Science and the Educated American: A Core Component of Liberal Education

Edited by Jerrold Meinwald and John G. Hildebrand
The health of American democracy in the twenty-first century will depend on the development of a larger number of scientifically literate citizens. Today’s political agenda includes a debate over the consequences of and solutions for global climate change, a continuing debate over the use of embryonic stem cells in biomedical research, a spirited set of disagreements over future energy sources, and a lingering concern over the possibility of a viral pandemic. In Europe, the political landscape is still divided over nuclear power and genetically modified foods. No serious student of public policy or science policy thinks that the public-policy agenda will become less populated by scientific issues in the twenty-first century. Yet only 28 percent of American adults have sufficient understanding of basic scientific ideas to be able to read the Science section in the Tuesday *New York Times* (Miller, 1998, 2000, 2001, 2004), and some research suggests that the proportion may be substantially lower when citizens are faced with strong advocates on both sides.

At the same time, most adults will learn most of their science information after they leave formal schooling. How many current adults can claim that they studied stem cells or nanotechnology when they were students? In the decades ahead, the number and nature of new scientific issues reaching the public-policy agenda will not be limited to subjects that might have been studied in school but will reflect the dynamic of modern science and technology.

Does this mean that formal schooling is irrelevant? No. To the contrary, framing science education and scientific literacy in terms that recognize that formal education, when done well, can provide a necessary conceptual foundation for a lifetime of scientific learning is essential. The evidence from the
last thirty years of international testing indicates that American secondary schools do a poor job in providing this foundation of basic understanding (Schmidt, McKnight & Raizen, 1997), and the recent Programme for International Student Assessment report from the Organisation for Economic Co-operation and Development reconfirms our national mediocrity in this area (Baldi et al., 2007). Unbeknownst to most Americans, the United States is the only major country in which almost all its college and university students are required to complete a year of general education, including a full year of science. Recent international comparisons have shown that approximately one in four American adults qualifies as scientifically literate and that exposure to college-level science courses is the primary factor in the performance of American adults (Miller, 2001, 2004).

The need for adults to learn new science after formal schooling is obvious. The overwhelming majority of American adults age thirty-five or older could not have learned about stem cells, nanotechnology, or climate change in school twenty years ago because these were new topics for scientists at that time and were not included in any textbook or curriculum. Similarly, few adults could have learned about the Human Genome Project in school; but the results of that work are often mentioned in public-policy debates, and surveys show that approximately 44 percent of American adults understand the role of DNA in heredity (Miller, 2001, 2004). Few scientists would assert that they could predict the science issues in the news twenty-five years from now, but the majority of today’s adults will have to make sense of those issues at some time in their life if we hope to preserve more than the rituals of democracy.

A CONCEPTUALIZATION OF SCIENTIFIC LITERACY AS A FOUNDATION FOR FUTURE LEARNING

Most of the definitions of scientific literacy that have been advanced in recent decades focus on the mastery of a set of terms, ideas, and concepts, reflecting a traditional view of student or adult learning. This ideal is rooted in a conceptual model of learning as a warehouse: an individual acquires pieces of information and places them on a mental shelf or in a cognitive warehouse and then turns to those facts when he or she needs them. This model is the foundation of most of our current school curricula and many of our informal learning institutions, such as museums and science learning centers. The adoption of this metaphor is the understandable legacy of a long period of industrialization, but it may be a poor conceptualization of learning in the twenty-first century.

In constructing a conceptualization of scientific literacy for the twenty-first century, we may be better served by returning to the idea of literacy itself. The basic idea of literacy has been to define a minimum level of reading and writing skills that an individual must have to participate and communicate in society. Historically, an individual was thought of as literate if he or she could
read and write his or her own name. In recent years, many adult educators have translated this requirement into more functional terms: for example, the ability to read a bus schedule, a loan agreement, or the instructions on a bottle of medicine. Adult educators often use the term “functional literacy” to refer to this new definition of the minimal skills needed to function in a contemporary industrial society (Cook, 1977; Harman, 1970; Kaestle, 1985; Resnick & Resnick, 1977).

Building on this basic conceptualization of literacy as the acquisition of tools needed to function in one's society, we might define scientific literacy as the level of understanding of scientific and technological constructs needed to function as citizens in a modern industrial society (Miller, 1983a, 1983b, 1987, 1995, 1998, 2000, 2001, 2004; Miller & Pardo, 2000; Miller, Pardo & Niwa, 1997; Shen, 1975). In an earlier essay on the conceptualization of scientific literacy, Shen (1975) suggested that we differentiate among consumer scientific literacy, civic scientific literacy, and cultural scientific literacy. Consumer scientific literacy would be the ability to understand and choose among contemporary consumer choices involving foods, medicines, chemicals, computers, and similar products. Cultural scientific literacy would focus on understanding the role of science in society and its relationship to other ways of knowing. And civic scientific literacy would encompass the level of understanding necessary to follow and make sense of public-policy issues involving science or technology. As a political scientist who believes that democratic systems are the best way to make collective decisions and perhaps the only way to sustain civil society over long periods of time, I have focused most of my work on the definition and measurement of civic scientific literacy. And, as I will argue in my concluding discussion, I think that schools and universities have a special responsibility to foster civic scientific literacy in our society.

The conceptualization of civic scientific literacy (CSL) as the acquisition of a set of foundation constructs is not a pedantic issue. Properly understood, CSL should provide valuable curricular guidance for high school science courses for all students and college science courses for non-science majors. I argue, for example, that it is more important for non-science majors to understand \( E = mc^2 \) at a conceptual level (the relationship of mass and energy) than at a mathematical level and that it is more important for non-science majors to understand the processes and dynamics of plate tectonics than to be able to differentiate between a sedimentary rock and a piece of basalt. Reflecting this orientation, the University of California, Berkeley, has changed the name of its introductory physics course from Physics for Poets to Physics for Future Presidents.

The task, then, is to develop a set of measures of CSL that reflects the acquisition of basic scientific constructs that are likely to be useful to students and adults over the course of a lifetime in acquiring and making sense of emerging scientific ideas and developments. The good news is that much progress has been made in this area over the last twenty years. The bad news is that the task is never-ending.
If we conceptualize scientific literacy as the acquisition of basic constructs for future use, then we must take care to design an instrument that will be useful over a period of years and will be sufficiently sensitive to capture changes in the structure and composition of public understanding. If a time-series indicator is revised too often or without consciously designed linkages, it may be impossible to separate the variation attributable to measurement changes from real change over time. The periodic debates over the composition of consumer price indices in the United States and other major industrial nations are a reminder of the importance of stable indicators over periods of time.

The durability problem can be seen in the early efforts to develop measures of the public understanding of science in the United States. In 1957, the National Association of Science Writers (NASW) commissioned a national survey of public understanding of and attitudes toward science and technology (Davis, 1958). The interviews for the 1957 study were completed only a few months prior to the launch of Sputnik I, making this the only measure of public understanding and attitudes to precede the space race. Unfortunately, the four major items of substantive knowledge the survey examined were (1) radioactive fallout, (2) fluoridation of drinking water, (3) the polio vaccine, and (4) space satellites. Fifty years later, at least three of these items are no longer central to the measurement of public understanding.

Recognizing this problem, my colleagues and I attempted to identify a set of basic constructs, such as atomic structure or DNA, that form the intellectual foundation for reading and understanding contemporary scientific issues but that will have a longer durability than specific terms, such as “the fallout of strontium 90 from atmospheric testing.” In the late 1970s and early 1980s, when the National Science Foundation began to support comprehensive national surveys of public understanding and attitudes in the United States, investigators had little experience beyond the 1957 NASW study in the measurement of adult understanding of scientific concepts. In a 1988 collaboration between Thomas and Durant in the United Kingdom and me in the United States, an expanded set of knowledge items was developed that asked respondents direct questions about scientific concepts. The 1988 studies included a combination of open-ended and closed-ended items that provided significantly better estimates of public understanding than had been collected in any prior national study. From this collaboration, a core set of knowledge items emerged that has been used in studies in Canada, China, Japan, Korea, India, New Zealand, and all twenty-seven members of the European Union.

To a large extent, these core items have provided a durable set of measures of a vocabulary of scientific constructs, but continually enriching the mix to reflect the growth of science and technology is important. For example, my recent studies of the American public have included new open-ended measures of stem cell, neuron, and carbon footprint construct understanding and new
closed-ended measures of the public’s understanding of the genetic modification of plants and animals, nanotechnology, ecology, and infectious diseases. Using item response theory (IRT), we can link survey results across years to obtain comparable measures on a common metric even as the set of items changes over time (Zimowski et al., 1996).

It is useful to look briefly at the primary items used recently in the measurement of civic scientific literacy in the United States and at the percentage of American adults able to answer each item correctly. A core set of items focuses on the meaning of studying something scientifically and the nature of an experiment (Table 1). Data collected over the last twenty years reveal that the proportion of American adults who are able to define the meaning of a scientific study has increased from 22 percent to 34 percent. By 2008, 61 percent of American adults were able to describe an experiment correctly. Although these percentages are low in terms of our expectations, each percentage point represents 2.3 million adults; thus, we can estimate that 78 million adults understand the meaning of a scientific study and 140 million adults understand the structure and purpose of an experiment.

Similarly, the proportion of American adults able to understand simple probability statements has increased from 56 percent to 72 percent since 1988. Nearly one in four can describe a molecule as a combination of two or more atoms. Many adults know that atoms, molecules, and electrons are very small objects but are confused about their relationship to each other. Four out of five adults know that light travels faster than sound, but only half know that a laser is not composed of focused sound waves (see Table 1). All these basic physical-science constructs are a part of middle school and high school science instruction and should have been acquired during formal schooling. If these basic ideas were understood during the school years, many Americans appear not to have retained them as adults and are unable to use them in reading a newspaper story or seeking to understand a television show.

Adult understanding of the universe and our solar system is uneven. Four out of five adults know that the center of Earth is very hot, and 72 percent understand the basic idea of plate tectonics (expressed as continents moving their positions; see Table 1). Two out of three adults know that Earth goes around the sun once each year, but only 30 percent understand or accept the idea of the Big Bang. The slight decline since 1988 in the acceptance of the Big Bang is undoubtedly the result of increased pressure from religious fundamentalists who reject both it and biological evolution. Three in five adults recognize that astrology is “not at all scientific.”

The level of public confusion is greatest in the life sciences, reflecting both fundamentalist pressures and a general unfamiliarity with genetic concepts. Only 37 percent of American adults accepted the concept of biological evolution in 2008, and the level of acceptance has declined over the last twenty years (see Table 1). Approximately 44 percent of American adults can define DNA correctly, but only 20 percent can define the meaning of a stem cell. Although
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<tr>
<td>Indicate that light travels faster than sound.</td>
<td>78%</td>
<td>75%</td>
<td>86%</td>
</tr>
<tr>
<td>Agree: “All plants and animals have DNA.”</td>
<td>–</td>
<td>–</td>
<td>85%</td>
</tr>
<tr>
<td>Agree: “The center of Earth is very hot.”</td>
<td>82%</td>
<td>81%</td>
<td>80%</td>
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<tr>
<td>Agree: “The continents on which we live have been moving their location for millions of years and will continue to move in the future.”</td>
<td>81%</td>
<td>80%</td>
<td>72%</td>
</tr>
<tr>
<td>Understanding of the meaning of the probability of one in four.</td>
<td>56%</td>
<td>55%</td>
<td>72%</td>
</tr>
<tr>
<td>Indicate that Earth goes around the Sun once each year.</td>
<td>50%</td>
<td>49%</td>
<td>67%</td>
</tr>
<tr>
<td>Agree that astrology is not at all scientific.</td>
<td>62%</td>
<td>59%</td>
<td>59%</td>
</tr>
<tr>
<td>Disagree: “Antibiotics kill viruses as well as bacteria.”</td>
<td>31%</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Agree: “Electrons are smaller than atoms.”</td>
<td>46%</td>
<td>46%</td>
<td>54%</td>
</tr>
<tr>
<td>Disagree: “Ordinary tomatoes . . . do not have genes but genetically modified tomatoes do.”</td>
<td>–</td>
<td>–</td>
<td>51%</td>
</tr>
<tr>
<td>Disagree: “Lasers work by focusing sound waves.”</td>
<td>40%</td>
<td>43%</td>
<td>48%</td>
</tr>
<tr>
<td>Disagree: “The earliest humans lived at the same time as the dinosaurs.”</td>
<td>40%</td>
<td>51%</td>
<td>47%</td>
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<tr>
<td>Provide a correct open-ended definition of “DNA.”</td>
<td>27%</td>
<td>29%</td>
<td>44%</td>
</tr>
<tr>
<td>Agree: “Human beings, as we know them today, developed from earlier species of animals.”</td>
<td>47%</td>
<td>45%</td>
<td>37%</td>
</tr>
<tr>
<td>Provide a correct open-ended definition of “what it means to study something scientifically.”</td>
<td>22%</td>
<td>22%</td>
<td>34%</td>
</tr>
<tr>
<td>Agree: “The universe began with a huge explosion.”</td>
<td>34%</td>
<td>33%</td>
<td>30%</td>
</tr>
<tr>
<td>Agree: “More than half of human genes are identical to those of mice.”</td>
<td>–</td>
<td>–</td>
<td>27%</td>
</tr>
<tr>
<td>Provide a correct open-ended definition of a “molecule.”</td>
<td>–</td>
<td>13%</td>
<td>25%</td>
</tr>
<tr>
<td>Provide a correct open-ended definition of a “stem cell.”</td>
<td>–</td>
<td>–</td>
<td>20%</td>
</tr>
<tr>
<td>Number of cases</td>
<td>1,600</td>
<td>1,883</td>
<td>1,147</td>
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Given the size of the samples, differences from year to year of less than three points may reflect sampling error rather than real differences.
85 percent of adults recognize that all plants and animals have DNA, only 27 percent of Americans think that “more than half of human genes are identical to those of mice.” The level of misunderstanding is not limited to human genetics: only half of adults reject the statement that “ordinary tomatoes do not have genes but genetically modified tomatoes do.” The proportion of adults who understand that antibiotics do not kill viruses has increased from 31 percent in 1988 to 55 percent in 2008 (see Table 1).

A MODEL OF THE FACTORS RELATED TO CIVIC SCIENTIFIC LITERACY

Although these descriptive results are interesting, a good summary measure of the level of adult understanding of these basic constructs is more useful. With IRT, we can construct a summary index of CSL, with scores ranging from roughly zero to one hundred. IRT is a standard testing technology and is widely used in many national tests, including the Graduate Record Examination (GRE) and other tests produced by commercial test publishers (Zimowski et al., 1996). IRT technology also allows the construction of time-series measures over a period of years, even when the mix of questions asked has varied slightly over time.

Using IRT estimates, the percentage of American adults who scored seventy or higher on the index of CSL increased from 10 percent in 1988 to 28 percent in 2008 (Figure 1). Although any cut point is inherently arbitrary, a careful examination of the mix of items that would be required to score seventy or higher suggests that individuals with this level of understanding would be able to read most of the stories in the Tuesday Science section of *The New York Times* or understand an episode of the *Nova* television program.

Using data from a 2007–2008 panel study conducted in the United States using Knowledge Networks’ online probability sample (Miller, Augenbraun, Schulhof & Kimmel, 2006), we can explore the relative influence of several major sources of scientific literacy among adults. It is useful to outline the major propositions to be examined.

First, we must assess the relative contribution of college science courses to adult CSL. Holding constant age, gender, and other background factors makes the identification of this effect possible.

Second, we expect that college science courses will provide a core vocabulary of scientific constructs that will facilitate and enhance the use of informal science learning resources. A simple structural equation model\(^1\) will allow us to

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\(^1\) In general terms, a structural equation model is a set of regression equations that provides the best estimate for a set of relationships among several independent variables and one or more dependent variables. For the structural analysis presented in this paper, the program LISREL was used; it allows the simultaneous examination of structural relationships and the modeling of measurement errors. For a more comprehensive discussion of structural equation models, see Hayduk (1987) and Jöreskog and Sörbom (1993). For a more detailed example of the use of this technique in the analysis of CSL, see Miller, Pardo, and Niwa (1997).
test this proposition and to isolate the indirect effect of college science courses on the use of informal learning resources without diminishing our ability to assess the direct or residual impact of those courses.

Third, we will be able to examine the impact of fundamentalist religious beliefs on adult use of informal science learning resources and on retained information in the form of CSL, while holding constant other factors in the general model.

To explore the relative influence of selected factors on the development of CSL, a structural equation analysis of the 2007 U.S. data set was conducted. The analytic model included each individual’s age; gender; highest level of education; number of college science courses completed; presence or absence of minor children in the household; interest in science, technology, medical, or environmental issues; personal religious beliefs; and level of use of television, print resources, and the Internet (Figure 2).

A path model is useful for examining the relative influence of variables that have a known chronological or logical order. Each individual has a gender at birth and an age based on his or her birth date. An individual’s gender may influence his or her education, although this influence appears to be diminishing in the United States and several European countries. For most adults, educational attainment and the number of college science courses have been determined by the time they reach their mid-thirties, although more adults
are returning to formal education than ever before. An individual’s level of CSL at any specific time may be thought of as the result of the combination of these and other factors (see Figure 2). In a path model, chronological or logical causation flows from left to right. The product of the path coefficients is an estimation of the total effect of each variable on the outcome variable—CSL in this case. It is useful to look first at the total effect of each of the variables in this model, and then return to examine some of the specific path coefficients.

The number of college science courses taken is the strongest predictor of CSL, with a total effect of 0.74 (Table 2). It is important to understand this variable and its impact. The variable is a measure of the number of college science courses, including courses in both community colleges and four-year colleges and universities. The number of courses was divided into three levels: (1) no college-level science courses; (2) one to three courses; and (3) four or more courses. Individuals with one to three courses typically took college science courses as a part of a general education requirement rather than as part of a major or a supplement to a major. The use of an integer measure would have given undue weight to majors and minimized the impact of general education science courses in the analysis.

Formal educational attainment is the second best predictor of adult CSL (0.69). This result indicates that students gain some additional value from the full range of university courses, including other general education courses in

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2. Educational attainment was measured with a five-category ordinal variable. The lowest level included all individuals who did not complete secondary school or obtain a general equivalency diploma (GED). The second category included high school graduates and GED holders. The third category included respondents with an associate’s degree. The fourth category included individuals who earned a baccalaureate but not a graduate or professional degree. The highest category included all individuals who completed a graduate or professional degree.
the humanities and the social sciences. The influence of formal educational attainment may also reflect a greater respect for and acceptance of academic authority as a source of knowing about the world.

After the effects of educational attainment and college science courses, five additional indicators had a total positive or negative effect between 0.15 and 0.22. It is not useful to try to differentiate among these indicators by the magnitude of their total effect, but it is useful to discuss briefly the meaning of each of these relationships.

The model finds a negative relationship between fundamentalist religious views\(^3\) and civic scientific literacy (-0.20), meaning that adults with fundamentalist religious beliefs are significantly less likely to be scientifically literate than adults with more moderate or liberal religious beliefs, holding constant differences in age, gender, education, children at home, and issue interest. Religious beliefs are placed to the right of college science courses in this path model because the religious variable reflects current religious beliefs and exposure to college science courses may have occurred several years prior to the interviews in the 2007–2008 panel study. In a longitudinal study that followed the same individuals over a period of time, we would likely find that parental and pre-

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\(^3\) The index of religious beliefs is a count of the number of times a respondent indicated agreement with (1) “The Bible is the actual word of God and is to be taken literally”; and (2) “There is a personal God who hears the prayers of individual men and women”; and indicated disagreement with (3) “Human beings developed from earlier forms of life.” Individuals who scored three on this index were classified as fundamentalist (22 percent); individuals who scored two were classified as conservative (15 percent); individuals who scored one were classified as moderate (25 percent); and individuals who scored zero on the scale were classified as liberal-none (38 percent).
college religious views influence the number of college science courses taken, but in a cross-sectional or short adult panel study, accurately assessing earlier influences of that kind is impossible. We are comfortable, however, in asserting that current religious beliefs may be influenced by prior educational experiences and that a negative path (-0.10) exists between educational attainment and religious attitudes in this model, which indicates a small but statistically significant effect between the two variables.

The model also indicates that adults who are relatively more frequent users of print and Internet information sources are more likely to be scientifically literate (0.15 for print and 0.22 for the Internet), holding constant the other variables in the model (see Figure 2 and Table 2). This relationship suggests that adults with better information acquisition skills are more likely to obtain and retain core scientific information and constructs than adults without those skills. Again, it is useful to recall that these effects are additive to the effects noted previously that were related to educational attainment and college science course experiences.

Finally, the model indicates that females and older adults are less likely to be scientifically literate than other adults (-0.18 for females and -0.22 for older adults), holding constant the other variables in the model. Although younger respondents are more likely to be scientifically literate than older adults because they would have had more education and more science education than older adults, it is important to recognize that the total effect reported in Table 2 is net of differences in education, gender, and other factors. Similarly, the differential in favor of males is net of differences in education and other factors (Hayduk, 1987; Jöreskog & Sörbom, 1993).

The level of personal interest in scientific, technical, environmental, or medical issues had only a small positive effect on CSL (0.05), as did the presence of preschool or school-age children in the home (0.03).

This model explains 75 percent of the total variance in civic scientific literacy among U.S. adults in 2007–2008. This is a very good fit for the model, and other indicators confirm the fit of the model. The model appears to have no measurement problems.

DISCUSSION

What do these results tell us about the conceptualization and measurement of civic scientific literacy in the twenty-first century?

First, at the conceptual level, one can make a strong case for thinking about scientific literacy as acquiring the tools to make sense of science and technology in the future as opposed to learning the details of current science. Science is a dynamic activity that will continue to produce new results requiring new terms and constructs, and the citizens of the twenty-first century will have to be able to use their understanding of basic ideas—atoms, molecules, the structure of...
matter—to make sense of new concepts such as nanotechnology. F. James Rutherford’s original conceptualization of Project 2061, an effort by the American Association for the Advancement of Science (AAAS) to improve science education in the United States, was designed to capture this sense of the science we will need to know to understand the future (AAAS, 1989).

Second, Shen’s distinctions among CSL, consumer scientific literacy, and cultural scientific literacy are useful. Good arguments can be advanced for each of these three aspects of scientific literacy, but my colleagues and I have focused on CSL because it is the key link between science and technology policy and democratic government. As modern science has become more expensive and more controversial, it has inevitably moved into the public arena. Science and technology are essential to a wide array of public policy objectives in environmental and biomedical areas but are also essential tools for sustaining American competitiveness in the emerging global economy (National Academies, 2007).

Third, the thirty-year time-series measurements that I and others have created provide a useful indicator of national progress in CSL, but these are indices that must continue to grow and change to reflect the nature of science and technology in the twenty-first century and beyond. Just as the contents of the household market basket used for computation of the U.S. Consumer Price Index periodically change to reflect national habits and tastes, so must our measures of CSL and related constructs.

Fourth, this analysis found that the nearly unique American requirement for general education at the university level has been a major factor in fostering CSL. The origins of this requirement are murky, but a consensus in favor of “general education” first emerged in the early decades of the twentieth century and was soon adopted by both land-grant and leading private colleges and universities. Dewey, Hutchins, and their colleagues were influential in promoting this conceptualization of higher education. As we approach the centennial of this American experiment in higher education, the results reported in this analysis suggest that the experiment has been beneficial.

Fifth, the accelerating pace of scientific development means that most Americans outside the scientific community will learn most of their science after they leave formal schooling. Few adults could have learned about stem cells, global climate change, or nanotechnology as students because the relevant science had not been done. The challenge today is to prepare students to understand science that will not occur for another twenty, thirty, or forty years. This is not easy, but it is possible. Although we cannot know the precise dimensions of future science, we can be sure that existing constructs such as atom, molecule, DNA, and energy will still be applicable.

In this context, the model of factors related to CSL demonstrates that acquiring a core vocabulary of basic scientific constructs can confer a distinct advantage on adults who use emerging information technologies to become and remain informed about scientific and other matters. Nearly four decades
ago, Tichenor and colleagues observed that better-educated adults gain more from any information campaign than less-well-educated adults; they referred to this differential as the knowledge gap (Tichenor, Donohue & Olien, 1970). With the emergence of new electronic technologies, more Americans have access to a wider array of information at lower cost than at any time in human history. Those adults with the ability to understand the information landscape and to make sense of new scientific and technical information will have important advantages in the decades ahead. Scientific literacy has become an essential component of the skills that every adult needs to thrive in the twenty-first century.

Finally, science policy has become a part of the political agenda, and it is unlikely to disappear in the foreseeable future. In broad terms, the twentieth century was the century of physics, and the twenty-first century will be the century of biology. The twentieth century was characterized by enormous advances in transportation, communication, and nuclear science—from the radio to the airplane to the transistor. Although these new developments and technologies eventually changed the very character of American society, most of them successfully avoided direct confrontation with traditional beliefs and values, especially religious values. As science continues to expand our understanding of the nature and structure of life and develops the technologies to intervene in those processes, the resulting political disputes will become more personal and more directly confrontational with traditional religious values.

Looking to the future, we must increase the proportion of scientifically literate adults in our society. As the survey results presented here demonstrate, formal education and informal science learning are partners in the process of advancing scientific literacy. Without a solid foundation of basic scientific constructs, even the best science journalism and communication will fall on deaf ears. Scientific literacy is not a cure or antidote in and of itself. It is, however, a prerequisite for preserving a society that values science and is able to sustain its democratic values and traditions.4

4. The U.S. national data sets for the years 1985 through 2007 were collected with support from the National Science Foundation (awards SRS8105662, SRS8517581, SRS8807409, SRS9002467, SRS9217876, SRS9732170, SRS9906416, ESI0131424, ESI0201155, ESI0515449). The 2008 wave of the Science News Study was funded by Dean Charles Salmon of Michigan State University. The 2008 participation in the American National Election Study was funded by Vice President Ian Gray of Michigan State University. The author gratefully acknowledges this support, but any errors or omissions are the responsibility of the author and not of the sponsors or any of their staff or officers.
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Contributors