



An Addiction to Education at All Levels

Bruce Alberts

I grew up long before the Internet, at a time when there was hardly anything of interest to watch on our tiny black and white television—in fact, the available TV channels would mostly display “test patterns.” As a result, school was by far the most interesting activity in my life; in comparison, the hot, humid summer vacation months, spent at home near Chicago without air conditioning, seemed endlessly boring. Later, accumulating the 21 Boy Scout merit badges needed for Eagle rank would fill my summers much more productively—a model that I have suggested schools might use today, to allow students to get credit for deeply exploring a few of their individual passions.

Why did I find school so interesting? In an era before Education Standards, my public school teachers had been free to be creative, devoting an entire year to Latin America, for example. I also distinctly remember writing a long report on “The Farm Problem” in seventh grade, in which I was forced to answer a question that I initially found incomprehensible: why was our government paying US farmers for *not* growing a crop? The next year, I was assigned a class presentation to explain how a television set works. And, in ninth grade, a highlight was grappling with science books in the huge, overwhelming Chicago public library, in order to write a report on how spectroscopy is used in chemistry.

I was surprised to do so well in high school, and I especially loved chemistry. For each of the four years, we were assigned to the same “home room” to start the school day, and by chance, mine was a chemistry lab full of what are now considered hazardous materials. Sitting in a trough each day in front of my seat at a lab bench were bottles of strong acids, bases, and pure chemicals—making chemistry much more exciting than the abstractions in textbooks.

Bruce Alberts engaging with budding scientists.

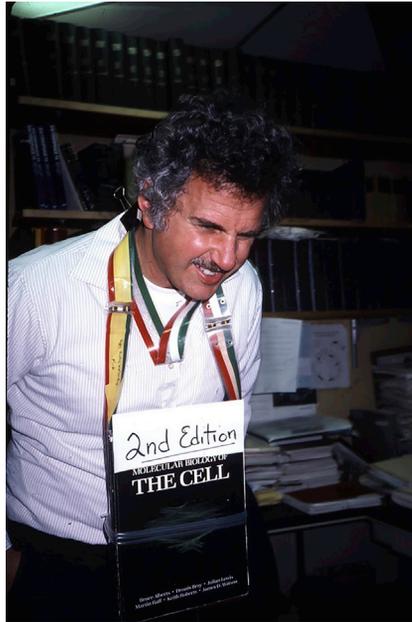


My inspiring home-room teacher, Carl Clader, eventually became chair of New Trier High School's Science Department; later, when serving as president of the US National Academy of Sciences, I had the privilege of returning to help honor him in retirement.

I have always been quite disorganized; true to form, I signed up too late for my oversubscribed high school biology class. In its place, I joined a very small class in amateur radio. My first introduction to biology was thus as a Harvard freshman. The first semester of the Harvard Course was tedious. It was taught by a botanist who believed in vitalism—the claim that living organisms cannot be explained by the normal laws of physics and chemistry, and I can remember almost nothing from that class. But then, boom!—in the second semester, we were assigned and examined on a new textbook just published in January 1957: *Principles of Zoology* by John A. Moore, then a 42-year-old professor at Columbia. This beautifully written book explained, in a highly conceptual way, how our understanding of heredity had developed step by step through careful experiments, quoting from original papers and reprinting original figures. It was the most exciting science book that I had ever read (much later, I was able to make a 1972 edition freely available on the web at <http://www.nap.edu/catalog/13199/heredity-and-development-second-edition>). Then, in 1959–1960, an insanely (and serendipitously) successful senior thesis research project, carried out with my tutor Jacques Fresco in Paul Doty's laboratory, committed me to a life of science.

Skip ahead about 25 years, and I am a professor of biochemistry at University of California, San Francisco (UCSF) with three children in the San Francisco Public Schools. After many years as an active school volunteer, my wife Betty had become the president of the San Francisco Parent Teacher Association (PTA). Recruited to listen to her speak on the radio nearly every two weeks at the evening school board meetings, I suddenly became aware of the vast mismatch between my well-supported institution, UCSF, and the science teachers in a very needy public school district, San Francisco Unified School District (SFUSD). This led to a meeting with a small group of outstanding science teachers, who were asked how our university might help: the result was a vigorous, bottom-up partnership between SFUSD teachers and the faculty and young scientists at UCSF that is now in its 30th year (<http://biochemistry2.ucsf.edu/programs/sep/>).

Ever since that time I have been deeply impressed by my interactions with large numbers of outstanding, dedicated science and math teachers at the precollege level. I have incredible respect for the difficulty of their jobs, and I am amazed by their skill, stamina, and dedication. And I have learned a tremendous amount from them about how to teach science. For example, I learned that one should always make students struggle with a problem that was solved by a scientific discovery, coming up with their own possible answers, before telling them the answer that science provides. Classroom research with long-term follow up reveals that students are likely to retain the understandings that they obtain in this way a year later; in contrast, scientific facts that are merely told to students and memorized for an exam tend to be quickly forgotten. This principle forms the



Bruce Alberts ca. 1987 donning a copy of *Molecular Biology of the Cell*, the essential reference text for cell biology.

basis for the truism that, for science teaching, “less is more” —in opposition to the all-to-common insistence on maximum “coverage” of each subject. Sadly, the emphasis on coverage remains dominant in US classrooms today, leading to biology textbooks for 12 year olds with 500-word glossaries. Such textbooks would drive anyone, including me at that age, away from science—and I claim that they are among the most difficult books to actually understand of any ever written (<https://brucealberts.ucsf.edu/publications/Failureofskin.pdf>).

My daughter is now a science teacher in a public school system, resuming a career that had been interrupted by raising three children. During this long leave of absence, and disturbed that her second grade child had thus far not been exposed to any science in school, she volunteered to help. She began her first science lesson by giving the children samples of three different types of soil, equipping each with a magnifying glass and asking them to write down what they observed in each sample. But she was surprised to find that the children seemed paralyzed, being unwilling to write anything. Why? It turned out that, after three years of schooling, these students were afraid to respond because they didn’t know “the right answer.” Life is nothing like a quiz show, and it is a monumental mistake to allow students to conclude that being educated means knowing all of the right answers. Is it any wonder that nearly half of U.S. middle- and high-school students are found to be “disengaged” from their schooling?

From teachers, I have also learned a great deal about the great damage that is being done by the top-down, compliance culture that dominates US public school system management today. As a scientist, I have struggled to find a strategy for beginning to change that culture, finally settling on a campaign to empower our best teachers in ways that can give them an effective voice in school district policymaking (<https://brucealberts.ucsf.edu/wp-content/uploads/2016/05/Alberts-from-Past-as-Prologue-NAEd-50th-book.pdf>). And I have long been intensely devoted to the Strategic Education Research Partnership (SERP), a non-profit organization that originated from studies by the National Academies; since 2003, SERP has been experimenting with ways to generate effective education research on the central problems of schooling, as defined by school districts themselves (serpinstitute.org).

From the seminal 1989 publication from the American Association for the Advancement of Science, *Science for All Americans*, I first became aware that science education is much more important for societies than even most scientists think. This is because, to quote that text, “Scientific habits of mind can help people in every walk of life to deal sensibly with problems that



Meeting with students in Indonesia, 2011.

often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems.” And in New Delhi in 1993, at the first-ever meeting of the presidents of the world’s science academies, it became strikingly obvious to me that the entire world badly needs much more of the creativity, rationality, openness, and tolerance that are inherent to science—what India’s first Prime Minister, Jawaharlal Nehru had so aptly termed a “scientific temper.” As Nehru wrote in his 1946 book, *The Discovery of India*: “the scientific approach, the adventurous and yet critical temper of science, the search for truth and new knowledge, the refusal to accept anything without testing and trial, the capacity to change previous conclusions in the face of new evidence, the reliance on observed fact and not on pre-conceived theory, the hard discipline of the mind—all this is necessary, not merely for the application of science but for life itself and the solution of its many problems.”

In my first two years as the National Academy of Sciences president (1993–1995), I devoted an enormous amount of time to producing the first-ever National Science Education Standards for the United States. From that massive effort, I became convinced that introducing high-quality inquiry-based science education (IBSE) at all levels, from age five through college, provides the best opportunity for developing the scientific temper that is so critical for every nation. The establishment of the InterAcademy Panel in 1993, currently an association of science academies from more than 100 nations, enables dedicated scientists from around the globe to share strategies and curricula, helping them work productively to spreading this form of active, inquiry-based science learning in many nations (<http://www.interacademies.net/File.aspx?id=8512>). From these and other experiences, it has become clear to me that a continuous input of energy and attention from local scientists will forever be essential, if school districts and nations are to shape science education in effective ways. Otherwise, as for chemical systems, education systems tend to regress to the free energy minimum—which is either teaching no science at all or, in

my opinion equally terrible, teaching science as a set of words and phrases for students to memorize and spit back on simple tests.

Last but not least, all of us who teach science at the college level need to face the hard fact that our teaching sets the standard for science education at all lower levels. Thus, for example, if professors only lecture to passive students, aiming to attain maximum coverage of the vast subject of biology in their introductory biology classes, college teaching will remain the major obstacle in the path of science education reform. Research carried out in the past few decades conclusively demonstrates that active learning can be incorporated effectively into even large lecture classes. As scientists, we can and we must do better (<http://www.nap.edu/catalog/18687/reaching-students-what-research-says-about-effective-instruction-in-undergraduate>).