

## **WHY WE NEED TO UNDERSTAND SCIENCE**

### **Ignorance of science threatens our economic well-being, national security, and the democratic process. We must do better.**

**By Carl Sagan**

*From Parade Magazine, September 10, 1989* – As I got off the plane, he was waiting for me, holding up a sign with my name on it. I was on my way to a conference of scientists and TV broadcasters, and the organizers had kindly sent a driver.

"Do you mind if I ask you a question?" He said as we waited for my bag. "Isn't it confusing to have the same name as that science guy?"

It took me a moment to understand. Was he pulling my leg? "I am that science guy," I said. He smiled. "Sorry. That's my problem. I thought it was yours too." He put out his hand. "My name is William F. Buckley." (Well, his name wasn't exactly William F. Buckley, but he did have the name of a contentious TV interviewer, for which he doubtless took a lot of good-natured ribbing.)

As we settled into the car for the long drive, he told me he was glad I was "that science guy" -- he had so many questions to ask about science. Would I mind? And so we got to talking. But not about science. He wanted to discuss UFOs, "channeling" (a way to hear what's on the minds of dead people -- not much it turns out), crystals, astrology ... He introduced each subject with real enthusiasm, and each time I had to disappoint him: "The evidence is crummy," I kept saying. "There's a much simpler explanation." As we drove on through the rain, I could see him getting glummer. I was attacking not just pseudoscience but also a facet of his inner life.

And yet there is so much in real science that's equally exciting, more mysterious, a greater intellectual challenge--as well as being a lot closer to the truth. Did he know about the molecular building blocks of life sitting out there in the cold tenuous gas between the stars? Had he heard of the footprints of our ancestors found in 4-million-year-old volcanic ash? What about the raising of the Himalayas when India went crashing into Asia? Or how viruses subvert cells, or the radio search for extraterrestrial intelligence or the ancient civilization of Ebla? Mr. "Buckley" -- well-spoken, intelligent, curious -- had heard virtually nothing of modern science. He wanted to know about science. It's just that all the science got filtered out before it reached him. What the society permitted to trickle through was mainly pretense and confusion. And it had never taught him how to distinguish real science from the cheap imitation.

All over America there are smart, even gifted, people who have a built-in passion for science. But that passion is unrequited. A recent survey suggests that 94% of Americans are "scientifically illiterate."

### **A prescription for disaster**

We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. This is a clear prescription for disaster. It's dangerous and stupid for us to remain ignorant about global warming, say, or ozone depletion, toxic and radioactive wastes, acid rain. Jobs and wages depend on science and technology. If the United States can't manufacture, at high quality and low price, products people want to buy, then industries will drift out of the United States and transfer a little prosperity to another part of the world. Because of the low birthrate in the '60s and '70s, the National Science Foundation projects a shortage of nearly a million professional scientists and engineers by 2010. Where will they come from? What about fusion, supercomputers, abortion, massive reductions in strategic weapons, addiction, high-resolution TV, airline and airport safety, food additives, animal rights, superconductivity, Midgetman vs. rail-garrison MX missiles, going to Mars, finding cures for AIDS and cancer? How can we decide national policy if we don't understand the underlying issues?

I know that science and technology are not just cornucopias pouring good deeds out into the world. Scientists not only conceived nuclear weapons: they also took political leaders by the lapels, arguing that their nation -- whichever it happened to be -- had to have one first. Then they arranged to manufacture 60,000 of them. Our technology has produced thalidomide, CFCs, Agent Orange, nerve gas, and industries so powerful they can ruin the climate of the planet. There's a reason people are nervous about science and technology.

And so the image of the mad scientist haunts our world from Dr. Faust to Dr. Frankenstein to Dr. Strangelove to the white-coated loonies of Saturday morning children's TV. (All of this doesn't inspire budding scientists.) But there's no way back. We can't just conclude that science puts too much power into the hands of morally feeble technologists or corrupt, power-crazed politicians and decide to get rid of it. Advances in medicine and agriculture have saved more lives than have been lost in all the wars in history. Advances in transportation, communication, and entertainment have transformed the world. The sword of science is double-edged. Rather, its awesome power forces on all of us, including politicians, a new responsibility--more attention to the long-term consequences of technology, a global and transgenerational perspective, an incentive to avoid easy appeals to nationalism and chauvinism. Mistakes are becoming too expensive.

Science is much more than a body of knowledge. It is a way of thinking. This is central to its success. Science invites us to let the facts in, even when they don't conform to our preconceptions. It counsels us to carry alternative hypotheses in our heads and see which best match the facts. It urges on us a fine balance between no-holds-barred openness to new ideas, however heretical, and the most rigorous skeptical scrutiny of everything -- new ideas and established wisdom. We need wide appreciation of this kind of thinking. It works. It's an essential tool for a democracy in an age of change. Our task is not just to train more scientists but also to deepen public understanding of science.

## **How bad is it?**

Very bad. "It's Official," reads one newspaper headline: "We Stink in Science." Less than half of all Americans know that the Earth moves around the Sun and takes a year to do it-- a fact established a few centuries ago. In tests of average 17-year-olds in many world regions, the U.S. ranked dead last in algebra. On identical tests, the U.S. kids averaged 43% and their Japanese counterparts 78%. In my book, 78% is pretty good -- it corresponds to a C+, or maybe even a B-; 43% is an F. In a chemistry test, students in only two of 13 nations did worse than the U.S. Compared to us, Britain, Singapore, and Hong Kong were so high they were almost off-scale, and 25% of Canadian 18-year-olds knew just as much chemistry as a select 1% of American high school seniors (in their second chemistry course, and most of them in "advanced" programs). The best of 20 fifth-grade classrooms in Minneapolis was outpaced by every one of the 20 classrooms in Sendai, Japan, and 19 out of 20 in Taipei, Taiwan. South Korean students were far ahead of American students in all aspects of mathematics and science, and 13-year-olds in British Columbia (in Western Canada) outpaced their U.S. counterparts across the boards (in some areas they did better than the Koreans). Of the U.S. kids, 22% say they dislike school; only 8% of the Koreans do. Yet two-thirds of Americans, but only a quarter of the Koreans, say they are "good at mathematics."

## **Why we're flunking**

How do British Columbia, Japan, Britain, and Korea manage so much better than we do? During the Great Depression, teachers enjoyed job security, good salaries, respectability. Teaching was an admired profession, partly because learning was widely recognized as the road out of poverty. Little of that is true today. And, so, science (and other) teaching is too often incompetently or uninspiringly done, its practitioners, astonishingly, having little or no training in their subjects -- sometimes themselves unable to distinguish science from pseudoscience. Those who do have the training often get higher-paying jobs elsewhere.

We need more money for teachers' training and salaries, and for laboratories -- so kids will get hands-on experience rather than just reading what's in the book. But all across America, school-bond issues on the

ballot are regularly defeated. U.S. parents are much more satisfied with what their children are learning in science and math than are, say, Japanese and Taiwanese parents -- whose children are doing so much better. No one suggests that property taxes be used to provide for the military budget, or for agriculture, or for cleaning up toxic wastes. Why just education? Why not support it from general taxes on the local and state levels? What about a special education tax for those industries with special needs for technically trained workers?

American kids don't do enough schoolwork. The average high school student spends 3.5 hours a week on homework. The total time devoted to studies, in and out of the classroom, is about 20 hours a week. Japanese fifth-graders average 33 hours a week.

But most American kids aren't stupid. Part of the reason they don't study hard is that they've received few tangible benefits when they do. Competency (that is, actually knowing the stuff) in verbal skills, mathematics, and science these days doesn't increase earnings for average young men in their first eight years out of high school -- many of whom take service rather than industrial jobs.

In the productive sectors of the economy, though, the story is different. There are furniture factories, for example, in danger of going out of business -- not because there are no customers but because few entry-level workers can do simple arithmetic. A major electronics company reports that 80% of its job applicants can't pass a fifth-grade math text -- and that's an American, not a Korean, fifth-grade test. The United States is already losing some \$25 billion a year (mainly in lost productivity and the cost of remedial education) because workers, to too great a degree, can't read, write, count, or think. Parents should know that their children's livelihoods may depend on how much math and science they know. Now, while the kids are in school, is the time for them to learn. Parents might encourage their schools to offer -- and their kids to take -- comprehensible, well-taught advanced science courses. They might also limit the amount of mind-numbing TV their children watch.

## **What we can do**

Those in America with the most favorable view of science tend to be young, well-to-do, college-educated white males. But three-quarters of new American workers between now and 2001 will be women, nonwhites, and immigrants. Discriminating against them isn't only unjust. It's also self-defeating. It deprives the American economy of desperately needed skilled workers.

Black and Hispanic students are doing better in standardized science tests now than in the late 1960s, but they're the only ones who are. The average math gap between white and black U.S. high school graduates is still huge -- two to three grade levels; but the gap between white U.S. high school graduates and those in, say, Japan, Canada, Great Britain or Finland is more than twice as big. If you're poorly motivated and poorly educated, you won't know much-- no mystery here. Suburban blacks with college-educated parents do just as well in college as suburban whites with college-educated parents. Enrolling a poor child in a Head Start program doubles his or her chances to be employed later in life; one who completes an Upward Bound program is four times as likely to get a college education. If we're serious, we know what to do.

What about college and university? There are obvious steps similar to what should be done in high schools: salaries for teachers that approach what they could get in industry; more scholarships, fellowships, and laboratory equipment; laboratory science courses required of everyone to graduate; and special attention paid to those traditionally steered away from science. We should also provide the financial and moral encouragement for academic scientists to spend more time on public education -- lectures, newspaper and magazine articles, TV appearances. This requires scientists to make themselves understandable and fun to listen to. To me, it seems strange that some scientists, who depend on public funding for their research, are reluctant to explain to the public what it is that they do. Fortunately, the number of scientists willing to speak to the public -- and capably -- has been increasing each year. But there are not yet nearly enough.

Virtually every newspaper in America has a daily astrology column. How many have a daily science column? When I was growing up, my father would bring home a daily paper and consume (often with great gusto) the baseball box scores. There they were, to me dry as dust, with obscure abbreviations (W, SS, SO, W-L, AB, RBI), but they spoke to him. Newspapers everywhere printed them. I figured maybe they weren't too hard for me. Eventually I too got caught up in the world-of baseball statistics. (I know it helped me in learning decimals, and I still cringe a little when I hear that someone is "batting a thousand." But 1.000 is not 1,000. The lucky player is batting one.)

Or take a look at the financial page. Any introductory material? Explanatory footnotes? Definitions of abbreviations? None. It's sink or swim. Look at those acres of statistics! Yet people voluntarily read the stuff. It's not beyond their ability. It's only a matter of motivation. Why can't we do the same with math, science, and technology?

By far the most effective means of raising interest in science is television. There's lots of pseudoscience on TV, a fair amount of medicine and technology, but hardly any science -- especially on the three big commercial networks, whose executives think science programming means ratings declines and lost profits, and nothing else matters. Why in all America is there no TV drama that has as its hero someone devoted to figuring out how the universe Works?

Stirring projects in science and technology attract and inspire youngsters. The number of science Ph.D.s peaked around the time of the Apollo program and declined thereafter. This is an important potential side-effect of such projects as sending humans to Mars, or the Superconducting Supercollider to explore the fine structure of matter, or the program to map all human genes.

Every now and then, I'm lucky enough to teach a class in kindergarten or the first grade. Many of these children are curious, intellectually vigorous, ask provocative and insightful questions, and exhibit great enthusiasm for science. When I talk to high school students, I find something different. They memorize "facts." But, by and large, the joy of discovery, the life behind those facts, has gone out of them. They're worried about asking "dumb" questions; they're willing to accept inadequate answers; they don't pose follow-up questions; the room is awash with sidelong glances to judge, second-by-second, the approval of their peers. Something has happened between first and 12th grade, and it's not just puberty. I'd guess that it's partly peer pressure not to excel (except in sports); partly that the society teaches short-term gratification; partly the impression that science or math won't buy you a sports car; partly that so little is expected of students; and partly that there are so few role models for intelligent discussion of science and technology or for learning for its own sake.

But there's something else: Many adults are put off when youngsters pose scientific questions. Children ask why the Sun is yellow, or what a dream is, or how deep you can dig a hole, or when is the world's birthday or why we have toes. Too many teachers and parents answer with irritation or ridicule, or quickly move on to something else. Why adults should pretend to omniscience before a 5-year-old, I can't for the life of me understand. What's wrong with admitting that you don't know? Children soon recognize that somehow this kind of question annoys many adults. A few more experiences like this, and another child has been lost to science.

There are many better responses. If we have an idea of the answer, we could try to explain. If we don't, we could go to the encyclopedia or library. Or we might say to the child: "I don't know the answer. Maybe no one knows. Maybe when you grow up, you'll be the first to find out."

But mere encouragement isn't enough. We must also give children the tools to winnow the wheat from the chaff. I'm haunted by the vision of a generation of Americans unable to distinguish reality from fantasy, hopefully clutching their crystals for comfort, unequipped even to frame the right questions or to recognize the answers. I want us to rescue Mr. "Buckley" and the millions like him. I also want us to stop turning out leaden, incurious, unimaginative high school seniors. I think America needs, and deserves, a citizenry with minds wide awake and a basic understanding of how the world works.

Public understanding of science is more central to our national security than half a dozen strategic weapons systems. The sub-mediocre performance of American youngsters in science and math, and the widespread adult ignorance and apathy about science and math, should sound an urgent alarm.

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Carl Sagan is widely known for his research on the atmospheres of Venus, Mars, and Titan, and for his skill at describing astronomical discoveries and concepts to the public. At the January 1993 meeting of the American Astronomical Society in Phoenix, Arizona, Carl Sagan was presented with the first Annenberg Foundation Award, for leadership in education in astronomy. In his remarks that followed, and in a press conference earlier in the day, Sagan addressed the state of science education and science literacy in today's society. The following article summarizes his thoughts on why we as a society need to understand science. Reprinted with permission from Parade magazine, copyright (C) 1989. Illustrations adapted from originals by Patrick McDonnell.

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