Science Through the Looking Glass: Winning the Battles But Losing the War?

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A millennium ago, like today, people were contemplating the significance of a new era. They reflected on the accomplishments of their past and on the possibilities for their future. In France, Germany, and throughout Europe, people gathered to witness the end of the world, and churches were erected to express thanks in the event of the postponement of Judgment Day. In science and mathematics, Alhazen worked to demonstrate that light travels in a straight line, and Sridhara, the Indian mathematician, first recognized the significance of the zero. It would be another 250 years before the importance of the scientific method would be established and Europe would be introduced to "zero" and to Arabic numerals.

In just the past century, the degree of progress achieved is extraordinary. One hundred years ago, the life expectancy was 46 to 48 years for whites, and non-whites were only expected to live into their early 30s. Pneumonia, tuberculosis, influenza, and childbirth were often fatal. People communicated by writing letters. The horseless carriage was proclaimed by *Literary Digest* to be a "luxury for the wealthy." The gasoline-driven motor and the internal combustion engines were developed. The wireless telegraph was pioneered. The Wright Brothers flew the first "heavier than air craft." Karl Landsteiner discovered three blood groups, later to be named A, B, and O. Max Planck proposed something he labeled "quantum" to explain the behavior of light. Freud published "The Interpretation of Dreams." The stratosphere was discovered by Léon-Philippe Teisserenc de Bort. And Lydia Pinkham's Vegetable Compound was widely advertised as "The Greatest Medical Discovery Since the Dawn of History." The compound, promising to remedy female complaints, and containing black cohosh, liferoot plant, fenugreek seeds, and other herbs in a 21% alcohol solution, continued to be sold for another 76 years.

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WINNING THE BATTLES BUT LOSING THE WAR

As we approach the new millennium, the scientific community has been captivated, perplexed, and excited by the array of questions and issues on the horizon of scientific discovery. Each scientific discipline is considering which topics warrant study and public attention. The disciplines, as well as science as a whole, have enjoyed tremendous recent victories in discovery, innovation, and graduate education that have paid great dividends to the economy and made meaningful contributions to the state of knowledge. There are many successes to celebrate as we look forward to a new century and new millennium of scientific innovation.

Paradoxically, there are many reasons to believe that the legacy of success will not be perpetuated as we enter the next millennium. Indeed, like Alice in Wonderland (*1*) peering through the "looking glass" into a world that was not as it initially appeared, American science must examine our own situation more closely and ask whether it is time to celebrate our successes or to feel concern about our future. Our nation's scientific achievements may not herald a future of continuing excellence; rather, a broader and deeper view of our current status may portend the impending demise of our research enterprise. Specifically, the excellence of U.S. graduate education and the exciting and productive growth of our scientific enterprise over the past decades are at risk of being compromised if the scientific community does not turn its attention to the desperate need to enhance public understanding of our efforts and to promote improved kindergarten-through-college (K–16) education of our youth, some of whom will be the next generation of scientists.

H. G. Wells once said that "Human history becomes more and more a race between education and catastrophe." In the case of U.S. science, we have entered that race. Although scientists often identify themselves by disciplinary area, researchers from all fields are brought together by similar training, processes, missions, and dilemmas. As a whole, then, there are broad and all-encompassing issues that demand the attention of the entire scientific community. Foremost among the shared concerns is the education of the nation's youth. It is clear that science is at a critical juncture, and that education is the principal factor responsible for the future.

It has become common, particularly for politicians, to decry the educational system in America. We continue to hear that "Johnny can't read," and there is growing emphasis on the establishment of literacy programs for traditional students and for those who have graduated without the skills necessary to survive in the job market. While this general education focus is essential to the future of our nation, it is also critical to explore science and mathematics education, the academic areas most tied to job creation and economic growth. As a whole, American youth are not learning science well. Curricula and textbooks are highly variable, as is the preparation of science teachers. Student achievement scores are falling, and many of the best students are choosing other career paths. Additionally, students are often exposed to mythology and mysticism. There is a very real danger, therefore, that we are not attracting the most talented students or preparing and nurturing their interests and talents adequately for them to become the next generation of scientists and engineers.

Science Literacy for All Americans

One of the most frequently espoused goals of the American science enterprise is to "produce the finest scientists." While the science community must attend to the development and education of our future scientists, we must not lose sight of the fundamental need to nurture the public's interest in science. Experience and education, both formal education and informal acquisition of knowledge, provide people with a lens through which to perceive the world around them. As the scientific and technological influences on society become more prevalent, it will become increasingly important to help the citizenry develop a scientifically sharp lens to the world. Science literacy, after all, will provide a clear vision and understanding of everyday events and the devices of the 21st century. A quality science education will ensure that the public develops an appreciation for science that will spawn their support for future research and innovation. Furthermore, an excellent general science education for all children will attract and inspire talented students to pursue further education and careers in science. For the next century, then, we must embrace the goal of guaranteeing that all of our citizens gain a basic understanding of science and technology, and that those who are talented and interested are properly prepared to pursue fulfilling careers in science and technology. If we expect the nation to support science in the national interest, we must promote a national interest in science.

LOSING THE WAR

K–12 Science and Math Education

Over the past several years, we have witnessed evidence of the decreasing academic performance of our schools' children. This situation is most distressing when the academic performance of U.S. students is compared with that of students from other countries. While our world has moved on to ever more science and technology dependence, the basic education we provide for our children has handicapped them by not keeping pace in curriculum or pedagogy. We now routinely hear about the failures of our curricula, teaching materials, and classroom instruction, and our newspapers run stories about the disciplinary and safety problems that interfere with learning in our neighborhood schools. The erosion of kindergarten-through-high-school (K–12) education puts at risk not only the next generation of scientists but our whole national support system for scientific discovery.

In 1995, the Third International Mathematics and Science Study, TIMSS, was conducted as an overall comparison of the educational process and accomplishments of 50 countries (*2–7*). In a cross-sectional study, classroom activities and materials, and student achievement, were studied at about the 4th-, 8th-, and 12th-grade level.

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In science achievement, at the 4th-grade level, U.S. students scored near the top of all nations tested. Yet the good news appears to stop with our youngest science students. U.S. students scored only in the average range in 4th-grade math and in 8th-grade science and math. Regrettably, 12th graders from the United States performed near the bottom of the international distribution in both science and math, as did U.S. students in advanced placement physics and mathematics. It appears, then, that the education system is failing to meet the needs of students at all levels, our most challenged students and our most gifted scholars.

TIMSS

Information about TIMSS and related science indicators can be found at the TIMSS Web site

www.timss.org

and at the Science and Engineering Indicators Web site

www.nsf.gov/sbe/srs

TIMSS provided additional data to help explain some of the weak performance evident throughout the science education pipeline. First, the increasingly popular criticism that our educational system is "an inch deep and a mile wide" is supported strongly by the data.

For example, while our textbooks appear to be larger (literally) than those in most other countries, they are designed to cover many more topics but with far less depth. Textbooks in Germany and Japan cover between 8 and 17 topics for 4th-, 8th-, or 12th-grade science classes. By contrast, the average number of topics covered by U.S. science textbooks astonishingly ranges from the low 50s to the high 60s for our students. The coverage of this number of topics certainly is more information than students could meaningfully assimilate in the time frame provided by our academic calendar. In addition, it is repetitive and not thorough.

Compounding the problem is the general preparation of the faculty charged with teaching this broad array of topics in science classes. A significant portion of K–12 science teachers did not pursue science-related majors or minors in college. In the high-school grades, just over 60% of science teachers majored in science while in college. In the middle-school grades, under 20% were undergraduate science majors, and in grades 1 through 4, fewer than 10% of the science teachers had even an undergraduate minor in science or science education. Throughout the educational cycle, it would seem vital to have teachers who had a depth of experience and breadth of knowledge about their topics. It is only through true understanding and experience that teachers could become poised not only to impart critical knowledge and inspire intellectual curiosity, but also to convey a sense of excitement and enthusiasm about science to all students, from our youngest to our most advanced.

Diversity

In the sciences, there has been considerable recent attention to the need to encourage more women and underrepresented minorities to pursue a course of study that would prepare them for careers in the sciences. The greatest resource that we have in the United States is our people, and one of the strengths of this resource is the diversity of experience, perspective, and opinion that our human capital brings to the table. Without attention to the value of diversity, we risk losing a cadre of talented minorities and women. The value of diversity in the scientific work force is evident from numerous anecdotes. Women and underrepresented minorities have influenced research questions, methodologies, and theories across the spectrum of disciplines (*8*). For example, in the medical and biological sciences, advances in such diseases as sickle cell, hypertension, and diabetes are often attributed to African American scientists, physicians, and advocacy groups asking new or more emphatic questions about these conditions. Similarly, women and persons with disabilities have stimulated great developments in areas related to their interests and personal experiences.

The attrition of underrepresented groups appears to begin early in the education pipeline. While in elementary and middle school, many potentially talented students choose or are directed to pursue curricula weak in science and mathematics. By the time these students apply to college, they either have not developed an interest in science and mathematics or their deficiencies essentially preclude them from following a course of study in these fields.

For minorities, many of whom attend disadvantaged schools, the problem may be more intractable owing to limitations in resources. Schools with high minority populations have fewer resources than majority schools. Across the academic spectrum, from classes in English through the sciences, there is a consistent pattern of high-poverty schools having a higher percentage of their students taking classes from less-qualified teachers (*7*, pp. 1–27). There are even differential levels of Internet connectivity, with higher poverty schools (that is, those with a greater number of students receiving free or reduced-price lunches) reporting a lower percentage of instructional rooms having Internet access (*7*, pp. 1–23).

Again, these students are less likely to be counseled to take the appropriate classes to meet the eligibility requirements for college, they tend not to perform as well on standardized college admissions tests, and many never matriculate to 4-year college campuses, let alone ever consider a career in science. The human potential lost through this inequity is incalculable.

In California, one of the states now mandated to ignore racial and ethnic background as a criterion for participation, the schools are quickly approaching a time when no racial or ethnic group will be a majority. White students now account for 34% of the state's kindergarten class, Hispanics represent 47.4%, African Americans comprise 8.2%, Asians 7%, and the remaining students hail from a variety of ethnic backgrounds. When one examines the kind of ethnic mix that is becoming more common across the nation, it is essential that the changing demography and linguistic skills be recognized as decisions are made about directing children into different academic tracks.

Through a persistent inattention to diversity, the United States is creating a society of "information haves and have-nots," and a "digital divide" that is confounded with race, ethnicity, and socioeconomic status. This divide is depriving our nation and our global society of creative ideas, new perspectives, and vital contributions. Should this inattention continue, economists have predicted that it could leave a legacy of a divided nation and an overall reduced potential to our children.

Science Education in Conflict with Political and Personal Agendas

Taking a step back from the prescribed activities in the classroom, science education is facing an additional, more insidious threat. Science teachers across the nation, especially at the K–12 level, are facing a powerful and vocal minority of parents and community leaders who are distrustful of, and antagonistic toward, science. This negative attitude and distrust appear to be especially strong when scientific data conflict with religious beliefs.

The most familiar controversy in this respect is the growing challenge to the teaching of evolution that K–12 biology and science teachers are currently facing. Across the nation, there are stories of school boards prohibiting the teaching of evolution, of disclaimers printed inside textbooks, and of announcements asserting that evolution is merely a theory and should be viewed with skepticism. This summer, for example, the Kansas Board of Education decided to discourage the teaching of evolution and the Big Bang, and to eliminate questions about this topic from formal assessments of student achievement. In October, there were reports that the Illinois Board of Education had "slowly eliminated" the term "evolution" from its school standards and replaced it with the phrase "change over time." Similarly, the Alabama State Board of Education offers a textbook disclaimer that reads, "Evolution is a controversial theory some scientists present as scientific explanation for the origin of living things, such as plants, animals and humans. No one was present when life first appeared on earth. Therefore, any statement about life's origins should be considered as theory, not fact" (*9*). Certainly, biologists consider evolution to be a theory, but one buttressed by a wealth of factual data. The above statement is a distortion of the current state of knowledge. It is sadly ironic that this action has been taken by the School Board in Alabama, the very state where E. O. Wilson, a preeminent evolutionary biologist, was born.

Three quarters of a century ago, our nation witnessed the Scopes Monkey Trial. Today, again, there are biology teachers who admit that they are so intimidated that they omit the topic of evolution entirely from their curriculum. Others teach the content, sometimes facing angry and hostile colleagues, students, and officials. Perhaps more surprising, a recent survey suggests that 24% of Louisiana biology teachers believe in creationism, and 29% believe that it is an appropriate topic to be taught in their high-school biology classes (*9*).

These actions limit a student's ability to seek knowledge, examine data, and reach conclusions on the basis of objective data rather than emotion. The practices of omitting or distorting scientific information have the impact of leaving students less prepared for the challenges that they face in their college classes. Perhaps even more unfortunate is that these omissions teach students that it is appropriate to ignore knowledge and to reject information before exploring issues or using data in formulating opinions.

Some Good News

The desire to improve K–16 science and mathematics education is hardly new. For many years, individuals and organizations have been working to improve our schools. Over the past few years, as the alarm has grown louder, a number of efforts have been initiated to address the problems that have been identified and discussed.

In many parts of the country, schools have become involved in significant and meaningful partnerships with industry, nonprofit organizations, universities, and government offices and agencies. Each of the partners has provided time, advice, and resources to projects across the nation. The government has invested time, staff effort, funding, and other resources. The National Science Foundation's Statewide Systemic Initiative, and its urban and rural sister programs, are excellent examples of the government wing of the science community reaching out to the K–12 community on a very large scale. Individual and coordinated efforts by professional organizations and scientific societies have provided leadership and guidance to the science education community. Two recent national efforts have helped to guide curricula and pedagogy in science education. A "bottoms-up" effort was spearheaded by the National Academy of Sciences (*10*) and included the participation of thousands of scientists and educators, and the AAAS Project 2061 (*11*) was a systematic effort to delineate the benchmarks that students should be expected to reach at different points of their education. As the standards and benchmarking movements have begun to affect the nation, most teachers have already begun to implement some of the recommendations, and many have become active participants in reforming K–12 education. Science and technology (S&T) museums are also forging remarkably effective partnerships with schools and with teacher training efforts. Among the most notable are the Smithsonian in Washington, DC; COSI in Ohio; and such California museums as the Exploratorium in San Francisco, the new Tech in San Jose, the Monterey Bay Aquarium, and the new Marine Discovery Center at the University of California, Santa Cruz. There is mounting evidence that these efforts collectively are having an impact.

Undergraduate Education

As students make their way through the current educational pipeline, the academic weaknesses to which they are subjected will accompany them through the gates of our universities. Many students enter college already deficient in the knowledge and skills of math and science, and many have never developed an interest in these topics. Perhaps worse, many students develop a fear of science and math during their primary and secondary education. Nevertheless, it is the responsibility of colleges and universities to ensure that *all* students leave school with a quality education that prepares them for the challenges they will face after graduation.

Many of the freshmen who enter college academically underprepared in science and math compound these weaknesses by pursuing a course of study that minimizes their contact with these areas of study. Undergraduate institutions often contribute to the problem by not constructing systematic requirements that would compel students to gain proficiencies in science and math. That is, the curricular requirements and guidance offered at many institutions allow or encourage students to maintain their deficiencies and avoid gaining new exposure and skills in these subjects.

For students who show a curiosity about science topics and issues, or who would like to take classes in an effort to broaden their interests, the attitudes of some faculty and counselors, along with widespread student perceptions, may interfere with enrollment. That is, student views of the work load and grading policies of many science classes may deter students from pursuing their interests. Reinforcing these negative attitudes, many universities use introductory science courses as "weed out" classes, intentionally imposing a more rigorous work load and grading policy. At some schools, for example, the failure rate in introductory biology and chemistry reportedly approaches 30 to 40%, a statistic that some administrators and faculty state with pride. Rather than entice students into the sciences, highlight the inherently fascinating aspects of our disciplines, and stimulate student interests, some faculty tend to make science classes a test of survival, thus ensuring flight from our fields. Throughout the pipeline, then, in our attempts to teach in a "rigorous" manner, we often make science classes an arduous and tedious experience, rather than an expansive, galvanizing one.

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Graduate Education

As important as undergraduate education is, it is the U.S. system of graduate education that is credited with establishing and maintaining our nation's reputation for scientific excellence. After all, students flock from around the world to our graduate programs. Yet U.S. graduate education, while still the envy of the world, is also beginning to show persistent blind spots.

Although academics often pride themselves on being open-minded and flexible, a trait that is demonstrated daily in our approaches to science and scholarship, in many ways we are quite conservative in our approach to pedagogy and graduate training. Academia still highly values traditional academic research careers, and still touts specificity in doctoral training. There are many who believe that these practices may ultimately harm our students. We are living in a time of changing expectations and opportunities. Students are pursuing new and exciting career opportunities, and rather than explore these avenues with great pride, many are discouraged by a professorate that refuses to recognize the extraordinary new opportunities and changing landscape.

Employers in industry, government, and other nontraditional professions continually ask that academia provide doctoral-level students with a more expansive base of knowledge and the ability to apply and adapt skills and knowledge to new and emerging challenges. Breadth and flexibility, rather than specificity and rigid tradition, are prized in much of the emerging job market. Industry also looks for professionals who have leadership skills, who understand and embrace teamwork approaches, who have developed oral and written communication skills, who have gained knowledge about business structure and economic theory, and who understand cultural norms and mores. Graduate programs that address these needs are likely to be the outstanding programs of the future.

Alternative careers and broader training are now commonly discussed as necessary goals for the training of current and future graduate students. There appears to be a growing number of incoming graduate students who are interested in the new career paths and who look to their faculty advisors for guidance. Yet many faculty still believe that research faculty positions are the only careers worth pursuing, and they often speak to their students about alternative careers in a manner that suggests, explicitly or implicitly, that nontraditional careers are for the less-qualified, less-talented graduates. This stigmatizing of new and emerging professional opportunities will be increasingly troublesome for students and for graduate programs that wish to educate the scientific leaders of the future.

WINNING THE BATTLES

Battles in Response to Crisis

It seems that scientists, by their very nature, are exquisitely responsive when there is an urgent call to arms. Indeed, many of the discoveries and advancements throughout history, as well as the successful budget battles, have come in response to moments of profound national need or perceived crisis.

In the 1860s, for example, the Land Grant Movement was the response to our nation's need for well-educated engineers and scientists to steer and manage the development of our land. The result, of course, is an enduring system of science-based, rather than religion-based, higher education. In World War II, scientists fought and won battles on a number of fronts, from the development of synthetic rubber and nuclear energy to advances in medical and behavioral sciences. The War provided scientists with the incentives, inspiration, public support, and the financial resources to pursue discoveries and innovations in the national interest, and against a tangible enemy. Forty years ago, the crisis was Sputnik. With the launch of the Soviet satellite, America's widely held belief that we were preeminent in science and education was shattered. Thomas N. Bonner wrote that the Russians had "punctured our magnificent conceit by making it clear that in a number of related areas of basic research and applied technology they have already outdistanced us...." Science and education had become the "main battleground of the Cold War" (*12*). The nation took notice of the value of science and invested in it, and the result was that the National Science Foundation (NSF) and others organized a *total* curriculum revision. Many of today's science leaders were the beneficiaries of these efforts. Among the crises that have energized the science community lately are the budget crises that we experience periodically. Yet, while science has achieved many victories, we have also lost some battles, including the discouragingly low percentage of our gross domestic product that is spent on nondefense research and development.

Battles of Discovery That Influenced Society

In the past few years, science has won a number of battles in the arena of discovery. As we look to the next century, it appears that we are in the midst of a platinum age of scientific discovery and innovation that will greatly influence society. Economists estimate that at least 50% of our nation's economic growth over the past half-century is the result of S&T advances. It is no surprise that scientific discovery has been such a profitable investment when one considers the emergence of multibillion-dollar industries that are directly linked to scientific breakthroughs. The biotech industry, information technology, new pharmaceuticals, and medical imaging all contribute to our economy in jobs, products, and services.

In addition to the financial dividends paid from these investments, discoveries have changed our daily lives. The developments in medical imaging have improved life expectancy and reduced the need for exploratory surgeries. The open, nonclaustrophobic MRI, x-rays, CAT scans, PET scans, and the like are the result of the investments in basic research in physics, chemistry, math, and computer science. Much of this research was initially funded with federal monies associated with the Department of Energy and the Department of Defense. Similarly, environmental sciences have seen a surge in activity, discovery, development, and public attention. Clean cars, the fodder of science fiction just a few years ago, are now seen routinely in many cities, and charging stations are available on public streets and airport parking lots.

"In the absence of knowledge and understanding, political or religious rhetoric is persuasive"

As recently as the early and mid-1990s, most Americans had not heard of the Information Superhighway. Yet, the research that led to the Internet began in the 1940s as basic physics research. Now, decades later, telecommunications companies are laying "glass" cables, or fiber optics, around the globe, and indeed, these developments may soon become overshadowed by advances in satellite or microwave communications technologies. The Internet has already revolutionized communication, and its potential influence has not yet been fulfilled or even conceptualized. Our lives have changed forever with the immediacy of information access and transfer, and the ease of communication, that the Internet allows.

In the area of life sciences, Human Genome research is a cutting-edge area that is fascinating both scientists and the public. A common roundworm, *Caenorhabditis elegans*, or *C. elegans*, has gained global celebrity with the recent publication of the nearly complete sequence of 97 million bases of its genome (*13*). The completion of the genome mapping sets biology on a new era of exploration and innovation. The recent scientific development will allow biologists to compare whole genomes across species, to explore the array of genes necessary for complex multicellular organisms to function, and to understand the functioning of individual genes and gene clusters and their evolution. Also fascinating to the scientific and nonscientific communities alike are the recent advances in cloning and genetic engineering. Again, the ultimate impact that these discoveries and advances will have on the daily lives of people across the globe is just now taking shape.

Battles of Public Opinion

An additional battlefield is that of public opinion. A variety of surveys suggest that the public is generally supportive of science. The Washington, D.C.–based organization Research!America has conducted and reviewed a number of the surveys. Their data demonstrate that, in many respects, science is winning in the court of public opinion, especially with respect to medical research. More than 80% of respondents to a national survey asserted that science and technology engender "satisfaction and hope" or "excitement and wonder." The American public reportedly has a very high opinion of science, with more than 50% of those surveyed agreeing that scientists have "very great" prestige. People reportedly believe that the benefits of scientific research outweigh the harmful results, and in state-by-state surveys, the vast majority of respondents believed that the United States should maintain a leadership role in medical research.

In many respects, it is no surprise that the public proclaims its support for medical research, and for general science and technology. After all, advances in these areas are, in many respects, tangible and their value is easily understandable. Yet the data from Research!America also suggest support for basic research, an area that is not well understood by the public. Survey data from a selection of states indicate that there is broad public support for basic research and for federal spending to sponsor science at universities. These findings are heartening to those who understand that basic research, although it brings no immediate tangible benefits to the public, is the mechanism that advances the frontiers of knowledge and thus should garner support from the government and the public.

While the data suggest fairly strong and broad favorable public opinion about science, Research!America's information also illuminates what may be a central obstacle to the public support: It appears that the public has a very weak understanding of scientific principles and theories. Indeed, many Americans do not understand even the most basic scientific concepts. For example, only about 10% of respondents understood the term "molecule," about 20% understood the term "DNA," and half of those surveyed actually believed that dinosaurs and early humans lived at the same time. Similarly, fewer than half of the respondents knew that electrons are smaller than atoms or that the Earth orbits the sun once per year. Data such as these may underlie the apparent paradox that leads school boards to try to eliminate the teaching of evolution. In the absence of knowledge and understanding, political or religious rhetoric is persuasive.

Another widely read public opinion survey, this time focused on the medical and biotech sciences, was reported in the 11 January 1999 special issue of *Time* magazine on "The Future of Medicine" (*14*). This survey, titled "What people think," reported public perceptions of research in the "Biotech Century." These results, like those from Research!America, illustrate that the public has many positive perceptions about science, but that there remains underlying confusion and suspicion. On the issue of genetic information, for example, more than 60% of those surveyed indicated that they would like to use genetic profiling to determine what diseases they, or their children, might suffer from later in life, and if given the opportunity to use genetic information to decide traits for their babies, 60% would use the information to rule out fatal diseases, 33% would ensure greater intelligence, 12% would influence height or weight, and 11% would use the information to determine the gender of their offspring. Sixty-two percent of respondents supported government regulation of gene therapy used to prevent or cure diseases, and respondents were about evenly split on whether the government should regulate animal cloning, or have oversight of the use of genetic testing to select traits in unborn children. It was clear, however, that Americans overwhelmingly supported privacy of this information. More than 90% of respondents wanted to deny access to genetic information from insurance companies and employers.

As is well known, confusion often leads to distrust. When scientific findings appear confusing or contradictory, it is no surprise that people disregard them or doubt their veracity. The First Amendment Center in Nashville recently issued a report on the divide between journalism and science (*15*). One of the findings of their report is that the public, while positive in its assessment of the value of science and innovation, can be quite suspicious of motive, especially when they perceive a possible motive of financial gain. Thus, for example, the public tends to distrust claims by manufacturers that their newly developed products are safe. The *Time* survey also found the public to be suspicious of the motives of private industry. Respondents, for example, seem to distrust the safety of some products, such as food, produced through genetic engineering, and believe it should be labeled for consumer information.

After reviewing the data from Research!America, from the *Time* survey, and from the First Amendment Center, one might question what factors are contributing to the public misunderstandings and confusion about science. Contributing to public confusion may be the fact that scientists are socialized to criticize one another's work. This is done, of course, to promote better science through a process of constructive criticism and revision of hypotheses and methodologies. But when that criticism is aired publicly, it is often misperceived and misunderstood as a rejection of the previously reported scientific finding, rather than as a suggestion that refinements or limitations might be necessary. The public might respond with confusion, assuming that science is inaccurate or self-serving and that results cannot be trusted. Recent examples of scientific policy discussions that have been greeted with some public skepticism include the newly released obesity standards, appropriate age for mammograms, changes in global warming, and of course, the risks and benefits of Viagra.

What to Do

Like Alice in the "looking glass world," the world of scientific achievement and potential may not be exactly as originally perceived. The successes and tradition of excellence that the United States has enjoyed for so long are not guaranteed to continue. Indeed, a closer look suggests that our potential for the future is being undermined by the deterioration of our base. By taking a closer look and developing a clear view, however, the scientific community is becoming better equipped to adapt to our environment. We have learned to pursue scientific inquiry and discovery despite bureaucratic complexities and hindering academic traditions. We have been able to improve the public's understanding of some areas of science, despite the low level of science literacy and the high level of distortion by the tabloid press. Just as Alice became effective in her world, we are coping rather well in ours.

It is time, then, that the science community focus widespread effort on repairing the education pipeline so that our base stops eroding and begins strengthening. In developing a plan for the future of science education, scientists should first focus our attention on the entities over which we have the most control: the colleges and universities. Attending our undergraduate institutions are our future scientists and engineers. But also sitting in our lecture halls and seminar rooms, and perhaps more importantly, are the future teachers, legislators, doctors, executives, lawyers, and community members. We need to reexamine and restructure undergraduate education to ensure that we are reaching all of these student groups.

Every student sitting in our classrooms has a need for science education. Conversely, every science student has a need for a well-rounded, broad education in the humanities and arts. We must ensure that all undergraduate students have science, math, and technical skills for the 21st century. We must guarantee that all science majors receive broad exposure to global and cultural issues, so that our scientists have a foundation in literature, art, international culture and foreign language, political theory and practice, and, definitely, written and oral communication to be truly effective in our emerging global society. We must also insist on science and math literacy in our professional schools. After all, it is in these programs that we have the greatest opportunity to touch the lives of budding professionals and help them to make the link between our science and their service.

We must improve and sustain graduate education. We, the faculty and administrators of our fine U.S. universities and colleges, have no excuse for not acting. This is our responsibility and no one else's. We must continue to provide the world's best scientific education, but we must also embrace the career trajectories of the future and nurture our doctoral students' aspirations, whether academic or nontraditional.

On the topic of graduate education, it is increasingly popular to assert that we are overproducing Ph.D.'s. The notion of offering too much education to too many people is absurd, especially in the emerging scientifically and technologically complex marketplace. The discussion, to date, has been driven by the fear of a shrinking academic job market. People are afraid that there will not be sufficient jobs if too many new doctoral-level scientists are trained. Instead of an overproduction of Ph.D.'s, it should be contended that there is an underemphasis on the value of the training that a Ph.D. education provides. Scientists are trained to observe situations, hypothesize plausible explanations, propose solutions to problems, collect and analyze data, communicate their findings, and advocate their positions. These skills, regardless of specific area of expertise, should allow scientifically trained individuals to succeed and excel in many positions in 21st-century organizations. Would it not be refreshing to see a scientist take his or her place in a governor's office (after all, a wrestler did it) or have more scientists on the floor of the House or the Senate? Would it not be appropriate for doctoral-level scientists to take more seats in the corporate board room? Leadership positions in every field could certainly benefit from the training, skills, and talents of scientifically trained executives. Thus, if we disregard the academic job market argument for a moment, the idea of limiting access to education makes no sense. After all, we live in a time defined by knowledge access and transfer, and one could argue that maximizing the education of all citizens who are motivated and capable could only have the effect of improving our nation's economic competitiveness and the quality of life of our citizens. When it comes to education, more is better.

Project 20/20: Scientists on School Boards

After pondering the positions of leadership that scientists are well suited to pursue, and after considering the array of educational problems facing our nation, I propose that the scientific community pursue a course of direct intervention that may best use the talents of scientifically trained citizens. We should begin a campaign to ensure that there is at least one scientist, engineer, or scientifically literate professional on every school board in America. For many years, the strategy of becoming involved in school boards has been pursued by a variety of grass roots organizations who see school boards as an opportunity to further their goals or agendas. Over the past couple of decades, for example, a number of creationists have positioned themselves on these education boards. The results of their actions are clear. There is a tremendous opportunity to be a positive influence by joining school boards. Board actions affect the widest possible sweep of the public by helping to determine such essential elements as curriculum reform, textbook choice, and pedagogy.

Scientifically literate individuals on school boards will have the value of improving vision for our schools. It is for this reason that I am referring to this plan as "Project 20/20" and I hope that it will result in the next generation receiving an education that will provide them with 20/20 vision of the world around them. We need to provide the entire citizenry with a lens that gives them a clear vision and understanding of their environment and their culture, which increasingly reflect the scientific, technical, and digital advances of our times.

We can start by identifying those members of AAAS who are already school board members. From there, we can begin to identify additional scientifically literate school board members. Finally, we can encourage more scientists to become active and pursue seats on their local boards.

Project 20/20 should be sustained and supported by AAAS. That is, across the nation, as scientists, technicians, teachers, or other scientifically literate and interested individuals take their seats on school boards, AAAS should be their home base. AAAS should provide the necessary information or advice to help these school board members enhance scientific content and accuracy for our schools. The Association should provide support and linkages for pedagogy, curricula, textbooks, assessment, and partnerships. And AAAS can provide programming time at its annual meeting to assist these individuals in networking with each other and pursuing a mutual agenda.

We all view the world through the lens of our culture and experiences. In the United States, and throughout much of the English-speaking world, our perceptions are guided by a common imagery that we gain from such popular sources as *Alice in Wonderland* and *Through the Looking Glass*. Children spend more time in school than they do in any other activity throughout their development. Thus, education is perhaps the factor that grinds the lens with most influence. All people, from all cultures, perceive the world through the lens of their education and accumulated knowledge.

As we approach the next millennium, we must remember that we are living in a dynamic time in which our personal and professional lives change rapidly. Education for our children, and lifelong education for all of us, must be paramount in this evolving era.

An anonymous source has been quoted as saying, "In times of change, it is the learners who will inherit the earth while the learned will find themselves beautifully equipped for a world that no longer exists."

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