Profile of Bruce Alberts: The education president

Bruce Alberts and children of staff of the Academy complex, National Academy of Sciences building, Washington, DC, 1997. Photograph by Jeremiah Burger.

As Bruce Alberts steps down July 1 as one of the most accomplished and distinguished presidents of the National Academy of Sciences (NAS), he is singularly focused on education—specifically, teaching his students about real science. He has been brewing an idea for a new science course that he would like to teach to graduate students at the University of California, San Francisco (UCSF), the approach for which is partly inspired by the 3 years he spent in graduate school charging straight into an experimental dead-end. First, Alberts says, he would toss out the traditional classroom lectures and instead hand students a small stack of carefully selected scientific articles. Then he would have them argue among themselves about which papers are outstanding and, most importantly, which are not. "We always talk about good papers, but we never talk about the substantial amount of mediocre work that's done," Alberts says.

Actually, Alberts prefers the term "boring" for papers that fail to rock the foundations of the scientific world and that describe work arguably not worth doing. He wants to get students and scientists talking about what he considers the critical issue in a scientific career: how a scientist learns where to spend limited time, money, and energy in the most effective way. "I think the right type of course could do a lot to help future scientists develop the kind of taste and judgment they need to really be successful," he says. Good scientists usually acquire this research acumen by osmosis or "trial and error," Alberts says. "In my case, it was a lot of error."

Nearly 30 years after his graduate school stumbling blocks, Alberts came to Washington, D.C., to be an "education president" of the Academy. His impressive list of achievements and accolades—including eight foreign academy memberships, 14 honorary degrees, and recognition ranging from the San Francisco Exploratorium to the National Academy of Education—reflects his abiding interest in science research and policy as well as basic science education. During his 12-year tenure, he has made immense strides in bringing science education reform to the classroom.

However, this path was by no means guaranteed. Alberts almost missed becoming a scientist himself, mostly because his own science education did not expose him to the true scientific culture of questioning and learning. Even as a young professor, his own teaching was at times "pathetic," he admits, because he simply did not know any better. It was not until much later that he was able to articulate what he, and the American educational system, had been missing. First and foremost, he believes that science education should resemble actual science, where asking "why?" and "how?" is more important than memorizing a list of facts.

A Stockroom of Reality

One of Alberts' fondest early science memories involves exploring the inside of a television set. In 1950 at Central School in a small Chicago suburb (Glencoe, IL), his teacher, Mr. Bonhivert, had him stand in front of his seventh-grade science class and explain how television works to his classmates. "Television was quite new, and I had no idea how it worked, but I had to be able to explain it," he says. "This was really exciting, because in order to teach it, you really had to understand it."

Later, in the ninth grade, he recalls grappling with books on spectroscopy in the Chicago Public Library for a report in chemistry class. Alberts had even more fun in his junior-year chemistry class, where he had a chance to play with beakers instead of slog through textbooks. "Chemistry was made real because we had real chemicals," he says. "Right in front of everybody were bottles of fuming hydrochloric acid and sodium hydroxide. The nice thing was that my teacher, Carl Clader, actually had a stockroom with many reagents, so that we could set off explosions, and we could see chemistry as being real. That was quite different from just reading about chemistry."

Alberts enjoyed such hands-on tinkering so much that he decided to pursue a career that would use chemistry. Not knowing how this science was used in the real world, however, he needed guidance. At his high school's "Career Night," he perused the program and found only two speakers who used chemistry in their jobs: a chemical engineer and a physician. The engineer drew dull pictures of pipes and tanks on the blackboard, he says, but the physician spoke about the importance of science for medicine. From this experience, Alberts decided to become a physician. At that point, he had no idea that a career as an actual scientist was possible.

Ivy League Cooking Classes

Alberts' hopes for more explosions and hands-on experiments were dashed soon after he arrived at Harvard University (Cambridge, MA) in 1956. As a premedicine major, he took introductory lecture courses such as analytical chemistry, organic chemistry, biology, and physics. None kept him truly engaged, he says. Instead of self-directed learning, he found himself exposed to mind-numbing facts. "Science words are not science," Alberts says. "I always feel that I want to under-

This is a Profile of the president of the National Academy of Sciences.

stand things and not just memorize them."

In his physical chemistry class during his junior year, Alberts was particularly frustrated by the textbooks. "So I went to the library and found a big, fat, older physical chemistry book," he says of the 1,300-page tome written by Samuel Glasstone (1). "It contained a lot of words. Most of the textbooks in physical chemistry have relatively few words, and they emphasize equations," Alberts says. "But Glasstone was a person who really wanted people to understand the essence of the subject, and he wrote beautifully about it. And I discovered from his book that I could actually get the understanding that I was looking for."

Alberts found the companion laboratory sections to be even more frustrating than the assigned textbooks. Laboratory assignments consisted of following a set of instructions, he says, then comparing answers with a friend, fudging data to get the right answer, and turning in a pointless notebook. "Cooking classes," he calls them. In the second half of his junior year, Alberts took action to improve the science education he was getting. He petitioned to leave the physical chemistry laboratory but was told only laboratory research performed that spring could substitute. Jacques Fresco, his tutor and a postdoctoral fellow in Paul Doty's laboratory, then invited Alberts to continue in the same laboratory for the summer. Since Alberts' girlfriend, Betty—now his wife of 45 years—was traveling to Europe that summer, Alberts accepted Fresco's invitation.

The Changing Fortunes of Real Science

Alberts soon realized that the college science he had experienced up to then was not like actual science at all. Working in Doty's laboratory, in fact, reminded him of his childhood explorations of the television's inner workings and high school chemistry hijinks. In Doty's laboratory, he could learn by asking questions and figuring out the answers on his own, accompanied by hands-on experimentation.

The laboratory focused on nucleic acids, and Alberts' project involved deciphering how errors in DNA or RNA base pairing affected the helical structure of these polymers. He used knowledge culled from a study of synthetic RNAs to determine how helical structures accommodate such mismatch errors. With the laboratory group, Alberts published these results in PNAS and *Nature* (2, 3). Suddenly, medical school did not seem as exciting as pure science to Alberts. He dropped his original plans and decided to pursue a doctorate in biophysics at Harvard, continuing work in Doty's laboratory.

After graduating *summa cum laude* from Harvard with a bachelor's degree in biochemical sciences, Alberts began graduate school in 1960 with what he calls overly ambitious plans, misled by his early research windfalls. "I thought science was trivial," he says. "It made me way too cocky." His ambition led him to embark on solving the genetic code, which was still undeciphered at that point, and he excitedly designed a series of experiments with a technique he had proposed in an earlier term paper.

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Not only did the method turn out to be cumbersome, it was also completely hopeless. The problem, Alberts says, was his overlooking of crucial control experiments that would have warned him of the method's limitations. Alberts regrouped, shifted his thesis topic, and resolved never to make the same mistake again. He graduated with his doctorate in 1965 and spent the following year as a postdoctoral fellow at the Institut de Biologie Moleculaire in Geneva, Switzerland, where he studied with Alfred Tissières and Richard Epstein. In 1966, Alberts joined Princeton University (Princeton, NJ) as an assistant professor in the Department of Chemistry.

Cultivating and Weeding the Classroom

Alberts' first experience on the other side of the lecture podium involved teaching a course on the physical chemistry of macromolecules, in 1968. His first assignment for the class, a mix of graduate students and advanced undergraduate seniors, was to read the newly published book *The Double Helix* by James Watson (4). At the time, members of the media were seizing on Watson's account to decry scientists for their single-minded pursuit of glory and Nobel Prizes. "I was trying to encourage my students to not be turned off by this book by thinking that all scientists wanted was to be famous and outrace other people."

When Alberts tried to teach his students physical chemistry, however, he grew disappointed in their level of preparedness. "I found that I had to re-teach thermodynamics because, even though they had had it one or two times, almost nobody understood it," he says. "They had just memorized formulas, and the things that you memorize and don't understand leave you very quickly." So not only were introductory lecture classes boring, Alberts decided, they were also failing in their mission to teach students basic concepts.

Yet Alberts was also starting to wonder if teaching concepts was the sole aim of introductory classes. He saw that many professors, including himself at first he confesses, had the attitude that their introductory science classes should weed out all but those most likely to become scientists themselves. All other students could be shuttled out of science classes as quickly as possible, so that they would not take up valuable space in upper-level classes.

When Alberts looked around at his and other science departments, he realized that his faculty colleagues were in fact a rather special group, in that they themselves had survived an earlier weeding-out process. "All of us who are professors did well with lecture-style teaching and tests," he says, "and so we think that everybody else should be able to learn well in exactly the same way." But Alberts' experiences were instead starting to point to much more variability in how people learn. "What I learned as a professor working closely with many graduate students is that there is no such thing as a single measure of intelligence. You can't rank people and their abilities on a linear scale, because different people are good at different things."

Teaching Experiments

After promotion to Associate Professor in 1971 and then Damon Pfeifer Professor of Life Sciences in 1973, Alberts moved to UCSF in 1976, after 10 years at Princeton. He served as American Cancer Society Research Professor, Vice-Chairman, and finally Chairman of the Department of Biochemistry and Biophysics. Alberts was elected to the NAS in 1981 at the age of 43, cited for his pioneering work on the protein machines that catalyze DNA replication (5). In 1987, he was surprised to be asked by the Academy to chair a committee on a proposed project to map the human genome. The resulting report, entitled "Mapping and Sequencing the Human Genome" (6), secured his reputation as a focused and energetic leader able to navigate through politics and controversy. He subsequently took on increasingly more responsibility at the Academy, including chairing the Commission on Life Sciences of the National Research Council (NRC), the operating arm of the NAS and the National Academy of Engineering (NAE).

Also during this time of juggling administrative and research responsibilities, Alberts continued to explore more and better ways to teach science to students. Every year for 17 years, he taught cell biology and biochemistry to more than 100 first-year medical students. When he and his colleagues noticed that their students were studying only to pass the multiple-choice examinations, they changed the test to include short essay answers. It was amazing, Alberts says, to see how this small change caused students to think so much more deeply about the material.

Spurred on by James Watson, who saw a need for reference material written clearly and engagingly on molecular and cell biology and biochemistry, Alberts and five coauthors published in 1984 what would become the canonical, influential, and best-selling scientific textbook, *Molecular Biology of the Cell*, now in its fourth edition (7). Twenty years later, he would donate a portion of royalties from the book's sales to help support the National Academies' Christine Mirzayan Science and Technology Policy Graduate Fellowship Program, until the NRC could officially step in.

In the late 1980s, Alberts watched his daughter exhaust herself with 75-hour work weeks as a science teacher. Surprised at the paucity of resources some of her fellow teachers labored with, Alberts came up with an innovative idea of connecting working scientists with public school science teachers, called the UCSF City Science program. Started in 1987, it was later the model for the National Academies' Project RISE (Regional Initiatives in Science Education).

Yet for the most part, Alberts tucked away his observations about education in the back of his mind. His schedule did not often afford him the luxury of sitting back to look at the big picture. "There's a strong tendency for scientists to be workaholics," he says. "I was always behind. We work 100 hours a week, and we don't feel that we have any time left to worry about the kinds of issues that the Academy deals with for the nation. That's why I think the Academy is so important, actually. We're a place where people are forced to take a long view and use their science in new ways."

Education for the Nation

In 1991, the NRC agreed to a request by a council of state governors to develop a set of national science education standards. This first-ever set of science educational standards was aimed for students from kindergarten through high school. In 1992, with Frank Press' tenure as president of the Academy nearing an end, the NRC began seeking a president who could help increase the Council's reputation as a force for advocacy and reform in science and mathematics education.

Bruce Alberts was nominated in 1992 and approved as NAS president in 1993. He immediately began attending to the National Science Education Standards (NSES) project, helping to shape its vision and move the project forward. In 1996, the NRC released its long-awaited NSES report, a 250-page guide containing recommendations on the content of science classes and on science teaching techniques (8). The report emphasizes logic and hands-on problem solving, collaborative group work, and inquiry-based science. More than 250,000 copies of the report have been distributed nationwide, and the voluntary standards detailed in it have now been adopted to some extent in almost every state.

Under Alberts' leadership, the National Academies—composed of NAS, NAE, Institute of Medicine, and NRC—helped usher in other science education initiatives. In 1995, the National Academies established a Center for Science, Mathematics, and Engineering Education (CSMEE), which later merged with the NRC's Board on Testing and Assessment. This merger formed the Center for Education, providing a locus for education activities and innovation. The National Academies tripled their education reports under Alberts' leadership, producing more than 190 publications focused on some aspect of education, from kindergarten through graduate school. Beginning in 1997, the National Academies helped establish the nonprofit agency SERP (Strategic Education Research Partnership), which aims to create collaborative networks of teachers and education researchers to decipher what works best in our nation's schools.

Back to School

Now that his second and final 6-year term as NAS president is ending, Alberts will serve the next 4 years as cochair of the InterAcademy Council, alongside Yongxiang Lu, president of the Chinese Academy of Sciences. The InterAcademy Council brings together the world's science academies to provide advice to international bodies, such as the United Nations and the World Bank. Alberts is also returning to teaching at UCSF, where he hopes to explore new methods of instruction, such as interactive minicourses between academic terms. He also plans to help UCSF's young faculty and postdoctoral fellows become more effective teachers and researchers themselves. This rich juxtaposition of returning to the classroom while heading the InterAcademy Council highlights Alberts' commitment to leading and teaching science from grassroots to global levels.

Looking back, Alberts can see the influences of his own education and teaching experiences on his philosophies of science education. From his childhood television presentation and chemistry class explorations, he saw the excitement that students can have by teaching themselves science with wise guidance and coaching. Alberts considers himself lucky to have accidentally discovered real science in Paul Doty's laboratory, before his impatience with traditional classroom lectures and laboratories drove him away from the field completely, and he wants to make sure other students enjoy the same opportunity. He saw the power that a good textbook can hold, and he experienced the consequences of learning too late the value of forming good scientific questions.

Alberts realizes that people are driven strongly by the pleasures of solving problems and feeling competent, not by external rewards, and these motivations hold for brilliant future scientists as well as struggling students. "I think that our education process should stress enabling every kid to realize in middle school that she or he is good at something, and that their job in life is to find out what they're really good at," he says. The importance of early science classes goes beyond the actual science, Alberts says. "You're trying to teach a much more basic skill—a strategy for dealing with life, basically. You're not trying to teach all students to be research scientists. You're trying to teach them how to deal with any problem they're going to encounter in a scientific way."

In a world of dizzying scientific progress, a questioning attitude and a skill for rational problem solving will prove much more valuable than a head full of scientific facts, according to Alberts. "All we know is that there are going to be much more impressive things coming out of science and technology than we can imagine today," he says. "You can't predict what comes out of knowledge."

Regina Nuzzo, *Science Writer*

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