The science education community has a long history of responding to the needs and aspirations of society. This chapter and the next provide contemporary perspectives on the response of science education to national priorities and goals. I first explore this theme with reflections from the Sputnik era of curriculum reform. Reflecting on the Sputnik era provides insights about the ways and means in which the science education community responds to national goals. I use insights from this exploration to make recommendations that will help science teachers respond to aspirations for 21st-century science education.

The theme of sustaining global environments and conserving natural resources centers on curricular topics such as climate change and energy efficiency. For science teachers, these topics imply greater emphasis on students’ understanding science and technology in personal, social, and global contexts.

**Reflections From the Sputnik Era**

The Sputnik era began in the 1950s with development of new programs that eventually became known by their acronyms. Science programs included the Physical Science Study Committee, known as PSSC Physics; the Chemical Educational Materials Study, known as CHEM Study; the Biological Sciences Curriculum Study, known as BSCS biology; and the Earth Sciences Curriculum Project, known as ESCP Earth science. At the elementary level there were the Elementary Science Study, known as ESS; the Science Curriculum Improvement Study, known as SCIS; and Science-A Process Approach, known as S-APA.

The years after World War II witnessed a debate between those supporting the progressive education identified with John Dewey and a conservative and traditional education identified with critics such as Admiral Hyman Rickover and Arthur Bestor. In fall 1957, the debate about American education reached a turning point. Sputnik resolved the debate in favor of traditionalists who recom-
mended greater emphasis on higher academic standards, especially in science and mathematics. Sputnik made clear to the American public that it was in its national interest to change education, in particular the curriculum in mathematics and science. Although they had previously opposed federal aid to schools—on the grounds that federal aid would lead to federal control—the public required a change in American education. After Sputnik, the public demand for a federal response was unusually high, and Congress passed the National Defense Education Act (NDEA) in 1958.

Curriculum reformers of the Sputnik era shared a common vision and general plan of action. Across disciplines and within the education community, reformers generated significant national enthusiasm for their initiatives. They would replace the current content of facts and topics that had a progressive orientation with curricula based on the conceptually fundamental ideas of science and the modes of scientific inquiry, technological design, and mathematical problem solving. The reform would replace textbooks with instructional materials that included films, activities, and laboratories. No longer would schools’ science, technology, and mathematics programs emphasize memorization of terms and applications of content. Rather, students would learn the conceptual structures and methodological procedures of science and mathematics disciplines.

These themes of curriculum reform should sound familiar. They are similar to those we have heard in the first decade of the 21st century. The context may be different (i.e., economic security, environmental quality, resource use), but the changes in curricula (i.e., fewer facts, core concepts, modes of inquiry, social connections) all reflect earlier themes.

The reformers’ vision of replacing the curriculum, combined with united political support for education improvement, stimulated a reform that clearly centered on national goals. The Eisenhower administration (1953–1961) provided initial economic support, and the enthusiasm of the Kennedy administration (1961–1963) moved the nation forward on reform initiatives. Although the Soviet Union had provided Sputnik as a symbol for the problem, President Kennedy provided a manned flight to the moon by the end of the decade as America’s vision, timeline, and strategic plan to win the race to space.

Reformers enjoyed financial support from both public and private sources for their curriculum projects. Federal agencies, particularly the National Science Foundation (NSF), and major philanthropic foundations, particularly Carnegie Corporation of New York and the Rockefeller Brothers Fund, provided ample support for attaining the vision, primarily through development of new curriculum programs.

The Sputnik era continued for two decades, into the mid-1970s. If I had to indicate an official end for the era, it would be 1976. Man-A Course of Study (MACOS), an anthropology program developed with NSF funds, came under scrutiny and widespread attack from conservative critics who objected to the
subject matter (Dow 1991). When a House subcommittee held hearings, NSF conducted an internal review, and the Government Accounting Office (GAO) investigated the financial relationships between NSF and the developers, the end of the era was imminent.

The common vision was to improve school programs and provide students with background and experiences that would encourage their entry into scientific and technological arenas. In addition, the reforms tried to design “teacher-proof” curriculum materials—that is, materials that were so well designed that students would learn regardless of the teacher. Although there are numerous political and economic factors that provided countervailing influences on the reform, emphasis on educating students for future careers in science and developing “teacher-proof” programs contributed to a less-than-effective reform.

**Five Insights From the Sputnik Era**

Examination of the Sputnik era reveals some strength and weaknesses that are worth noting by contemporary reformers. I present several observations from the experience.

**Curriculum Reform Is at Best Difficult, and Emphasizing “Teacher-Proof” Materials Makes It Impossible.**

Replacement of school science programs is extremely difficult at best. Although leaders in the Sputnik era used terms such as revision and reform, the intention was to replace school science programs with teacher-proof curriculum materials. They had tremendous zeal and confidence for this ill-informed and misguided goal. They approached their programs and the reform with a “field of dreams” perspective. If they built good curriculum materials, then science teachers would adopt them, thus replacing traditional programs with teacher-proof curricula. Such an approach, however, faces pervasive institutional resistance, raises the personal concerns if not resentment of science teachers, alarms the public, and fails to recognize the essential role and responsibility of science teachers. Furthermore, the perspective does not acknowledge the systemic nature of science education.

From a science teacher’s point of view, curriculum materials present a natural means of educational reform. Instructional materials are the means that science teachers use to improve their programs. There is a second insight embedded in this point. In some cases, entire programs are replaced when, for example, states or school districts adopt new elementary programs or high school science programs. With this type of reform, the selection of programs becomes a critical leverage point for professional development.

The lesson here centers on the importance of both recognizing the essential place of science teachers and supporting their work with a systemic approach to reform. Recall the instructional core theme. Not only are new programs impor-
tant, but other components of the education system must change as well and provide support for the implementation of innovative programs and instructional practices. Those components include peers who are practicing science teachers; administrators; school boards; the community; and a variety of local, state, and national policies.

**Resistance to Curriculum Reform Increases Proportionally to Variance From Current Programs.**

The reluctance of science teachers to embrace and implement innovative programs and practices increases proportionally to the variance from current programs and practices. Teachers had difficulty with the content and pedagogy of new programs such as PSSC, BSCS, CHEM Study, SCIS, and ESS. Lacking educational support within their local systems and experiencing political criticism from outside education, teachers sought security by staying with or returning to the traditional programs.

The education lesson here centers on the importance of both initial and ongoing professional development and support for new knowledge and skills. In addition, education reformers have to recognize that changes in social and political forces have an effect on school programs. The importance of high-quality, sustained professional development aligned with curriculum reform cannot be overstated and is worth repeating. It is way past time to move beyond handing science teachers a new book and a single workshop and calling this curriculum reform and professional development.

**Excluding Professionals in the Science Education Community Reduces Effectiveness.**

The exclusion of other professionals in the larger science education community (e.g., teacher educators and science education researchers) contributed to a slower-than-desired acceptance of the new programs, reduced understanding by those entering the profession, and provided less-than-adequate and appropriate professional development for teachers in the classroom.

This is a lesson of professional inclusion. Education is a system consisting of many different components. One important component includes those who have some responsibility for teacher preparation, workshops and professional development, and the implementation of school science programs. Another important component involves assessment practices. A perspective that attempts to unify and coordinate efforts among teachers, educators, and scientists works best.

In contemporary education, the particular role of curriculum development groups often is undervalued or overlooked by states and school districts interested in improving their science programs. With the Sputnik era, the science education community created professional groups with the expertise to design, develop, and implement innovative, state-of-the-art curriculum materials.
Individuals working in these groups understand their role in bridging the gap between theory and practice. The combined expertise of those involved in curriculum reform stands in stark contrast to most materials designed by traditional textbook authors and teachers tasked with the development of local science programs.

**Don’t Underestimate State and Local Realities.**
Realities and power of state and local school district policies, programs, and practices generally went unrecognized in the Sputnik era. Support from federal agencies and national foundations freed developers from the political and educational constraints of state and local agencies and the power and influence of commercial publishers.

This lesson directs attention to a broader view of education, one that includes a variety of policies. One way to think about this perspective is to use four Ps—purposes, policies, programs, and practices (Bybee 1997). Usually, individuals, organizations, and agencies contribute in various ways to the formulation of purposes, policies, programs, and practices; however, there must be coordination and consistency among the various efforts. Designing and developing new programs, as we did in the Sputnik era, surely marginalizes the success of the initiative if we do not attend to policies to support both those programs and changes in classroom practices to align with the innovative program.

**Pay Attention to Equity.**
Restricting initiatives to curriculum programs for specific groups of students (i.e., science and mathematically prone and college-bound students) resulted in criticism of Sputnik-era reforms as inappropriate for other students, such as average or disadvantaged students. To the degree that school systems implemented the new programs, teachers found that the materials were inappropriate for some populations of students and too difficult for others. Restricting policies or targeting programs opens the door to criticism on the grounds of equity. Ironically, proposing initiatives for all students also results in criticism for not addressing specific groups.

This lesson presents a major paradox of curriculum reform. To paraphrase Abraham Lincoln, you can please some of the people some of the time, but you will never please all of the people all of the time. My recommendation is to be clear about what you are doing, and do not try to fool some of the people by telling them your program was designed to do something for which it was not designed.

Examining the nature and lessons of Sputnik-era reforms, as well as those that came before and after, clearly demonstrated that education reforms differ. Although this may seem obvious, we have not always paid attention to some of the common themes and general lessons that may benefit the steady work of
improving science, mathematics, and technology education. Stated succinctly, those general lessons are to use what we know about education change; include all the key players in the education community; align policies, programs, and practices with the stated purposes of education; work on improving education for all students; and attend to the support and continuous professional development of science teachers because teachers are the most essential resource in the system of science education. In the next section, I address new national aspirations and the vital importance of curriculum reform as a complement to other essential initiatives, such as common core standards and assessments.

In the late 1950s, the United States responded to the Sputnik challenge from the Soviet Union by accelerating, broadening, and deepening efforts to reform science and technology education. At that time, the national aspiration was to send a man to the Moon and have him return safely to Earth. We needed scientists and engineers to fulfill this goal, and the education community responded. Now the United States is being challenged again. The new national aspiration includes maintaining our economic competitiveness and sustaining global environments. Our contemporary response should be to heed lessons from the Sputnik era and must include reforms at the instructional core of science education, which includes the curriculum.

**National Aspirations for the 21st Century**

**Sustaining Global Environments and Resources**

Scientific literacy is essential to an individual’s full participation in society. The understanding and abilities associated with scientific literacy empower citizens to make personal decisions and participate appropriately in the formulation of public policies that affect their lives. Assertions such as these provide a rationale for scientific literacy as the central purpose of science education. Too often, however, such a rationale lacks connections that answer questions concerning “personal decisions—Concerning what?” “Fully participate—in what?” or “formulate policies—relative to what?” One could answer these questions using contexts that citizens confront daily—for example, personal health, natural resources, natural hazards, and information at the frontiers of science and technology. One other domain stands out—the environment. In the following discussion, I center on environmental issues as one context for reform of science curricula.

Environmental issues are a global concern. For more than a decade, climate change has been central to science and public policy at the local through global levels. Human activities such as the accumulation of waste, fragmentation or destruction of ecosystems, and depletion of resources have had a substantial effect on the global environment. As a result, threats to the environment are discussed prominently in the media, and citizens of every nation increasingly face the need to understand complex environmental issues. Noted scientist Edward O. Wilson summarizes the situation by using an economic metaphor:
What humanity is inflicting on itself and Earth is, to use a modern metaphor, the result of a mistake in capital investment. Having appropriated the planet’s natural resources, we chose to annuitize them with a short-term maturity reached by progressively increasing payouts. At the time it seemed a wise decision. To many it still does. The result is rising per-capita production and consumption, markets awash in consumer goods and grain, and a surplus of optimistic economists. But there is a problem: the key elements of natural capital, Earth’s arable land, ground water, forests, marine fisheries, and petroleum, are ultimately finite and not subject to proportionate capital growth. (2003, p. 149)

Wilson’s use of an economic metaphor and my selection of this particular quotation are deeper and more insightful than they may seem. Citizens often hear economic arguments for the continued use of resources and destruction of environments. What Wilson’s metaphor points out is the need to understand scientific ideas such as renewable and nonrenewable resources and ecosystems’ capacity to degrade waste. Stated succinctly, understanding issues of ecological scarcity directly influences economic stability and social progress (Ophuls 1977). I maintain that ecological scarcity directly relates to environmental issues and a citizen’s scientific literacy.

A scientifically literate individual has more than knowledge of environmental issues. A scientifically literate individual also must have attitudes that contribute to actions. Although not totally unrelated to civic attitudes and values, the attitudes referred to here are grounded more in an understanding of the environment and less in democratic values. Examples of values associated with the environment include conservation, prudence, and stewardship (Kollmuss and Agyeman 2002; Morrone, Manci, and Carr 2001; Tikka, Kuitunen, and Tynys 2000).

**Asking and Answering the Sisyphean Question—Again**

Here is one variation of the Sisyphean question in science education: What is important for citizens to know, value, and be able to do in situations involving natural resources and the environment?

For three decades, I have answered this question in a variety of forms and venues. My answers generally have been consistent, and the urgency of an explicit and direct response has only increased during the decades. So I see little need for a different statement, only the necessity for a coherent and sensible response by the larger science education community. The following response is for the most part a contemporary statement that is consistent with and builds on earlier recommendations (see, e.g., Bybee 1979a, 1979b, 1979c, 1984, 1991, 2003).
Being Clear About the Purposes of K–12 Science Education

Education has the purpose of preparing students for their future as citizens. As such, education should prepare students with the fundamental knowledge, skills, abilities, and sensibilities for the various situations they will fulfill in work and as citizens. During the K–12 years, education should center on students’ general education and prepare them for both career and college. This view is a 21st-century perspective. In the past, students often were encouraged or counseled onto a college or vocational path. Now, the requirements for entering a career just out of high school or entering college are the same.

So how can one express the purpose of K–12 science education? The term scientific literacy expresses the general education goal described in the prior paragraphs. The PISA 2006 framework for science defines scientific literacy in terms of an individual:

- Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues. These phrases express the central components of scientific literacy. For example, when individuals read about a health-related issue, can they separate scientific from non-scientific aspects of the text, and can they apply knowledge and justify personal decisions?
- Understanding of the characteristic features of science as a form of human knowledge and enquiry. For example, do individuals know the difference between evidence-based explanations and personal opinions?
- Awareness of how science and technology shape our material, intellectual, and cultural environments. This component of scientific literacy centers on the influence of science and technology on society. Can individuals recognize and explain the role of technologies as they influence a nation’s economy, social organization, and culture? Are individuals aware of environmental changes and the results of those changes on economic and social stability?
- Willingness to engage with science-related issues, and with the ideas of science, as a reflective citizen. Finally, this dimension of scientific literacy underscores the attitudinal dynamics of scientific literacy. Are students interested in science? Memorizing and reproducing information does not necessarily mean students will select scientific careers, engage in science-related issues, or be willing as citizens to see public money allocated to scientific and technological research.
Establishing Policies for School Programs and Classroom Practices

Following is a discussion of education policies that are guidelines for science education programs, instruction, and practices. The policies are based on the fundamental divisions of ecology—organisms, environments, and populations. Using this ecological model and placing it in a human context, I asked, What is it about these divisions that is essential from a global perspective of sustainable development? My answers included both a conceptual and ethical orientation. Here are the answers, stated as policies. Science education programs and practices should guide learning toward (1) understanding and fulfilling basic human needs and facilitating personal development, (2) maintaining and improving the physical environment, (3) conserving natural resources and using them wisely, and (4) developing an understanding of interdependence between people at the local, national, and global levels, that is, development of a sense of community.

The ideas inherent in the first policy are simple and straightforward: All humans have basic physiological needs, such as clean air and water and sufficient food. They also need adequate shelter and safety. At higher levels, humans have the need to belong to groups and to perceive themselves as adequate and able. Simply stated, individuals need sustenance, order, community, and purpose for healthy physical, psychological, and social development. Education programs can contribute directly to the fulfillment of students' basic needs. They can be designed to help individuals gain knowledge about fulfilling these needs, inform individuals about the unfulfilled needs of others, and present the problems and possibilities associated with fulfilling human needs. The policy has a universal nature. All individuals have basic needs. Food and the development of a personal identity are both needs. Individuals in developed nations often think that alleviation of hunger and freedom from disease are the only basic needs in developing countries. The hierarchy of needs makes it clear that individuals in all nations are influenced by needs, though the needs may be different from one individual to the next and from one country to the next. A principal function of any society is to fulfill the needs of its citizens.

Science educators recognize only part of the problem, however, by presenting ideas that can help fulfill basic human needs. In State of the World (1990), Lester Brown and his colleagues clarify the role of values:

In the end, individual values are what drive social changes. Progress toward sustainability thus hinges on a collective deepening of our sense of responsibility to the earth and to future generations. Without a re-evaluation of our personal aspirations and motivations, we will never achieve an environmentally sound global community. (Brown et al. 1990, p. 175)

To have any effect, policies must include both ideas and values, and it is essential that the values are compatible with the policy and serve to direct personal
decisions toward achieving and maintaining sustainable growth. The values
of justice and beneficence underlie the policy designed to fulfill basic human
needs. With resource scarcity and a majority of world citizens with unfulfilled
basic needs such as food, developed countries can no longer afford unnecessary
goods and overconsumption, even for the cause of economic growth and the
claims that all people are living a better life relative to the past.

Achieving this aim requires beneficence toward others, a value that can
restrain personal consumption and encourage greater sharing. In turn, justice
encourages the fair and equitable distribution of goods and services. This policy
is more than an appeal to altruism. Adoption of green lifestyles that make use of
appropriate goods and services in developed countries not only helps those in
less developed countries but also better fulfills our own actual needs.

The second policy for programs and practices is designed to care for and
improve the natural environment. Air, water, and soil are the common heritage
of humankind, and they are essential to fulfilling basic needs. Many individuals
perceive the environment as a receptacle of unlimited capacity to receive and
degradate waste. But environmental systems are limited. The negative synergistic
effects of pollution are becoming clear. Global warming and climate change are
examples of this idea writ large. Realizing our dependence on the environment
establishes a moral obligation to both ourselves and future generations to see
that the environment can sustain life. Education programs should enable indi-
viduals to make informed decisions and take appropriate actions, in the short
and long terms, to maintain and improve the physical environment.

The third policy concerning the conservation and wise use of resources is
closely related to improvement of the physical environment and fulfillment of
both the physical environment and basic needs. Just as we once believed in the
limitless capacity of the environment to degrade waste, so too we once thought
that resources were unlimited. They are not. Education about sustainable devel-
opment will inform students of the need for resources, transitions to renewable
resources, and the conservation of nonrenewable resources.

If one perceives the environment and resources as unlimited, then it is unnec-
essary to make value judgments about their use. The aim of sustainable devel-
opment has an ecological ethic grounded in the idea of limited environmental
capacities and limited depletion of resources. This, in a word, is prudence. Like-
wise, those with a vision of sustainability must think of themselves as stewards:
managers and administrators of our natural environment.

The fourth and final policy is to develop increased interaction among people
through education. This policy is directed toward establishing a greater sense
of community. If fulfillment of human needs, improvement of the environment,
and conservation of resources are to become realities, we must increase commu-
nity involvement and cooperative participation at all levels, from local to global.
One of the first steps toward productive personal interaction is the elimination
of prejudicial barriers to community. Specifically, education programs should reduce prejudices such as racism, sexism, ethnocentrism, and nationalism. As long as one individual, group, or nation has a need to dominate another, the opportunities for harmonious living are reduced and the possibilities for disastrous conflict increase. Establishing a greater sense of community is clearly a prerequisite related to achieving the other three policies.

Cooperation and mutual regard are values essential for effective implementation of the fourth policy concerning growth and sustainable development. Inevitably, conflicts will arise among the crucial choices inherent in managing sustainable development. Societies can no longer afford to hold military force as the dominant means for resolving conflicts because force is ultimately divisive and results in destructive, not constructive, resolution of conflicts. Cooperative interaction is essential if all parties to a conflict are to achieve their goals and sustain a positive relationship. Finally, there is a profound need for a universal recognition of human rights and compassion for others. This is the value of mutual regard for each other now and consideration for future generations of humankind.

The education policies form a coordinated system of ideas and values supporting sustainable development. These policies would facilitate sustainable development while preserving personal freedom and minimizing governmental control. Education based on these policies could simultaneously produce changes in the ideas and values of individuals and implement means of regulating social change. Regulations, however, would not necessarily be the unilateral imposition of rules and laws by an authority on the majority. They would be, to use Garrett Hardin’s phrase from his classic article “Tragedy of the Commons,” “mutual cohesion mutually agreed upon” (Hardin 1968). Two factors justify this assertion. First, the ideas (needs, environment, resources, and community) and the values (justice, beneficence, stewardship, prudence, cooperation, and mutual regard) are sources of personal obligation as well as social regulation. Individuals with these ideas and values would be inclined to make informed decisions concerning their needs, the needs of others, the environment, and resources; practice self-restraint and self-reliance as necessary; and participate in the democratic development of rules based on the concept of sustainability. Second, a specific type of obligation is also inherent in the ideas and values. The obligation is reciprocal. The concern is not only for oneself but also for other people and their environments and resources.

Education programs that emphasize a sense of reciprocal obligation would develop an individual’s sense of duty to others and the natural environment. Obligation alone can be engendered through social rules and laws. But this type of obligation is unilateral and can easily become little more than obedience to authority. This tendency is reduced, but not eliminated, through reciprocity among people who respect one another and their environments. Many indi-
Individuals in social groups are reciprocally obligated to one another, so this idea is neither uncommon nor unachievable. Reciprocal obligations are grounded in empathizing with other people, coordinating efforts to solve problems, recognizing different points of view, balancing good and bad, and cooperating in the resolution of conflict. Humankind must take this direction if it is to avoid human ecological catastrophes and develop patterns of sustainable development.

So the education policies proposed here converge on the goal of sustainability and preservation of personal freedom through development of reciprocal obligation. The view presented here follows a course of least-restrictive regulation on the individual based on the possibility of changing personal ideas and values through education. In other words, regulations would increasingly influence the decisions of those individuals whose ideas and values are aligned with the old vision of unlimited industrial growth. An individual’s freedom would be maintained to the degree that education achieves the described policies, thus developing personal ideas and values supporting sustainable growth. Education would create a dynamic interaction between self-restraint and social restriction, and that interaction would maximize personal freedom while achieving sustainable development.

Concluding Discussion

In the early years of the 21st century, the science education community must respond to an important challenge: helping citizens develop a greater knowledge and appreciation for resources and environmental issues. In an earlier section, I quoted E. O. Wilson, who used an economic metaphor in describing the environmental situation and his proposed solution. Today, the importance of understanding natural resources and the environment is even more important than it was last year, a decade ago, or 50 years ago. Being scientifically literate about resources and the environment is essential for all citizens, not only in the United States but in the global community as well.

A sound understanding of the dividends on the investment in scientific literacy accrues to all students in the form of enhanced learning and achievement. Science teachers, however, control the rate of interest and, therefore, the potential to increase the investment. The interest rates, and thus dividends, are largely determined by the degree to which the teaching includes challenging science content; increased curricular coherences; and greater congruence with personal, social, and global contexts. We must renew and double efforts to facilitate students’ interdependence with nature and responsibility for sustaining a healthy and healing environment.