under this legislation, each state sets its own standards for proficiency and is required to assess its students with respect to those standards. This federal requirement has the potential to have enormous impact on the educational system. At present, the federal mandates require annual testing in mathematics and reading in grades four through eight and once between grades 10 through 12. Science will be tested at three grade levels in 2007-2008 school year, but under present legislation, science will not be part of the annual yearly progress determination, which affects the designation of the school as meeting or not meeting expectations. In addition, states are not required to provide content standards consistent with any nationally recognized vision of what quality science education is. As noted earlier, the primary goal of NCLB is to raise reading and math proficiency to 100% for all populations of students in the country by 2014. In addition to the requirements of the federal legislation, some states have made their own decision to test science throughout the grades and to use those results for making high-stakes decisions, including graduation from high school.

There is no question that states have made good use of and will most likely continue to consult the national standards as they develop and revise their own state content standards in science. But most states have chosen to create something unique to their state rather than to appropriate the national standards without modification. There is often an antipathy in state legislatures to anything *national* when it comes to education, especially when it suggests the possibility of a national curriculum. When the Colorado standards were drafted between 1994-1995, the drafting committee used *Benchmarks for Science Literacy* as a guide but they also

used current drafts of the NRC *Standards* as well as the California and New Jersey frameworks. According to an SRI report: "Key drafters pointed to the usefulness of *Benchmarks* as an intellectual guide, but the committee did not feel obliged to deal with all of *Benchmarks* and certainly did not believe that they had to justify excluding something included in *Benchmarks*.... Furthermore, the day-to-day criteria the committee used in drafting the standards were independent of national standards" (SRI International, 1996b, p. 4). Specifically, Colorado placed restrictions on the number of standards taught, on the degree of specificity of content to be covered, and on recommendations concerning pedagogy. According to SRI, "For political reasons, it was important that these should be seen as model content standards, that they not tell teachers how to teach, and there not be teaching standards" (p. 4).

Although state standards vary greatly in their degree of consistency with the national standards, an examination of current state content standards and the accompanying assessment instruments reveals that the general vision of science literacy is present in most of them, and many of the specific content areas that appear in the national standards are in the state standards as well. One observer concluded that the state frameworks capture "the spirit and essence of the national standards and the *Benchmarks* remarkably well" (SRI International, 1996a, pp. 36-37). From the perspective of national reform efforts, this is an encouraging observation. However that does not mean that state framework documents treat the full range of concepts found in the national standards or approach all concepts in the same manner as the national standards do. One problem found by the SRI evaluators was that of overgeneralization of the content. In some cases "the standards had become so diluted by generalization that they doubted a teacher or other practitioner could make use of them and certainly could not develop assessment tasks to measure the stated standard" (p. 39). An example of a typical overgeneralized standard said that students should be able to identify the characteristics of and understand the relationships among heat, light, sound, magnetism, and electricity (p. 38). Specifically *which characteristics* and *which relationships* were not noted in the state standards document.

Given the decentralized nature of schooling in this country and the lack of a national infrastructure for implementation, influencing the quality of education nationally must depend on state and local efforts. There is, for example, no tradition of school inspectorates in the United States to monitor what happens in classrooms as there is in many European countries. In fact, states themselves often do not exert much centralized control over education. In some states basic curricular decisions are made at the district or even the individual school level and pedagogy is almost always an individual matter for each teacher to decide. It is not clear that

a centralized approach would ever work in this country. According to Atkin (1997):

> With the country's traditions of local autonomy, the increased assertiveness of teachers, and the changes taking place in science itself, it would be surprising in American science education reform if any central agency ... will be able to maintain strong and direct influence over actual classroom practices for very long. (p. 237)

According to another observer:

> Standards-based reform that begins with developing a set of ambitious goals for what students should know and be able to do is a very rational theory of change. However, the political and educational systems operate in ways that are not always describable as rational. (SRI International, 1996a, p. 20)

Thus, national efforts to reform science education are inevitably going to encounter obstacles "due to the intrinsic difficulty of changing such a large, complex enterprise as American education" (SRI International, 1996b, p. 89).

But, in general, states do want coherent, integrated educational systems. Therefore, the potential still exists for national groups to have a significant impact on the continuing development of state standards and resources for implementing those standards through the creation of educational products in which standards, instructional practices, curriculum materials, and assessment are aligned.

Universities, Colleges, and the Professional Development Community

Unlike countries that have a national education system, where a ministry of education can directly influence preservice and in-service education programs and, therefore, what teachers know and can do, there is no centralized control over what happens in preservice teacher education or in-service teacher development programs in the United States. There are thousands of college- and university-based preservice teacher education programs, all operating independently. The only centralized control of these programs is the general oversight that each state has over its colleges and universities, and direct control over the curriculum in colleges and universities is rare. In the case of preservice teacher education programs, where state certification and licensure is an issue, the states establish standards that colleges and universities must meet with respect to

these programs, but rarely at the level of what gets taught in any particular course.

Similarly, in-service professional development is a decentralized activity in the United States, controlled to some extent by states, but largely an activity organized by local school districts or voluntarily selected by teachers as part of their own personal growth as teachers. There is little hope of broadly impacting such a system; any influence will most likely be at the level of individual school districts. Even in New York, which recently enacted a statewide requirement of 175 hours of professional development every 5 years to retain licensure for teachers newly certified in 2004, the options for meeting that requirement are many (New York State Education Department, n.d.). Often agreements of this kind between teachers and the states are negotiated as part of collective bargaining agreements.

The degree of flexibility in the many ways to meet the professional development requirement in New York raises the question of the role of professional development for teachers. Is its main purpose the general enrichment of teachers with decisions about those experiences left largely to their personal preferences, or should professional development be used as a tool for directly affecting the educational system? According to Elmore (2002), there is disagreement in the field on this issue. He says that whereas some educators believe that schools should take a more instrumental view of professional development many "argue that teachers, as professionals, should be given much more discretion and control as individuals and in collegial groups in deciding the purpose and content of professional development" (p. 32).

In either case, to achieve their approval and full participation, professional development should be planned with the real-world necessities of teachers in mind, and as much as possible, teachers should be engaged in the planning of the professional development experiences. If the experience is related to the work they are doing, and it has a high probability of impacting student learning, teachers are more likely to participate. In Elmore's words: "The work itself, then, is the primary motivator for learning and improvement. If the work is not engaging and if it is not demonstrably beneficial to student learning, then any incentives are likely to produce weak and unreliable effects" (2002, p. 21).

For reform of science education to become a reality, teachers and the college and university students who will become teachers must understand the reform vision, but they also need to have available to them specific tools to help them implement that vision. This means that the people who provide preservice and in-service educational experiences to teachers must be well-informed of the vision themselves and have ways to communicate it clearly and evidence that it can be accomplished successfully. With no centralized system for delivering the knowledge needed to

advance the reform agenda, progress depends on the quality of the reform ideas and their fit with existing professional development delivery systems.

Curriculum Materials Developers

For the most part, commercial textbook publishers have not yet accepted the ideals of the current reform movement. The textbook publishing industry is a profit-driven and demand-driven enterprise. Publishers are unlikely to make changes unless they are certain that those changes are what the purchasers of textbooks want. According to SRI: "To protect their competitive position, publishers are not willing to align textbooks with reforms that a majority of teachers have not fully accepted" (SRI International, 1996a, p. 18) and publishers have little incentive to "take on what they perceive as greater business risk in order to be aligned with reform documents that, according to them, have not taken hold within the teaching community—at least at this point in time" (p. 19).

Most textbooks are still very large and cover many more topics than the national standards call for. To quote SRI:

> Voluminous biology texts reflect the organization of high schools around science disciplines. Technical vocabulary abounds (in each case, the glossaries contain about 1,000 technical terms that are used in the body of the book), and the authors have not eliminated material extraneous to what is required to meaningfully convey key concepts.... Not only are the textbooks 'designed to cover the standards, [they] cover everything.' (SRI International, 1996a, p. 17)

By providing coverage of many topics, publishers can appeal to a wider range of states that may have differing content lists.

> Publishers admit that texts continue to be laden with superfluous details because 'Even though people ask for 'less is more,' when they go to make their decision, they want everything.... From a business point of view, we can't make the decision to cut content. Every state looks at content differently ... to cut content would be financial suicide.' (p. 18)

To date, the changes in curriculum materials have been small at best. Some of the ideas present in the national standards have been incorporated, such as suggestions to include historical episodes and strategies for linking science, mathematics, and technology (SRI International, 1996a, p. 15). The publishers, however, have made little attempt to incorporate the pedagogical supports that are consistent with the vision of teaching

that the reform documents encourage (Kesidou & Roseman, 2002). Most experimentation with curriculum materials has come with the support of federal funding, primarily through the projects sponsored by the instructional materials development programs of the National Science Foundation. Some of these innovative materials and ideas are finding their way into the marketplace as commercial publishing companies often offer one or more textbooks that appeal to the reform market, but the impact so far has been small. For the innovative federally funded materials development projects to have an impact, they will have to appeal to teachers and help teachers meet the new accountability demands being placed on them.

As with other elements of the educational system, there is no centralized infrastructure for affecting the textbook publishing industry. The closest thing is the statewide adoption committees of some states and, to a lesser extent, district and local adoption committees. By controlling the list of approved materials, these committees have the potential to significantly affect what gets taught and how it gets taught. Educational reformers can influence these decision makers by providing clear and compelling guidelines for choosing materials that are consistent with the reform vision, along with accompanying documentation of the effectiveness of those materials to advance student learning in the areas recommended in those reform documents.

Teachers

As Atkin (1997) noted: "One of the clearest lessons of successful reforms is the importance of according considerable weight to the insights and initiatives of those closest to the point of provision of educational services" (p. 219). Without the support of teachers and a vision that is consistent with their values and capabilities, change is unlikely. Teachers control the classroom. Regardless of the curriculum they are given, they enact the curriculum the way they see fit. We also know that, historically, classroom instruction is a story of diversity. Teachers are unlikely to march lockstep with respect to any innovation. Teachers develop and follow their own guidelines (Demarest, 2002, p. 319).

The extent to which teachers have accepted the vision of reform in the national content standards is not clear. A 2000 survey of teachers conducted by Horizon Research, Inc. showed that about 25% of respondents felt that they were prepared to explain the NRC *Standards* to their colleagues; 20% felt that the standards had been thoroughly discussed in their schools; approximately 39% believed that teachers had implemented the *Standards* in their teaching, and less than 30% believed that

their principal was well-informed about the *Standards* (Weiss, Banilower, McMahon, & Smith, 2001). Other responses suggest that teachers have not yet embraced, or perhaps do not yet know about, national content standards. But whether they are familiar with the standards themselves or not, what is more important is whether they are sympathetic to the goals found in them. There is some evidence that they are, but there are reasons for concern as well.

In a survey of participants in Project 2061 professional development workshops over a 3-year period, 85% of teachers strongly agreed with the statement that "science teaching should be consistent with the nature of scientific inquiry" and 69% strongly agreed that "students should learn scientific 'habits of mind' that explicitly include ways to assess the validity of claims and arguments." However, only 33% agreed strongly that "most students are not currently learning science well, even in the best schools," 53.6% that "changes in the education system should be driven by important, specific goals to be achieved by all students," and 56.8% that "identification of appropriate materials for curriculum and instruction requires detailed study of how they relate to specific learning goals." In addition, 60.7% of teachers agreed strongly that "improving student understanding of science requires reducing in number and detail the science topics in the current curriculum, leaving time for more effective teaching of important ideas" (SRI International, 1996a, p. 69). The SRI report concluded:

> When one notes that only 61% of teachers strongly agree that the level of detail taught to students must be reduced, this is cause for real concern. Considering that a much smaller percentage of the teachers who did not attend Project 2061 workshops are likely to agree, the data suggest that there is much work to be done if teachers' classroom practice is to become consistent with the philosophy that 'less is more.' Furthermore, only 54% of teachers strongly agree that education system reform should be driven by specific goals for all students. This would be consistent with the finding ... that teachers as a group, particularly those at the high school level, are unwilling to discard much of the content that is now taught and do not, as yet, fully embrace standards-based reform efforts. (SRI International, 1996a, p. 87)

There is some evidence that teachers view most of the statements in national reform documents as being too general and vague for their purposes. Thus they are influenced in what they teach primarily by the more specific requirements of their district administrators and building principals, the curriculum materials that they use, and the culture of the school. State testing may also have an impact on what teachers teach especially in school districts where many students are likely to do poorly.

When it comes to how teachers teach, high-stakes testing is a major factor in their willingness to try alternative instructional approaches. In a high-stakes testing environment where student performance on the tests is a concern, teachers are very reluctant to modify their teaching unless it can be demonstrated that the new approach is clearly superior in achieving improved test scores. In schools where students generally do well on tests, testing pressures are minimal, but there, as well, teachers are not likely to change how they teach without good reason. As Elmore notes,

> Few people willfully engage in practices that they know to be ineffective; most educators have good reasons to think that they are doing the best work they can under the circumstances. Asking them to engage in work that is significantly different from what they are already doing requires a strong rationale and incentive. (2002, p. 20)

According to Demarest (2002), it is not surprising that an attitude of caution or even cynicism is sometimes present among teachers, bombarded as they have been by "waves of reformist exhortations" and what some teachers perceive to be "faddish pendulum swings." For this reason, it is essential that proposals to change teaching should be driven by "foundational beliefs and theories" (p. 94).

Besides a clear foundational rationale for change, teachers also need to see clear models of what is expected. The Project 2061 vision of reform did not specify a particular approach to pedagogy. Teachers were expected to interpret the reform vision and implement it in their own way. This was consistent with a widely held view in the U.S that teachers should develop and follow their own approaches to teaching. *Science for All Americans* identified general principles of good teaching, such as the importance of teaching for understanding and making science teaching consistent with the nature of science, but it did not tell teachers in any detail how to do that. The absence of detailed guidelines allows the teacher flexibility in meeting the goals of the reformers, but it also means that teachers must know what "teach for understanding" means and have a solid grasp of what they can do to achieve such understanding in their students. Without detailed prescriptions of what to do, teachers need examples of teaching practices and curriculum materials that are effective and consistent with the reform vision.

In contrast to the lack of specification regarding pedagogy taken by Project 2061, the NRC took a very strong position on inquiry teaching as a favored pedagogy and recommended that student investigations become a central part of science classrooms. This raises additional challenges for teachers because, historically, teachers have found project-based work difficult to deal with in the classroom. Teachers often see such

lessons as too "difficult and troublesome" (St. John, 1987; and Weiss, 1987, as cited in Demarest, 2002, p. 328).

Ultimately, then, the impact of any reform effort comes down to the individual classroom, and with so many teachers and so many classrooms, it is impossible to directly reach each one of them individually. The impact of national reform efforts on teachers' behavior is more likely to be indirect rather than direct. It will come through changes in professional development programs, curriculum materials, and assessment systems. But without a consideration of the values and capabilities of teachers who have so much independent control over what happens in the classroom, efforts at reform will not be productive.

Students

Attempts to change the goals and methods of education must also be consistent with the deep educational purposes that are imbedded in our culture with respect to our children and youth. Is education primarily about acquiring skills and information or is it about the development of social competence, identity, and belonging? (See Wenger, 1998, as cited in Brown, Demarest, Freeman, & Dalton, 2002, p. 193). Brown et al. (2002) argue that

> educators are unlikely to be successful with students—especially with the full diversity of students who attend today's schools—unless they broaden their concept of education so it attends not only to academic competence, but to social competence, interpersonal connection, and identity as well. (p. 194)

According to sociocultural theories, people are motivated by a desire to pursue their own interests, to develop competence, and to build on their own life experiences. Competent performance in most real-life situations requires individuals to draw on knowledge not only in the cognitive domain, but also from the social and affective domains. "Schools are expected to prepare young people to become adults who are capable of participating fully in and contributing to the economic, civic, and social life of their communities and the nation" (Demarest, 2002, p. 243). Many teachers devote a considerable amount of energy to the human interactive aspects of life in the classroom. This means that if national content standards in science are going to take hold, consideration must be given to students in the classroom, where interpersonal competence and personal identity are important to the participants, including the students, their teachers, and their parents. It needs to be asked if the new demands

being placed on students are consistent with the identity and social competence needs of students.

It is clear that the standards-based reform movement and accompanying pedagogies do place new demands on students. Students are expected to know more than facts and information. They must also know processes and causal connections, and they must be able to use those ideas to identify and solve nontraditional problems. According to Wilson and Peterson (2002): "They need to learn about the ideas, theories, facts, and procedures of a discipline. They need to become fluent with the linguistic systems of a field, with developing the skill and knowledge associated with inquiry in that field" (p. 108). In reform-based classrooms, students are kept mentally engaged through questions and probes of what they know and how they think. They are asked to provide explanations and rationales, give reasons, make their ideas public, accept the critique of their peers, and offer comment on the thinking of others. Although these expectations and practices are not new and have characterized some classrooms for many years, it is not the predominant mode of teaching in most classrooms. To make it so is an enormous challenge, and to make it fit the learning styles of all students is ambitious to say the least.

When we consider the combined efforts of the science education reform agenda and the accountability movement brought on by federal legislation, the potential impact on students' lives in classrooms is enormous. Student performance is the measure of school success under the present federal legislation. Accountability and reporting is at the school level, but the data comes from student performance on tests. It is they who ultimately will feel the pressure to reach higher levels of performance. As with teachers, the support of students is crucial to the success of any reform efforts. Methods that are not consistent with the nature of children and adolescents, their needs as young people, and their sense of who they are and the importance of what they are learning will be ineffective. It is essential that proposals to reform educational goals and methods, as well as plans to develop curriculum materials and to design activities for classroom use, take the lives of children and youth into account.

Schools

Reform of science education takes place within a context of classrooms, state bureaucracies, professional development systems, and university pre-service teacher education programs. It also takes place within a context of school-based accountability. Under current federal legislation, accountability is at the school level and is based on individual student per-

formance. Science education reformers must realize that for reform to be successful, implementation takes place in an environment where each school is being held accountable for the performance of each student. Just as teachers need new knowledge and an understanding and acceptance of the goals and methods of the reform movement, so too must schools *buy in* to the reform agenda. What kind of institution is a school? How equipped is it to effect the kinds of changes being proposed? According to Elmore,

> American schools and the people who work in them are being asked to do something new—to engage in systematic, continuous improvement in the quality of the educational experience of students and to subject themselves to the discipline of measuring their success by the metric of students' academic performance. Most people who currently work in public schools weren't hired to do this work, nor have they been adequately prepared to do it either by their professional education or by their prior experience in schools. (2002, p. 3)

Elmore goes on to say that

> there are few portals through which new knowledge about teaching and learning can enter schools; few structures or processes in which teachers and administrators can assimilate, adapt and polish new ideas and practices; and few sources of assistance for those who are struggling to understand the connection between the academic performance of their students and the practices in which they engage. (p. 5)

When considering the knowledge needed to reform science education, most school personnel currently have very little detailed knowledge of what the reform agenda in science entails. Weiss et al. (2001), for example, found in a 2000 survey of teachers that, depending on whether it was elementary, middle, or high school teachers who were responding, only 19% to 29% believed their principal was well-informed about the NRC *Standards*. A similar number of teachers felt their district superintendent was well-informed.

In discussing why it is so difficult for fundamental change to take place in schools, Cuban (1993) provides a number of possible reasons. One of these is the "inattention of policymakers to the details of implementing reforms" (p. 251). In describing past efforts at reform, Cuban says: "Absent, more often than not, were administrative mechanisms to dispense information, organizational linkages between school practices and district-wide goals, and teacher participation in the process" (1993, p. 252).

So, in addition to taking the other parts of the educational system into account, reformers also need to look at the schools themselves and consider their ability to allow information to enter, to apply that knowledge effectively, and to connect new ideas to changes in students' performance. These are enormous challenges for schools, but essential if reform is going to become a reality.

SUMMARY

What I have tried to do in this chapter is to provide historical background for the current science education reform movement and to show how closely interconnected, but perhaps diverging in their fundamental mission, are a standards future vision of reform and the federally driven standards present accountability movement. I have also looked at the contexts in which reform must take place, where existing interests, needs, and capabilities of participants play a major role in any efforts at reform.

It is clear from this analysis that there are a number of things that still need to be done to move the reform agenda forward. To begin, we need to provide models of excellence that will be perceived as such by the educational community. Because we are operating in a decentralized, free market system where ideas compete with each other for acceptance, implementation cannot be effected through tightly controlled bureaucratic channels. In a sense we are left with a hopeful *build it and they will come* approach. If the product is good enough, if it is convincing enough, if it is integrated and coherent, if it can be implemented with reasonable effort and resources, and if it can deliver anticipated results, then the hope is that it will be used.

But, even then, without a clear and compelling reason to change, most people will continue to behave as they have behaved in the past. Most people act as they do because they believe it is the right thing to do. Our efforts should continue to go into building a system of well-connected and coordinated parts. But that system must be built with a full awareness of the values and capabilities of the many participants in the system, and, as much as possible, with a level of involvement that achieves a sense of ownership for those participants. It should also be built with an awareness of how the many parts of the system work together. But obviously, we cannot wait for everything to be completed before the new model goes on display. As innovative curriculum materials, instructional strategies, and student assessments that are aligned with content standards and sound pedagogical principles become available, we can expect there to be steady movement toward the reform vision. An internally consistent set of reform-based instructional tools and resources built on the foundation of

carefully developed content standards should have great appeal to practitioners in the field. It is also important that state education departments, local school districts, teachers, and professional organizations that are concerned with education issues be kept up to date on our reform efforts.

We now know that the changes being proposed will take time, much more time than originally imagined. And we know that there is no single and final solution to our problems. Our challenge is long-term and far-reaching: We must promote a clear and uncomplicated message of reform and engage the education system at all levels in ongoing and practical efforts to offer the best science education possible to the greatest number of people. We should not be trapped into a narrow and short-sighted standards past or standards present accountability mode, but rather keep our eyes looking toward the future.

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