Science Education Leadership

BEST PRACTICES FOR THE NEW CENTURY

Science Education Leadership

BEST PRACTICES FOR THE NEW CENTURY

Edited by Jack Rhoton

NSTApress
National Science Teachers Association

NSTApress®
National Science Teachers Association

Claire Reinburg, Director
Jennifer Horak, Managing Editor
Andrew Cocke, Senior Editor
Judy Cusick, Senior Editor
Wendy Rubin, Associate Editor
Amy America, Book Acquisitions Coordinator

Art and Design
Will Thomas Jr., Director
Tracey Shipley, cover and interior design

Printing and Production
Catherine Lorrain, Director
Jack Parker, Electronic Prepress Technician

National Science Teachers Association
Francis Q. Eberle, PhD, Executive Director
David Beacom, Publisher

13 12 11 10 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Science education leadership: best practices for the new century / Jack Rhoton, Editor.
p. cm.
Includes index.
ISBN 978-1-936137-00-8
1. Science—Study and teaching—United States. 2. Leadership. I. Rhoton, Jack.
Q183.3.A1S3544 2010
507.1'073—dc22
2009047474
eISBN 978-1-936137-83-1

CONTENTS

Section Three:

School and District Science Leadership: Rationale, Strategy, and Impact

Section Four:

School Improvement Processes and Practices: Professional Learning for Building Instructional Capacity

Foreword

Brenda Wojnowski
NSELA President 2009–10

The United States is at a critical juncture as many states, districts, and schools struggle to develop strategies and methodologies to prepare our students for life in this still relatively new century. We are well aware of the significant changes we, as educators, must make in our ways of thinking and doing in educating our populace, from preK education through career inservice. The need is critical; the structures and thought patterns which must be developed and implemented within our education system is the crux of the struggle. According to Tom Friedman, "the school, the state, the country that empowers, nurtures, enables imagination among its students and citizens, that's who's going to be the winner" (Pink 2008).

The Partnership for the 21st Century (2008) identifies the forward-thinking learning and innovation skills that are critical to students as (1) creativity and innovation skills, (2) critical thinking and problem-solving skills, and (3) communication and collaboration skills. To attain these skills, our students must be able to interact both with their immediate neighbors and with other students and potential workplace partners around the globe. We must develop mindsets that allow our students to understand and be sensitive to the intricacies of cultures that are very different from our own. At the same time, we must help our students to develop the science/technology/engineering/ mathematics strengths that will allow the United States to prosper and thrive in the modern world.

The chapters within this volume address many of the issues that currently occupy education leaders who are working to address the skill sets needed for 21st-century success in a global community and marketplace. *Science Education Leadership* will aid leaders in guiding the teaching and learning occurring within our classrooms as well as the thoughts and policies being formulated within our state and federal departments of education. The work of 21st-century education is imperative—the timing of the guidance and planning is crucial.

The National Science Education Leadership Association is pleased to be a part of the infrastructure that stands in support of quality publications that will be used to improve education and inspire the future of young people throughout the United States and the world.

References

Partnership for the 21st Century. 2008. *21st century skills, education, and competitiveness: A resource and policy guide*. Tucson, AZ: Partnership for 21st Century Skills.

Pink, D. 2008. Tom Friedman on education in the "flat world." *The School Administrator* 2 (65): 12–19.

Preface

Jack Rhoton

At no other time in the history of science education has the need for leadership been more important to ensure that all students in our nation's schools get the training they need to succeed. It has almost become a cliché to recognize that we live in the Information Age, an age that has mushroomed into the globalized knowledge economy. There is no doubt, however, that there is extensive support for the notion that science is vital for our economic competitiveness and for a science-literate public that can share in discussions—and make intelligent decisions regarding—science issues. In order to prepare students for success, we must instill in them the ability to constantly adapt through lifelong learning. Clearly we operate within a very complex educational system, and this will require strong science education leadership from a wide of array of individuals, businesses, organizations, and institutions.

Just as change is a permanent attribute of our time, leadership in science education needs to be continuously exercised with the ultimate goal of improving student learning. We all know that leadership takes on many forms, but a common theme in leadership is that leaders have vision. Leaders are able to develop a consensus around an idea, goals, and a course of action. They are able to mobilize people's commitment to improve. They make it possible for others to do good work. However, different leaders take on different roles and may have different ways of clarifying a vision. For example, some science leaders may craft futuristic models of science education or examine the impact of brain research on the teaching and learning of science. Some leaders may be able to impact science education through policy initiatives, others through their writing, and still others by defending the integrity of science. Science teachers can also be leaders in their individual classrooms and schools.

The community of science education is made up of systems and subsystems, all of which consist of individuals and groups with different agendas and goals for improving science education. Science teachers, science educators, administrators, curriculum directors, university personnel, scientists, business and industry, Congress, and members of the current administration all have unique roles to play in advancing the support of science education. Science education leaders must know their constituents and be able to enlist people in a vision. Leaders must understand their needs, speak their language, and fashion a unity of purpose that enables constituents to share in a vision. These visions are played out in different ways. Not all in the science education community can or should be engaged in research, crafting curricular materials, developing technology programs, or providing professional development. We all have distinct talents, roles, and responsibilities. If we take action, we can turn our vision for a better tomorrow into initiatives that become actions that will make a difference for our students. Leadership is the conduit that can assemble the various components of science education reform efforts in ways that improve instruction and learning at all levels.

It is my belief that the central goal of science education should be to allow every student to achieve high levels of scientific literacy. Achieving this type of literacy for all students requires science education leadership from all constituent groups. Furthermore, all groups must communicate and work together toward clearly identified, mutually agreed upon objectives. Leadership must forge connections between the important components of the science education system, including national, state, and local science programs, as well as individual classroom practices such as teaching, curriculum design, and assessment. Collaboration will be required of science education leaders as they work in an increasingly complex educational environment.

With these challenges in mind, this book addresses issues and outlines the practical approaches needed to lay the foundation upon which science education leaders—at all levels—can work together to develop a more science literate society. This book shares the research, ideas, insights, and experiences of individuals representing a wide array of constituent groups, ranging from science teachers to science supervisors to university personnel to those who work for agencies representing science education. The authors discuss how to contribute to the success of science education and how to develop a culture that allows and encourages science education leaders to continually improve science programs.

The 18 chapters in *Science Education Leadership* are organized into five major sections. This organization places each chapter within a general theme. The intent is not to provide an exhaustive coverage of each section, but rather to present a stimulating collection of essays on relevant issues. Those major themes are:

The Science Education Challenge: Redefining Science Education Leadership for the 21st Century. Whether in the classroom, the curriculum office, or the boardroom, the science education leader has a desire to inspire others and pioneer changes that build stronger science education programs. Leaders are willing to relinquish familiar and commonly held practices and embrace change. We introduce this theme in "Looking Forward Into the 21st Century: Implications for the Science Leader." Next, we consider the leadership exhibited by business leaders and how they are investing resources and energy to target systemic reform initiatives in science education. This is followed by a look at the challenges that science leaders face as they develop ways to imbue upcoming generations with 21st-century workforce skills. The section concludes with a look at the many faces of leadership found in a complex educational environment.

The Role of School and District Science Leadership for Building Instructional Capacity. Strong science education leaders are needed to build and organize an infrastructure that supports deep learning for both teachers and students. Instructional leadership consists of actions that promote improved student learning not only in one's own classroom, or one's own school, but throughout an extended community. Therefore, science education leaders not only view instructional quality as a top priority, they also encourage others around them to share this priority. Successful science programs involve many participants—among them teachers, principals, and science supervisors. This theme develops over four chapters that examine the impact of instructional leadership on instructional quality and student outcomes. See in particular, "Content Coverage and the Role of an Instructional Leader."

School and District Science Leadership: Rationale, Strategy, and Impact. Science education leaders can create a robust digital age educational community that supports the use of advanced technologies in the teaching and learning of science. This section begins by addressing the critical role of transformational leadership in the science education community for effective and appropriate infusion of educational technology as a fundamental component of K–12 education. This topic is followed by examples of leaders who foster inquiry-based learning and teaching in a variety of settings, including classrooms, local communities, schools and districts, college science classrooms, teacher preparation programs, and professional experiences. Other chapters in this section address teacher preparation, induction, and ongoing professional development as well as the role of graduate mobility in recruiting new teachers and developing new leaders.

School Improvement Processes and Practices: Professional Learning for Building Instructional Capacity. The role that professional learning communities have in improving and coordinating our efforts to establish higher expectations for students, improve instructional practices, and increase student achievement outcomes through a shared curriculum-focused vision is of inestimable value. This theme emerges most fully in "Professional Learning Communities: School Collaboration to Implement Science Education Reform." Other topics in this section include leading through collaboration, assessing assessment to inform science leadership, and professional development.

Leadership That Engages the Public in the Understanding of Science. This country places a high value on science and science teaching, and this content area is well established in the American school curriculum. Our nation invests a significant amount of resources in science education at all levels. We value science, because our society believes it is important for preparing our students for the 21st-century workforce, preparing future scientists, and providing nonscientists with the science knowledge necessary to make informed decisions about issues affecting their everyday lives. However, the results of efforts to engage the general public in science have been mixed. For this reason, an argument is made that education and science education leaders should be prepared to communicate with the public, media, and decision makers to facilitate a better exchange of information between science professionals and society as a whole. These themes are highlighted in two chapters in this section: "Leadership for Public Understanding of Science" and "Science Communication and Public Engagement With Science."

In addition to the themes described above, the need to address local, state, and national science standards is prominent throughout the book.

Previous publications in this NSELA/NSTA series are *Issues in Science Education, Professional Development Planning and Design, Professional Development Leadership and the Diverse Learner, Science Teacher Retention: Mentoring and Renewal,* and *Science Teaching in the 21st Century*.

Science Education Leadership: Best Practices for the New Century captures the best thinking and best practices for science education leaders. Science educators can use it to vitalize their work. The book is directed at science teachers, science department chairs, principals, science supervisors, curriculum directors, superintendents, university personnel, policy makers, and any other individual who has a stake in science education. The final determinant of success in our effort to improve science education will be the degree to which we achieve high levels of scientific literacy for all citizens. The exercise of science education leadership is of the utmost importance if we are to achieve this goal.

Acknowledgments

Jack Rhoton

I wish to express my sincere appreciation to the individuals who made this publication possible. In particular I would like to thank the authors. In all cases, they addressed the theme, submitted manuscripts in a timely fashion and responded to reviewer recommendations. No volume is any better than the manuscripts that are contributed to it; we appreciate the time and effort of those whose work lies within the cover of this book.

I would also like to thank and acknowledge the support, help, and encouragement of my colleagues in the National Science Education Leadership Association (NSELA): Brenda Wojnowski, president; Linda Adkins, past president, for their suggestions and guidance in the early stages of the project, and executive director Susan Sprague in the later stages of the project. The support and advice offered by Pat Shane, NSTA President, is very much appreciated. I also thank and acknowledge some long-time professional colleagues: LaMoine Motz, Gerry Madrazo, Nicola Micozzi, Ken Roy, Emma Walton, and Fred Johnson, for the impact they have had on science education leadership at the K–12 level.

We are deeply appreciative of all the support and assistance provided through the outstanding staff at NSTA Press including David Beacom, Claire Reinburg, and Andy Cocke. And last but not least, I express my deepest appreciation to my graduate assistant, Amy Selman, who did a yeomen's job revising manuscripts and keeping track of hundreds of important details.

About the Editor

Jack Rhoton has devoted his entire career to teaching, writing and advocating for the support and advancement of science education at all levels, K–16. He began his career as a high school science teacher and subsequently served as a K–12 science supervisor for fourteen years. He joined East Tennessee State University as professor of science education in 1987 where he is currently serving as executive director of the ETSU Center of Excellence in Mathematics and Science Education. He has served as president of the National Science Education Leadership Association (NSELA), Tennessee Academy of Science (TAS), and the Tennessee Science Teachers Association (TSTA). Among his many publications are several NSTA edited books, including *Teaching Science in the 21st Century*. Rhoton earned a bachelors of science in biology from East Tennessee State University, masters in biology from Old Dominion University, masters in science education from the University of Virginia and a doctorate in science education from the University of Tennessee. He has received many honors, including the National Science Teachers Association Distinguished Service Award.

Chapter 17

Leadership for Public Understanding of Science

George E. DeBoer

There is no question that American society places a high value on science and science teaching. Science is well established in the American school curriculum and has been since the 19th century. Each state requires students to take science courses to graduate from high school and, under the current No Child Left Behind Act of 2001 (NCLB), students must be tested in science at the elementary, middle, and high school levels. Some states also make passing a comprehensive science test a requirement for high school graduation. Science is part of the curriculum because the society believes it is a way to attract future scientists, to provide early experiences in science to those who will become scientists, and to provide nonscientists with a familiarity with science.

Society also invests significant amounts of its resources in science education at the college and university level, not only to prepare future scientists but also to increase nonscientists' understanding of science. In addition, the mass media, science centers, natural history museums, zoos, botanical gardens, and other informal science institutions play a significant role in educating the public about science.

The results of these efforts to engage the general public in science have been mixed. When compared to the youth of other countries, American students do not fare very well (PISA 2007; Gonzales et al. 2008). But when adult science literacy is compared internationally, American adults appear to be more knowledgeable about science than the adults of just about any other country (Trefil 2008, pp. 85–86). Jon Miller, who has conducted surveys of adult science literacy for decades, attributes the comparative success of American adults in science to the fact that college students in the United States are typically required to take at least some science in college regardless of their major field of study, which is not true in most other countries (Trefil 2008, p. 86). Some also have attributed the greater science literacy of American adults to the vast network of informal science institutions in the country.

The focus of this chapter will be on the formal system of schools and the role they have played in the public's understanding of science. Science is generally considered to be one of the most important subjects in the school curriculum, even if it does not receive as much attention as math and reading–language arts, which have always formed the central core of the elementary school curriculum and, to a slightly lesser extent, the secondary school curriculum as well. For example, citing a survey conducted by Achieve, Inc., the Center for Public Education reports that at present most states require students to complete either two or three years of science to graduate from high school, and two states require four courses. In comparison, 40 states require high school students to take four years of English to graduate, and 13 states require high school students to take four years of math to graduate (2008).

Also, although science must be tested once in elementary, middle, and high school under current federal legislation, reading and mathematics are tested annually from grades three through eight, and the test results are used to determine if schools are making adequate yearly progress (AYP). Schools have only recently (since the 2007–08 school year) been required to test students in science, and science is not included in the determination of AYP status. Furthermore, the National Assessment of Educational Progress (NAEP) is given every two years in reading and mathematics, but only every four years in science, social studies, and other subjects. As part of NCLB legislation, schools must participate in the national assessment of reading and mathematics, but science testing is voluntary, as is testing in social studies and other subjects. Also, the Common Core State Standards Initiative, which was recently introduced by the National Governors Association and the Council of Chief State School Officers (CCSSO), aims to create high-quality and internationally benchmarked national standards that could be voluntarily adopted by states; however, the new initiative is moving forward in math and reading but not in science (CCSSO 2009). Finally, school resources, including money spent on specialists and remedial services, are often allocated disproportionately to math and reading programs.

Yet there are many who believe that because of its central importance to our society, science should have the same status as mathematics and reading in the school curriculum. A number of proposals have been introduced in the past two years that would do that. For example, on October 30, 2007, the National Science Board (the governing body of the National Science Foundation) released the National Action Plan for Addressing the Needs of the U.S. Science, Technology, Engineering, and Mathematics (STEM) Education System. The plan recommends (1) the creation of a nonfederal National Council to facilitate STEM programs and initiatives throughout the nation, (2) the coordination of STEM education among the states including defining national content guidelines that would outline essential knowledge and skills needed at each grade level, and (3) the development of measures to assess student performance that are aligned with the national content guidelines. In addition, the Standards to Provide Educational Achievement for Kids (SPEAK) Act (S. 224 and H. R. 2790) that was introduced by Rep. Vernon Ehlers (R-MI) and Sen. Chris Dodd (D-CT) on January 9, 2008 was reintroduced on June 10, 2009. This legislation would create voluntary national standards in math and science that would be aligned with postsecondary and workforce needs and would be comparable to the best standards in the world. The legislation would provide incentives for states to adopt these standards through competitive grants, and it would add science to the biennial National Assessment of Educational Progress to place it on par with reading and math.

Progress in developing high-level policies that give science the status in the curriculum that many believe it deserves has been slow to materialize. Although scientists and science educators recognize the importance of science in the school curriculum and have argued vigorously to elevate the status of science in the curriculum, it is not clear how strong that support is among the general public or the legislators who represent them. For example, in a survey that was conducted for AAAS Project 2061 by Global Strategy Group in 2001, 800 interviews were conducted with a nationally representative sample of parents of school-age children (students in grades 4 through 10), that asked them about their attitudes regarding the importance of science in society and in the school curriculum, as well as their attitudes about the quality of the science instruction their children were receiving. When asked to reflect on the importance of mathematics, reading, and science in their own lives, 45% chose math, 41% chose reading, and 5% chose science as the subject that they used the most in their everyday life. When asked what subject their children needed to do well in to succeed in their chosen line of work, 18% chose science, but when the question was phrased to determine the subject parents considered most valuable to their children without regard to the job they would have as adults, 59% chose reading, 28% chose math, 3% chose history, and 1% chose science (2001). A similar result regarding student and parent attitudes about the relative importance of reading, math, and science was reported by the Carnegie-Institute for Advanced Study Commission on Mathematics and Science Education (2009, p. 12).

Clearly there is work to be done to convince the public of the importance of science—not only its importance for those who wish to pursue careers in science but also for all future citizens. Leadership is required at multiple levels of the system. This chapter will focus on the distributed leadership that exists in a decentralized system such as the U.S. education system. In a decentralized authority system, it is the power of well-crafted arguments and the ability to have those arguments heard that is most important. Because we operate in a free market of ideas, the ideas that can convince a critical mass of policy makers to act and that are consistent with the values and attitudes of the public are the ones that have the most influence on practice. Because many of the policy initiatives that would improve the public's understanding of science through improved science instruction require the allocation of resources, policy makers need to be convinced not only of the worth of the project but also of its value relative to the vast array of other policy initiatives that compete for attention. In this chapter we take a historical approach to the examination of three questions about leadership for public understanding of science.

- What arguments have been made for what the public should know about science and why they should know it?
- What have been the implications of these arguments for public understanding of science in K–16 education?
- What leadership has been successful in accomplishing the goals of public understanding of science?

This chapter examines the arguments for science at various points in time, the implications of those arguments for K–16 education, and the various contributors whose arguments were most compelling given the conditions in society at the time. In the space available, it is impossible to go into any significant detail regarding the ways in which various leadership influences intersected and ultimately led to the establishment of policies and practices, so for each time period we will only touch on the key individuals, professional organizations, published reports, and legislative decisions that have influenced society's perspective on science as well as the impact that this has had on education. This discussion is intended to provide a sense of the complexity of science education policy development in the United States, the fundamental consistency of the set of arguments over time, and the influence of broad social conditions on the presentation of and response to those arguments. The importance of the public's understanding of science is a common theme in all of these debates, and this idea will sound similar from one era to the next. However, there are also features that vary according to the prevailing social attitudes and the values of the individuals and groups making the arguments. In addition, the expectation is that a historical perspective will temper and refine the arguments we make today in support of the public's understanding of science.

Mid- to Late 19th Century

In the mid- to late 19th century, practicing scientists and supporters of science took the lead in arguing for the importance of public knowledge about science and the scientific way of thinking. Their arguments focused on two main points: Science as a way of thinking was more suitable for life in a democracy than the more authoritative methods offered by the classics and mathematics because the methods of science allowed individuals to be their own observers of the natural world and to draw conclusions independently based on those observations and the power of their own reasoning. Science was also thought to be important for the practical knowledge it provided to citizens, especially for maintaining personal health. In his classic essay "What Knowledge Is of Most Worth?" Herbert Spencer (1864) said that knowledge of the functions of the human body and how to maintain health were essential for self-preservation, and that knowledge of the apparatus, materials, and scientific principles involved in modern manufacture were important skills for employment. He also argued that an understanding of science was important for appreciating as well as constructing art. Proportion, balance, and physical form were all physical concepts that were important in the arts. Science also supported the development of the intellect. "The constant habit of drawing conclusions from data, and then of verifying those conclusions by observation and experiment, can alone give the power of judgment correctly. And that it necessitates this habit is one of the immense advantages of science," Spencer claimed (p. 88). Finally, science was important for developing independence of thought, perseverance, sincerity, and a willingness to abandon any preconceived notion that proved to be incorrect. Spencer called these qualities "moral discipline."

In 1867, Edward Livingston Youmans, science writer and public lecturer, argued that the study of science could provide useful knowledge about practical things such as sanitation, hygiene, health, and disease, as well as strengthen the intellect by offering an effective way of thinking that included observation, experimentation, and reasoning (DeBoer 1991, p. 8). In 1899, Thomas Huxley explained that a study of biology could be helpful in avoiding infection and would be valuable for farmers to improve crop yields and avoid plant disease. Each of these scientists argued that science deserved a place in the curriculum alongside the classics and mathematics because of its importance for life in a democratic society.

By the end of the 19th century, science was slowly becoming a legitimate study in the school curriculum, not just as preparation for technical careers but also as part of a liberal education for all students. In 1893, the science conferences of the National Education Association's (NEA) Committee of Ten worked to place science on an equal footing with Greek, Latin, and mathematics in the school curriculum. Again, it was the scientific community that took the lead in arguing for the value of science. As did the scientists a few decades earlier, these scientists argued for the value of science in two ways: First, the study of science would develop one's intellectual skills, especially the ability to reason clearly from empirical evidence; and because empirical observation was the starting point for scientific reasoning, science should be studied in the laboratory or out in the field. Second, the study of science offered practical knowledge related to personal health, agriculture, and manufacturing (NEA 1894). Alexander Smith, a noted chemist at the University of Chicago, said that if science could be shown to provide useful information and to have disciplinary value, the subject would be "practically indispensable" (Smith and Hall 1902, p. 14).

In support of these arguments, the Committee of Ten suggested four recommended courses of study that could lead to high school graduation and college admission, all of which included significant numbers of science courses. Even the classical course of study included three years of high school science. Overall, across all four proposed plans, approximately one-fifth of a student's total time would be devoted to the study of science. It was recommended that all of the courses of study be considered acceptable for college entrance because they were thought to provide equivalent intellectual preparation for college. Following the report of the Committee of Ten, the NEA met in 1895 to discuss the Committee's recommendations. At that meeting, the NEA created a joint committee from higher education and secondary education to make recommendations for implementation of the Committee of Ten Report. This committee, the Committee on College Entrance Requirements, took a less positive view of the value of science. They recommended that only one course (out of a total of 16) should be required in science for high school graduation and college admission, whereas a total of six courses should be required in linguistic studies—four in languages and two in English literature. However, six of the 16 courses would be electives, giving students additional opportunities for taking science (NEA 1899). The scientists had a significant impact on educators' thinking about the role of science in society and, therefore, the place it should have in the curriculum; but in the end, the powerful NEA took a more conservative approach in its recommendations and let the study of the classics continue to dominate high school graduation and college entrance requirements, at least into the near future.

The Early 20th Century

During the second half of the 19th century, arguments in support of the importance of science in society focused primarily on the value of science for the individual's personal intellectual development and acquisition of practical knowledge. In contrast, by the early 1900s most arguments in defense of science (and other subjects as well) were made in terms of its usefulness in a 20th-century industrial society. As society became more complex and the numbers of people immigrating to the United States increased, social stability and social utility became paramount. Schools were seen as one of society's major socializing forces, and all parts of the curriculum became justified in terms of their practical value. Practical studies were also seen as a way to attract more students into the educational system. In 1900, only 10.2% of children ages 14 to 17 were enrolled in public and private secondary schools, and most of the students did not graduate (National Center for Education Statistics 1981). For schools to have an impact on society, greater numbers of students would have to attend.

In order to emphasize the practical and applied benefits of education, the NEA, which had established standards for high school graduation and college admission in 1896 based on the recommendations of the Committee of Ten, significantly liberalized those recommendations in 1911 by moving away from a focus on classical and linguistic studies and toward more applied and vocational studies. The committee recommended that up to four electives could be chosen from vocational offerings, that the current graduation requirement in foreign language be reduced from four units to two, and that foreign language could be avoided altogether if substituted by a course in science or social studies (NEA 1911).

The commitment to social relevance in all parts of the curriculum was embodied in the report of the NEA's Commission on the Reorganization of Secondary Education in 1918. The commission argued that education should be aimed toward a democratic life for all, with neither the individual nor the society being subordinated to the other. The role of education was to prepare the individual for life in society, and educational goals should be developed based on the activities of individuals in society. The commission identified seven major categories of educational goals, which came to be known as "cardinal principles" of education: (1) health, (2) command of fundamental process, (3) worthy home-membership, (4) vocation, (5) citizenship, (6) worthy use of leisure, and (7) ethical character (NEA 1918). As part of the NEA's reorganization effort, its Committee on Science justified the presence of science in the curriculum on the basis of six of the cardinal principles. Only "command of fundamental processes"—that is, reading, writing, and calculating—was left out, because it was dealt with in other parts of the curriculum.

The committee said that science is valuable for maintaining "good health" because knowledge of pubic sanitation and personal hygiene can protect people from illness and help to control disease. Science contributed to "worthy home-membership" by teaching students about the functioning of electrical appliances, how to repair heating and ventilating systems, and the operation of other conveniences found in the home. With respect to "vocations," the committee said: "In the field of vocational preparation, courses in shop physics, applied electricity, physics of the home, industrial and household chemistry, applied biological sciences, physiology, and hygiene will be of value to many students if properly adapted to their needs" (NEA 1920, p. 13). Regarding the goal of "citizenship," science courses could give the citizen the ability to select experts wisely for specialized positions in society. Science could contribute to the enhancement of one's "leisure" through such avocations as photography by making the optical and chemical principles used in photography clear to students. And science study could contribute to the development of "ethical character" "by establishing a more adequate conception of truth and a confidence in the laws of cause and effect" (NEA 1920, p. 14).

The schools took these recommendations to heart and instituted programs to appeal to the practical interests of students. New programs provided students with knowledge that would be of use to them in their everyday lives, especially knowledge related to health, industrial manufacturing, and applications of technology in everyday settings, such as understanding how household appliances worked.

In addition to the very significant leadership of the NEA in these matters, the Association for the Advancement of Progressive Education, which was founded in 1919, and later renamed the Progressive Education Association (PEA), also provided leadership in the development of practical and applied studies aimed at the improvement of society. The association was inspired by the writings of John Dewey, an advocate for progressive principles in education and of the importance of science in society. In

Democracy and Education, Dewey, describing the importance of science for social progress, said:

> Man's life is bound up in the processes of nature; his career, for success or defeat, depends upon the way in which nature enters it. Man's power of deliberate control of his own affairs depends upon ability to direct natural energies to use: an ability which is in turn dependent upon insight into nature's processes (1916, p. 228).

But not everyone was enamored of applied science and a curriculum focused on the immediate practical needs of students. John M. Coulter, a science professor at the University of Chicago who had served as a member of the Conference on Natural History of the Committee of Ten, disagreed that science teaching should focus only on what was within the experience of the students: "That our science teaching should consist only in explaining to a student what he encounters in his own experience, is to limit his life, rather than to enrich it by extending his horizon" (1915, p. 99). Robert Bradbury, head of the Department of Science in the Southern High School in Philadelphia, speaking of the new practical approach to teaching chemistry, said, "We should firmly grasp the fact that in changing from chemistry to technology, we are deserting knowledge of proved permanent worth to deal in information whose chief characteristic is the evanescence of its value. The technology we teach now will merely mislead our students ten years hence" (1915, pp. 785–786).

One solution to the controversy over traditional versus applied science in discipline-based courses such as biology, chemistry, and physics was to place the more applied topics in the newly created general science course, a course primarily intended for junior high school students but sometimes taught at the high school level as well. This course would introduce them to the various areas of science, the experimental method, and the applications of science in society. The Thirty-First Yearbook Committee of the National Society for the Study of Education (NSSE) said that topics for that course should be chosen from "aspects of the environment which, from the point of view of science, are most significant in the everyday life of individuals and of society" (1932, p. 203). Topics would include "food, water, air, clothing materials, materials of construction, fuels, plant life, animal life, heat, light, electricity, sound, machines, the weather, the climate, the sky, the crust of the earth, and the soil" (p. 198). In addition, this course would teach students about the methods of science. According to the NSSE Yearbook Committee, "Science is essentially an experimental study of materials and phenomena and requires, therefore, learning activities that are designed to solve problems relating to concrete and objective instructional materials, whether in pure science or in its applied aspects" (p. 213).

Throughout the first half of the 20th century, progressive educators continued to argue for the value of applied science, but resistance to those ideas also continued, so that support for the approach was widespread but not universal. In 1940, for example, there were still many educators and scientists who believed that there was value in disciplinary science and in a traditional approach to science teaching. Thomas Smyth provided some insight into the nature of the debate as he reiterated the principles of applied, socially relevant science in a critique of a biology curriculum endorsed by the National Association for Research in Science Teaching. He asked:

> How important is it for high school students to go into details concerning the nature and properties of protoplasm, or how worthwhile is it to delve into cytology and know the morphology and physiology of the parts of a cell? Why burden the high school group with the intricacies of mitosis? Is there nothing more worth bringing to this group? If we are teaching for the enrichment of human life the time is here now when we must pack our high school science courses with life values and not fill them with a lot of stuff that few will ever use or even think of again the rest of their days (1940, pp. 258–259).

Leadership for teaching applied science and practical studies throughout the first half of the 20th century rested with the National Education Association, the Progressive Education Association, the National Society for the Study of Education (which was sympathetic to progressive ideals and whose Thirty-First and Forty-Sixth Yearbook Committees summarized the principles of progressive education and its applications to schooling) (NSSE 1932, 1947), and the many individuals associated with the progressive movement in education, especially John Dewey. The arguments focused on the practical value of science for the improvement of society and the individual as part of that society. Scientists were less of a presence in these arguments than they had been in the 19th century and in the years leading up to the turn of the century. The net effect of the efforts to increase the public's understanding of science through the applications of science was that, by the late 1940s, most students learned about science through the general science course and one other disciplinary course, usually biology (DeBoer 1991).

The 1950s and 1960s

By the late 1940s, arguments in favor of science knowledge began to head in a somewhat different direction. The social utility of science was still widely acknowledged, but it took on a new character following the experience of World War II. The loss of science students and faculty during the war produced several years when few scientists were being trained. Following the war, reducing this deficit in science personnel became a high-level national priority and led to efforts to quickly prepare scientists and technical personnel. This was of such concern for national security that all discussions about the importance of public understanding of science or science being included in the school curriculum must be viewed in the context of this immediate and pressing need. In 1944, President Roosevelt asked Vannevar Bush, Director of the Office of Scientific Research and Development, to report on a variety of issues, including the question, "Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured?" (Bush 1945, p. 4). In his report, *Science: The Endless Frontier*, Bush recommended that "the Government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. These responsibilities are the proper concern of the Government, for they vitally affect our health, our jobs, and our national security" (1945, p. 8). This call for federal involvement and support for science and scientific training represented a turning point in the ways that society, through its governing bodies, would guide the development and dissemination of scientific knowledge. To a greater and greater extent, leadership in science education would come from the federal government.

Bush recommended the establishment of a national research foundation, which led to the creation in 1950 of the National Science Foundation, a unified agency for the funding and coordination of basic scientific research and the support of education through the dispersal of grants and scholarships to students. Bush had received a doctorate in engineering from MIT and held many influential science policy positions, especially during the war years, including Director of the National Defense Research Committee and Director of the Office of Scientific Research and Development, which controlled the Manhattan Project. He was also president of the Carnegie Institution of Washington, and in that position he was able to influence the direction of scientific research through the dispersal of research funds.

Then in 1946, to address the crisis of personnel shortages, President Truman created the President's Scientific Research Board. The Board began its report by saying:

> The security and prosperity of the United States depend today, as never before, upon the rapid extension of scientific knowledge. So important, in fact, has this extension become to our country that it may reasonably be said to be a major factor in national survival. (President's Scientific Research Board, vol. 1, 1947, p. 3)

The Research Board said that science was important for military and economic reasons, and because other countries were investing heavily in science, it was critical that the United States did so too. The Board asked AAAS to study the effectiveness of science education to meet these purposes at all levels of the educational system. In its findings, which were included in the report of the President's Scientific Research Board, the AAAS Cooperative Committee on the Teaching of Science and Mathematics emphasized the dual role of science education:

> While it is the primary object of this report to deal with the production of professional scientists, account must be taken of the degree of comprehension of science by the general population. For in a democracy it is upon the popular attitude toward science that the attractiveness of the profession, the resulting selectivity for those finally entering the profession, and the degree of support obtainable for their work will depend. (President's Scientific Research Board, vol. 4, 1947, p. 113)

This idea that the public should learn about science so that they would develop a positive attitude toward science went hand-in-hand with the argument that a robust scientific enterprise was needed for national security.

The importance of science as a part of general education was also taken seriously by a number of colleges. In 1945, the Harvard Committee on General Education published *General Education in a Free Society*, in which they argued the importance of science for the nonscientist as part of a general or liberal education.

At the same time that national leaders and the scientific community were becoming convinced of the national security importance of science and the importance of a public that was knowledgeable about and sympathetic to science, the practical education being offered in schools during the previous half century had become what was now being referred to as "life adjustment education." In 1947, the U.S. Commissioner of Education appointed a National Commission on Life Adjustment Education for Youth and a second national commission in 1950 to promote this concept (U.S. Office of Education 1951). The life adjustment programs that were being developed had a decidedly nonacademic focus, emphasizing instead the real-life needs of students such as their health and well-being, knowing how to drive and care for an automobile, and managing personal finances wisely (Sanford 1950). In the minds of many, the content of science had been almost completely removed from the curriculum. Although his comments were not aimed at science specifically, Mortimer Smith, a writer and advocate for academic excellence in elementary and secondary schools and later co-founder of the Council for Basic Education in Washington, said that social skills should not take the place of intellectual training. In his book *The Diminished Mind*, he said that although practical usefulness in the curriculum was legitimate, "a school program which teaches little beyond how to fix a fuse, drive a car, set the dinner table, and enhance your personal appearance, isn't useful enough if your aim is the development of maturity and intelligent citizenship" (1954, p. 3). To Smith, the primary mission of the school was the development of intelligence, a mission he believed the schools had abandoned.

National security–based arguments for the importance of science that were stimulated by personnel shortages following the war, and arguments for more rigorous intellectual training, brought on by the perceived excesses of progressive education, came to a head when the Soviet Union launched its Earth-orbiting satellite, *Sputnik,* in 1957. In response, a major effort to improve science education was launched by the federal government as a way to enhance the scientific capabilities of the nation. Based on recommendations of the scientific community, the United States embarked on an unprecedented program of science education reform. To accomplish these national security goals, the National Science Foundation, with significantly increased congressional funding, sponsored projects that brought an approach to science teaching that focused on the logical content structure of the discipline and the nature of scientific thinking. In addition, the National Defense Education Act of 1958 was designed to provide the country with specific defense-oriented personnel. It also provided financial assistance, through the National Defense Student Loan program, for thousands of students to enroll in colleges and universities in the 1960s.

In speaking of the importance of science in terms of national security, Joseph Schwab (1962), a key advocate for reformed science education in the United States, said:

> A hundred fifty years ago, science was an ornament of a leisurely society. It was still mainly pursued by amateurs and gentlemen. It was a gratuitous activity of the enquiring intellect, an end pursued for its own sake.… It is so no longer. Industrial democracy has made science the foundation of national power and productivity. Science now plays the part once played by exploration, by empire, and by colonial exploitation (p. 18).

Schwab described the need for science teaching to keep pace with scientific development as "urgent" and "compelling." The nation needed an increased supply of scientific and technical personnel, competent political leaders who could develop policy agendas based on the sometimes conflicting claims of scientists, and a public willing to support scientific research and discovery that was long-term and ongoing and to support science even when it did not yield obvious practical outcomes.

Some thought that the way to increase the supply of scientific and technical personnel was to improve the education of the most talented students. Proposals included the creation of separate schools for the gifted, honors classes, use of a two-track system so the most talented could advance more rapidly, and the use of gifted students as assistants in class (DeBoer 1991, p. 137). In 1955, Paul Brandwein published *The Gifted Student as Future Scientist*, in which he discussed the characteristics of gifted students, ways of identifying them, and proposals for increasing the number of gifted students taking science courses.

In the postwar and *Sputnik* years, the arguments for the importance of science in society had been transformed from ones that for half a century had emphasized its everyday personal and societal usefulness into arguments that emphasized the military and economic security of the country. Along with that change, the approach recommended for teaching science changed from one in which the technological applications of science were taught to one in which a rigorous and highly conceptual structure of the disciplines were to be taught. Leadership for the reform efforts came largely from the scientific community, supported by the federal government through the National Science Foundation. Scientists valued the disciplined thinking that science provided and the general applicability of the core concepts of the disciplines to a range of scientific and practical problems in society. The new curriculum materials offered scientific validity to course content, engaged students in independent scientific investigations that were characteristic of the way science was actually done, and attempted to present a realistic picture of the nature of the scientific enterprise.

But as effective as the arguments of scientists were in convincing high-level policy makers that students should be introduced to science that was intellectually rigorous, the new instructional approaches and curriculum materials generally ignored the technical applications of science, were unconnected to students' interests or to the concerns of everyday living (Hurd 1970), and often proved too difficult for many students. Because of the mismatch between curricular expectations and students' interests and capabilities, and because of a shift in the issues that the country as a whole saw as important, more changes would follow in the years ahead.

The New Social Relevance of the 1970s

By the late 1960s and early 1970s, the arguments for the value of science in society had again shifted, this time to a tone more reminiscent of the first half of the 20th century than of the previous 30 years. The term "scientific literacy" was used to describe what adults needed to know for effective citizenship and what they needed to know to create a more humane society (DeBoer 2000). Educators, concerned that the reforms of the 1960s had gone too far in moving science teaching away from practical interests of students and the technological applications they encountered in daily life, argued that social relevance justified and should guide the teaching of science. Science literacy included science content knowledge, knowledge of the methods of science, and awareness of the relationship between science and society. Some defined science literacy as the knowledge and skills that enabled one to engage in the scientific issues of the day (in other words, the ability to read and understand the science being discussed in the popular media; Koelsche 1965).

The theme of science literacy was identified by the National Science Teachers Association (NSTA) at its annual meeting in 1971 as the most important goal for science education for the 1970s. In its statement on scientific literacy, NSTA said: "The major goal of science education is to develop scientifically literate and personally concerned individuals with a high competence for rational thought and action" (1971, p. 47). The scientifically literate person is one who "uses science concepts, process skills, and values in making everyday decisions as he interacts with other people and with his environment" and "understands the interrelationships between science, technology and other facets of society, including social and economic development" (pp. 47–48).

In 1982, the NSTA board of directors adopted a similar position statement entitled Science-Technology-Society: Science Education for the 1980s. In that statement, they said:

> Many of the problems we face today can be solved only by persons educated in the ideas and processes of science and technology. A scientific literacy is basic for living, working, and decision making in the 1980s and beyond.... The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. (NSTA 1982)

Science was again seen as having utility for citizens—useful for helping people make decisions on issues having a scientific basis and for improving the quality of their own lives and the lives of their fellow citizens.

Leadership for this "new-progressivism" (Ravitch 1983) came mainly from professional educators—including classroom teachers, professors of science education, and professional organizations such as the NSTA, but less so from practicing scientists.

The 1980s: *A Nation at Risk* and the Beginning of the Standards Movement

During 1981 and 1982, the United States experienced its most severe recession since the Great Depression. The recession followed nearly a decade of high unemployment and high inflation rates. In this difficult economic environment, and at a time when American students' test scores in science and mathematics were low and declining, President Reagan established the National Commission on Excellence in Education (NCEE) on August 26, 1981. The report of the Commission, *A Nation at Risk*, was released on April 26, 1983, and called for the federal government, along with states and local school districts, to raise the level of competence of American students in all academic areas, with special emphasis on science and mathematics. Science and mathematics, rigorously taught, were seen as the route to new economic prosperity.

A Nation at Risk

The NCEE concluded that the nation had lost sight of its true educational mission and of the need for high expectations for students. It recommended a return to a more academic educational focus and more disciplined effort on the part of students. The NCEE also claimed that international competitors were well educated and highly motivated and that the United States needed to be as well if the nation was to compete successfully. The new raw materials of international commerce were knowledge, learning, information, and skilled intelligence. The NCEE pointed to the value of an education where comprehension, analysis, and problem solving were fostered, instead of rudimentary knowledge or technical and occupational skills. In high school, all students would learn the "New Basics," including English, mathematics, science, social studies, computer science, and, for the college-bound students, two years of foreign language.

A Nation at Risk recommended that schools, colleges, and universities 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). The report also 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. Although these recommendations were broad, and included science content and the applications of science as well as the scientific way of thinking, what was most distinctive was the emphasis on academic rigor. The NCEE believed that higher standards and expectations were needed to raise the scientific competence of students and to give them a deep respect for intelligence, achievement, learning, and self-disciplined effort.

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. They said that the educational system had undergone a period of neglect, resulting in unacceptably low performance levels in science and mathematics, that U.S. national security and economic health depended on its human resource development, and that 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, local responsibility for meeting these goals, local variation in how the goals would be implemented, and strong national leadership for monitoring the quality of local efforts. The commission recommended increased student exposure to science, higher standards of participation and achievement (citing comparisons to Japan's system where students spent more time in school), and a system of objective measurement to monitor progress.

Educating Americans for the 21st Century provided more detail in its recommendations regarding the content of the science, mathematics, and technology curriculum than was in *A Nation at Risk*. The commission 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 in school, and they should be given opportunities to 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. For example, at the high school level it was 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).

As had been true at previous times when the focus shifted away from the applications of science and toward the traditional content of science, there was concern that by emphasizing academic rigor, the commission's recommendations would be seen as advocating intellectual elitism intended only for those students who would pursue careers in science, mathematics, and technology. 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).

A Nation at Risk and *Educating Americans for the 21st Century* aptly summarized 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 can help build a knowledgeable and competent citizenry well-prepared for life in a free democratic 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.

In response to the call for added rigor in the educational system, many of the state legislatures and state departments of education during this time implemented policy initiatives that were structural in nature but often did not pay attention to the broader goals of educational reform. As Paul 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 various calls 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. The work of Project 2061 began with the publication of *Science for All Americans* (AAAS 1990) and has continued to this day with the development of tools and resources to bring the vision of science for all into full realization. The creation of Project 2061 was led by F. James Rutherford, Executive Director of the Education Division at AAAS. Rutherford was a science educator who had worked with Gerald Holton and Fletcher Watson on the development of Harvard Project Physics (Holton 2003), and had served in the administration of President Carter as head of the National Science Foundation's Science, Mathematics, and Engineering education programs and as Assistant Secretary for Research and Improvement in the U.S. Department of Education.

The 1990 publication of *Science for All Americans* (AAAS) was a bold statement of what Americans should know in science to participate fully in a democratic society. That core knowledge included concepts and skills in science, mathematics, technology, and the social sciences. It also included knowledge of the nature of science, the nature of mathematics, and the nature of the designed world. Furthermore, it included an understanding of historical perspectives; common themes dealing with systems, models, constancy and change; and issues of scale.

The language of *Science for All Americans* stressed 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)

Science for All Americans suggested that schools should focus on the essentials of science literacy—a common core of ideas and skills that have the greatest scientific, educational, and personal significance. Consistent with statements made earlier in the decade, the recommendations for science content 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 (AAAS 1990, pp. xix, xx).

There were also recommendations regarding pedagogy. *Science for All Americans* suggested that: "Young people learn most readily about things that are tangible and directly accessible to their senses—visual, auditory, tactile, and kinesthetic" (p. 199). Other pedagogical approaches that would support conceptual understanding included 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.

According to *Science for All Americans*, to appreciate the special modes of thought of science, mathematics, and technology, students should experience the kinds 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" (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 (pp. 201, 203).

Science for All Americans recognized that to be consistent with the nature of science, science teaching should encourage students to raise questions about the ideas 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 scientific investigations are 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.

Benchmarks for Science Literacy

In 1993, the vision of science literacy laid out in *Science for All Americans* was translated into *Benchmarks for Science Literacy*, a statement of knowledge and skills that students should gain by the end of each of four grade bands (K–2, 3–5, 6–8, and 9–12) in order to achieve the goal of science literacy by the end of high school.

The call for higher standards in *A Nation at Risk*, the efforts of the Commission on Precollege Education in Mathematics, Science, and Engineering to begin to define the science content that all students should know, and the publication of *Science for All Americans*—the most comprehensive statement yet written describing what science literacy entails—were the first steps in a new approach to science education.

First, the vision for science education described in both *A Nation at Risk* and in *Science for All Americans* was broadly humanistic and inclusive. Although they recognized the importance of scientific knowledge for the nation's economic development and for individual occupation, those documents also acknowledged the personal intellectual value of science. For example, *A Nation at Risk* pointed to the importance of a high-level of common understanding in a free and diverse democratic society. The concern was not only 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. Similarly, *Science for All Americans* asserted that science education "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" (p. xiii). Both documents also recognized the value of science for all, not just for an elite few, and that science education should include knowledge about how science is done as well as scientific knowledge.

Second, the idea of organizing curriculum, instruction, and assessment around clear and precise content standards (or learning goals), whether national in scope or defined by the state or school district, took hold in the subsequent years. Content standards were used to describe important goals of quality science instruction, and they were also used for accountability purposes through progressively more restrictive federal legislation that held states responsible for defining and measuring student performance with respect to specific science content standards.

Public Accountability

With respect to the specification of content standards called for in *A Nation at Risk*, following the publication of *Benchmarks for Science Literacy* in 1993, the National Research Council published the *National Science Education Standards* in 1996. Those two documents, which shared a high degree of content agreement between them (AAAS, 1997), were then used by virtually every state in the preparation of their own content standards.

The federal government was clearly on the path toward a system of standards and accountability when President George H. W. Bush met with state governors in September 1989 in Charlottesville, Virginia, to discuss a national agenda for education. Although the increasing role of the federal government in science education is traceable to the national security concerns of the post-war years, the launching of *Sputnik* in 1956, and the funding of science education through the National Science Foundation, the Charlottesville summit on education led to policies that vastly increased the federal government's role in science education. Whereas individual scientists, professional scientific societies such as AAAS, and teachers' organizations such as the NEA and NSTA had been the major influences on policy up to that point, this summit marked a significant shift in leadership for science education. At the summit, the president and the governors agreed to establish clear national performance goals and strategies to ensure U.S. international competitiveness. They also agreed that there should be annual reporting on progress toward meeting those goals. Then, on April 18, 1991, the president released *AMERICA 2000: An Education Strategy* (U.S. Department of Education 1991) which described a plan for moving the nation toward national goals. Six goals were identified that would be accomplished by the year 2000, one of which was to "make U.S. students first in the world in math and science achievement" (p. 4).

The strategy for accomplishing the national goals was to include an accountability package that would encourage schools and communities to measure and compare results and insist on improvement when the results weren't good enough. The package included national standards, national tests, reporting mechanisms, and various incentives. Content standards in each of five core subject areas and tests to measure achievement of that content would be developed in conjunction with the 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). The tests would be national but voluntary and tied to the national standards. The president's proposals called for Congress to authorize the National Assessment of Educational Progress—which had been established by Congress in 1969 to provide national data on educational outcomes—"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). This move toward state-level, and sometimes district-level, reporting represented a significant increase in accountability.

Although the specific proposals in President Bush's *America 2000* report were not enacted into law during his presidency, many of them became law when President Clinton signed the *Goals 2000: Educate America Act* on March 31, 1994. The act focused on educating workers for productive employment, with special reference to competition in international trade. Again, the government's primary interest in education was the development of human capital so the United States could remain economically competitive internationally (Spring 2001). 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, n.d.). Also in 1994, President Clinton signed the *Improving America's Schools Act* (IASA), which reauthorized the *Elementary and Secondary Education Act* of 1965 (ESEA), first enacted as part of President Johnson's War on Poverty and intended to improve education for disadvantaged children in poor areas. Under the education act, states had to

- develop challenging mathematics and language arts content standards that clearly define the knowledge and skills expected of students;
- develop performance standards representing three levels of proficiency for each of those content standards—partially proficient, proficient, and advanced;
- develop and implement assessments aligned with the content and performance standards in mathematics and language arts at three grade spans: 3–5, 6–9, and 10–12;
- 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
- use performance standards to establish a benchmark for improvement referred to as "adequate yearly progress" (AYP).

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 assessment, begun in the early 1980s, was strengthened with the 1994 legislation. The legislation also provided the basis for the *No Child Left Behind Act* of 2001 (NCLB) as it moved the focus away from national standards combined with voluntary national testing to a state-by-state system of standard setting and accountability. In addition, as would be true under NCLB, the *Improving America's Schools Act* required states to test students in math and language arts but not in science. The pullback from national-level standards and toward state-level accountability was due to a continuing concern among many national policy makers about the nationalization of education, a concern that had been present from the earliest days of the country.

Leadership during the 1980s and '90s came from many places. Most notably, the federal government took a more and more active role through agency-sponsored reports such as the NCEE's *A Nation at Risk*, presidential goal statements such as *Goals 2000*, and enacted legislation such as the *Improving America's Schools Act*. In addition, professional scientific societies such as AAAS played a significant role in defining both the goals of a quality science education for all as well as the pedagogical approaches that could be used to accomplish those goals. But, although both AAAS and the National Research Council had written statements about the importance of science in the society, in the end, federal legislation focused on the teaching of reading and mathematics, but not on science.

Leadership for 21st-Century Science Education

This historical overview of arguments for the importance of scientific knowledge in our society and in our schools reveals how advocacy leadership came from many different places and in many different forms. Arguments by individual scientists such as James B. Conant and Vannevar Bush, influential books and essays such as Herbert Spencer's What Knowledge Is of Most Worth (1864) or Mortimer Smith's *The Diminished Mind* (1954), and national level reports such as the Report of the Committee of Ten in 1893 or the Report of the National Commission on Excellence in Education (*A Nation at Risk*) in 1983 all had a significant impact on the direction that science education took. But these arguments did not stand alone. They have to be viewed in light of the dominant social forces operating at the time. The events of the day often determined whether the justification for science was based on its importance for personal intellectual development, for building a civil society, ensuring national security, or improving economic competitiveness. We also see trend lines in the various influences affecting which arguments were made and which ones were listened to. For example, during the 19th century and early 20th century, the federal government played a relatively limited role in defining the knowledge considered to be of most importance to society or in establishing education policy. That role was greatly increased in the years following World War II as the federal government saw education in science much more strategically linked to national security and, following the economic troubles of the 1970s and early 1980s, much more linked to economic security. It should also be clear from this review that leadership is a complex phenomenon that involves the intersection of individuals, professional organizations, and government agencies among others.

Is it possible to describe where we are today in terms of the perceived value of science in our society and the nature of the leadership needed to affect K–12 science education to achieve our goals? Are opinions again coalescing around a particular idea or set of ideas? Are we headed in a new direction in science education? Who is providing leadership? Let us look briefly at what is being said about the importance of science today, the people making various arguments, and the implications of the proposals for K–16 education.

On June 10, 2009, Rep. Vernon Ehlers (R-MI) and Sen. Christopher Dodd (D-CT) introduced S. 224 and H.R. 2790, the Standards to Provide Educational Achievement for Kids (SPEAK) Act. Under the SPEAK Act, the National Assessment Governing Board would create or adopt rigorous content standards in math and science for grades K–12 that would be anchored to the math and science frameworks and achievement levels of the National Assessment of Educational Progress and voluntarily chosen by the states. The act also authorizes establishment of a fund to provide financial incentive to states willing to adopt the higher standards. In the legislation, it is argued that the reason common standards are needed is to ensure that all American students are given the same opportunity to learn no matter where they reside and how often they move from one state to another, instead of the current system of 50 individual states creating 50 different standards of varying quality and as many different variations in the sequencing of content. The key argument is that a lack of common standards has led to wide variation in the levels of knowledge, skills, and preparedness among America's student-aged population. The legislation also argues that science is important to prepare students for jobs in a global economy and to ensure the economic competitiveness of the country.

After a period of pulling back from national standards, this legislation, if adopted, would reestablish their role. The legislation is consistent with the Common Core State Standards Initiative recently introduced by the

National Governors Association (NGA) and the Council of Chief State School Officers (CCSSO) to create high-quality and internationally benchmarked national standards in math and reading that would be voluntarily chosen by the states (CCSSO 2009).

Another major effort to raise the profile of science education was undertaken by the Carnegie Corporation of New York and the Institute for Advanced Study of Princeton, NJ. Their joint Commission on Mathematics and Science Education issued its report, *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy*, on June 10, 2009. In the executive summary of the report, the commission says:

> The nation's capacity to innovate for economic growth and the ability of American workers to thrive in the global economy depend on a broad foundation of math and science learning, as do our hopes for preserving a vibrant democracy and the promise of social mobility for young people that lie at the heart of the American dream. Our nation needs an educated young citizenry with the capacity to contribute to and gain from the country's future productivity, understand policy choices, and participate in building a sustainable future. Knowledge and skills from science, technology, engineering, and mathematics—the so-called STEM fields—are crucial to virtually every endeavor of individual and community life. All young Americans should be educated to be "STEM-capable," no matter where they live, what educational path they pursue, or in which field they choose to work. (Carnegie Corporation of New York 2009, p. vii)

A key observation made by Commission members is that many students and their parents do not think that it is important to do well in math or science unless the student intends to pursue a career directly related to them. According to Phillip A. Griffiths, cochair of the commission, "It is imperative that we impress upon all young people that knowledge of math and science is crucial to many more careers than they may realize. All young Americans should have a sufficient grounding in science, technology, engineering, and mathematics no matter where they live, what educational path they pursue, or in which field they choose to work" (Carnegie Corporation of New York 2009).

Clearly, there is a renewed emphasis within the scientific and science education community on common national standards in science. This is consistent with the push for common standards in math and reading within the National Governors Association. The arguments for science today primarily have to do with the role of science in keeping us competitive internationally in a global economy. The argument is that most jobs in the 21st-century workforce will require knowledge of science, mathematics, and technology.

The leadership for these initiatives has come from many different places. For one, there are members of Congress who are particularly aware of the role that science plays in society. For example, Rep. Vernon Ehlers (R-MI) and Sen. Mark Udall (D-CO) launched the bipartisan Science, Technology, Engineering and Mathematics (STEM) Education Caucus for members of Congress; dozens of members have joined the caucus. On their website (*www.stemedcaucus.org*) are listed three kinds of intellectual capital that STEM Education is responsible for providing our country:

- Scientists and engineers who will continue the research and development that is central to the economic growth of our country,
- Technologically proficient workers who are capable of dealing with the demands of a science-based, high-technology workforce, and
- Scientifically literate voters and citizens who make intelligent decisions about public policy and who understand the world around them.

As already noted, the Carnegie Corporation of New York and the Institute for Advanced Study has taken a leadership role in establishing the joint Commission on Mathematics and Science Education. In addition, the National Governors Association, in their alliance with the Council of Chief State School Officers, has shown significant leadership in bringing the idea of internationally benchmarked common standards in math and reading to the public attention, and may do so in science as well. The Secretary of Education, Arne Duncan, has supported the idea of common standards that is being proposed by the National Governors Association and has pledged the backing of the U.S. Department of Education, including support from the $4.35 billion Race to the Top Fund. With respect to common standards in science, professional societies such as AAAS have publicly argued the long-term economic and workforce advantages of providing all students across the country with access to a high-quality education in science, which begins with high-quality standards (Leshner

2007; Leshner and Roseman 2009). President Obama also has publicly supported the idea of improved standards in science education.

From this, it appears that support is coalescing around the idea of voluntary, common, internationally benchmarked standards in math and reading, and concerted efforts are being made to include science as well. There is also widespread support for the idea that science is important for economic competitiveness and for a scientifically literate public that can engage in discussions about science and make wise decisions regarding science issues. Time will tell whether the support that has been pledged by the current administration will be realized so that American students will be well-prepared for life in the twenty-first century.

But history should teach us that the debate will be ongoing, that education will forever be on the minds of American citizens and their leaders, and that leadership in science education needs to be continuously exercised by individual scientists, science educators, professional organizations, as well as by members of the administration and Congress. Leadership in our democratic society is truly a distributed activity.

References

American Association for the Advancement of Science (AAAS). 1990. *Science for all Americans*. New York: Oxford University Press.

——. 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

——. 1997. *Resources for science literacy: Professional development*. New York: Oxford University Press.

Bradbury, R. 1915. Recent tendencies in high school chemistry. *School Science and Mathematics* 15: 782–793.

Brandwein, P. 1955. *The gifted student as future scientist*. New York: Harcourt, Brace.

Bush, V. 1945. *Science: The endless frontier. A Report to the President, July 1945* (1960 reprint). Washington, DC: National Science Foundation.

Carnegie Corporation of New York-Institute for Advanced Study Commission on Mathematics and Science Education. 2009. *The opportunity equation: Transforming mathematics and science education for citizenship. www.opportunityequation.org*

Center for Public Education. 2008. *Student graduation and beyond: What* *courses do our students need to complete in order to graduate from high school? www.centerforpubliceducation.org/site/apps/nlnet/content3.aspx?c=lvIXIiN0JwE&b=5079529&content_id={C30C1763-A684-44B2-932C-AAC097ADD4DC}&notoc=1*

Coulter, J. 1915. The mission of science in education. *School Science and Mathematics* 15: 93–100.

Council of Chief State School Officers (CCSSO). 2009. Forty-nine states and territories join common core state standards initiative. *www.ccsso.org/whats_new/press_releases/13359.cfm*

DeBoer, G. 1991. *A history of ideas in science education: Implications for practice*. New York: Columbia University Teachers College Press.

——. 2000. Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching* 37 (6): 582–601.

Dewey, J. 1916. *Democracy and education*. New York: Macmillan.

Elementary and Secondary Education Act of 1965, 20 U.S.C. § 6301 *et. seq.* 1965.

Global Strategy Group, Inc. 2001. A public awareness initiative to build support for science literacy. *www.project2061.org/publications/articles/psl/presentation.pdf*

Goals 2000: Educate America Act, 20 U.S.C. § 5801 *et. seq.* 1994.

Gonzales, P., T. Williams, L. Jocelyn, S. Roey, D. Kastberg, and S. Brenwald. 2008. *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth- and eighth-grade students in an international context*. Washington, DC: National Center for Education Statistics, U.S. Department of Education.

Harvard Committee on General Education. 1945. *General education in a free society*. Cambridge, MA: Harvard University Press.

Holton, G. 2003. The project physics course, then and now. *Science and Education* 12: 779–786.

Hurd, P. 1970. *New directions in teaching secondary school science*. Chicago: Rand McNally.

——. 1989. Science education and the nation's economy. In *Scientific literacy*, eds. A. Champagne, B. Lovitts, and B. Calinger, 15–40. Washington, DC: AAAS.

Huxley, T. 1899. *Science and education*. New York: Appleton.

Improving America's Schools Act of 1994, 20 U.S.C. § 8001 *et. seq.* 1994.

Koelsche, C. 1965. Scientific literacy as related to the media of mass communication. *School Science and Mathematics* 65: 719–724.

National Center for Education Statistics 1981. *Digest of education statistics*. Washington, DC: U.S. Government Printing Office.

National Commission on Excellence in Education (NCEE). 1983. *A nation at risk: The imperative for educational reform*. Washington, DC: U.S. Department of Education.

National Conference of State Legislatures. n.d. *No child left behind: History*. *www.ncsl.org/programs/educ/NCLBHistory.htm*

National Defense Education Act of 1958, 1 U.S.C. § 101, 72 Stat. 1581. 1958.

National Education Association. 1894. *Report of the committee on secondary school studies*. Washington, DC: U.S. Government Printing Office.

———. 1899. Report of the committee on college-entrance requirements. *Journal of Proceedings and Addresses of the Thirty-Eighth Annual Meeting.*

———. 1911. Report of the committee of nine on the articulation of high school and college. *Journal of Proceedings and Addresses of the Forty-Ninth Annual Meeting.*

———. 1918. *Cardinal principles of secondary education: A report of the commission on the reorganization of secondary education* (U.S. Bureau of Education, Bulletin No. 35). Washington, DC: U.S. Government Printing Office.

———. 1920. *Reorganization of science in secondary schools: A report of the commission on the reorganization of secondary education* (U.S. Bureau of Education, Bulletin No. 26). Washington, DC: U.S. Government Printing Office.

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. 1983. *Educating Americans for the 21st century: A report to the American people and the national science board*. Washington, DC: National Science Foundation.

National Science Teachers Association (NSTA). 1971. NSTA position statement on school science education for the 70s. *The Science Teacher* 38: 46–51.

———. 1982. *Science-technology-society: Science education for the 1980s*. Washington, DC: NSTA Press.

National Society for the Study of Education (NSSE). 1932. *A program for teaching science: Thirty-first yearbook of the NSSE*. Chicago: University of Chicago Press.

National Society for the Study of Education (NSSE). 1947. *Science education in American schools: Forty-sixth yearbook of the NSSE*. Chicago: University of Chicago Press.

No Child Left Behind Act of 2001, 20 U.S.C. § 6301 *et seq.* 2002.

President's Scientific Research Board. 1947. *Science and public policy*, vols. 1 and 4. Washington, DC: U.S. Government Printing Office.

Programme for International Student Assessment (PISA). 2007. *PISA 2006: Science competencies for tomorrow's world, vol.1—analysis.* Paris: Organisation for Economic Co-operation and Development.

Ravitch, D. 1983. *The troubled crusade*. New York: Basic Books.

Sanford, C. 1950. High school science and mathematics—For whom and for what? *School Science and Mathematics* 50: 307–319.

Schwab, J. 1962. The teaching of science as enquiry. In *The teaching of science*, eds. J. Schwab and P. Brandwein, 1–103. Cambridge, MA: Harvard University Press.

Smith, A., and E. Hall. 1902. *The teaching of chemistry and physics in the secondary school*. New York: Longmans, Green.

Smith, M. 1954. *The diminished mind*. Chicago: Regnery.

Smyth, T. 1940. Problems associated with the high school science sequence. *School Science and Mathematics* 40: 255–260.

Spencer, H. 1864. *Education: Intellectual, moral, and physical*. New York: Appleton.

Spring, J. 2001. *The American school: 1642–2000*. New York: McGraw-Hill.

Standards to Provide Educational Achievement for Kids (SPEAK) Act. H. R. 2790/S. 224, 111th Cong. 2009.

Trefil, J. 2008. *Why science?* New York: Teachers College Press.

U.S. Department of Education. 1991. *America 2000: An education strategy sourcebook*. Washington, DC: U.S. Department of Education.

U.S. Office of Education. 1951. *Life adjustment for every youth*. Washington, DC: U.S. Government Printing Office.