Q+A

The Reformer

BRUCE ALBERTS is a biochemist who has spend decades trying to improve science education. Alberts has been the president of the National Academy of Sciences, editor in chief of *Science*, and science envoy for the U.S. State Department. He is currently the Chancellor's Leadership Chair in Biochemistry and Biophysics for Science and Education at the University of California, San Francisco. *Distillations* writer Jacob Roberts sat down with Alberts to find out how to improve science education, what makes a good textbook, and why more scientists should wear wacky ties.

Q: How would you define science education? A: Science education should be about learning to think and solve problems like a scientist—insisting, for all citizens, that statements be evaluated using evidence and logic the way scientists evaluate statements. If you look at recent political debates, politicians are getting away with saying nonsense because a lot of people are not used to looking for evidence, can easily be fooled, and have been fooled, both by politicians and by people trying to get their money.

I don't care so much whether people know how many days it takes for the earth to go around the sun. I mean, they should know that, but the critical thing is that they understand how to think like a scientist and how to behave in a logical way that looks at evidence.

Q: What are some of the problems facing science education right now? A: Science education has become overloaded with facts that squeeze out all understanding or real joy from the subject. The result is that science education is in pretty bad shape in most parts of the world, including many schools in the United States. Facts are easiest to teach and easiest to test for. Unfortunately, many of these tests' multiple-choice questions or fill-in-the-blanks only require the recall of factual knowledge. They ask, "What have scientists discovered about the world, and can you spit back to me all the words and what they mean?" It has gotten much worse over time because science has become more complicated. We seem to have greater expectations for younger kids to know complex names of things, even though we know they don't have any understanding of them.

In my field of cell biology the standard curriculum in middle school has students memorize all the parts of a cell so they can spit back a couple of sentences about each one. This is totally meaningless, as if they're writing down equations for string theory. The endoplasmic reticulum is something I never learned about until I wrote a book on cell biology as a college professor, but now every kid is supposed to memorize a few sentences about the endoplasmic reticulum; and it has absolutely no significance to them because it's just a word-association exercise. I wouldn't call that science education.

Q: How can science education be improved? A: By not just conveying information in a stream of talking, where the student passively sits in the classroom, but by interrupting lectures with problem solving.

One of my favorite research papers, which I read long ago, involved a researcher who sat in on an upper-level high-school history class. The researcher sat there all year and recorded what was said and what happened in the classroom. After every test the researcher interviewed the students; it was a huge amount of work. The innovative part is that a year after the original final exam, the students were given the same final exam. They couldn't remember what they had originally memorized; by and large they only remembered those things they had to struggle with by solving a problem or by interacting with somebody. Is education defined as something you can spit back on a test by staying up all night? Is that education? Or is it defined by what you remember after a year? Nobody's going to give much importance to what you memorized and then forgot.

Q: In a perfect world, when a student finishes high school, what would you want that person to know about science? A: Well, in a perfect world I want the student who has finished high school to understand how this enterprise we call science works. Where does scientific knowledge come from? Science is an amazing human invention: when you discover something, you have to put it out there for everybody else to analyze, along with all of your methods, so people can reproduce it. You haven't discovered anything until somebody reproduces your discovery or fails to reproduce it.

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My mentor in science education was a man by the name of John A. Moore. He was a member of the National Academy of Sciences, originally taught at Columbia University, and was a zoologist. He invented the term "science is a way of knowing." We want people to understand that science is a way of knowing about the world, and high-school graduates should be able to use some of those approaches in their everyday lives.

Q: Should history play a role in teaching science? A: I was a teaching assistant in a course taught by Leonard Nash at Harvard University in 1961. It was a general education course. Much of it was based on a series of historical essays he wrote with James Conant, the former president of Harvard. I was sitting in the class, and Nash was explaining why phlogiston was the best explanation in the 18th century for how fire worked. Because of the way I had been taught in high school, I had thought that phlogiston was always a stupid idea and, therefore, that people must have been unintelligent back then. Of course, that's the complete opposite of the truth.

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I think the appropriate use of history is to make people recognize how hard science is. Everything is obvious in retrospect, but before you know it, it's very hard to figure it out.

Q: You coauthored a textbook titled *Molecular Biology of the Cell* in 1983. How did you apply your beliefs about improving science education to writing a better textbook? A: Unlike with most textbooks, at least two authors worked on every chapter. I was reading the chapter on immunology. I knew nothing about immunology; so I was a good reader for that chapter because if I didn't understand it, then others wouldn't. Likewise, I wrote the biochemistry chapters, and my friend Martin Raff, one of the original authors, didn't know any chemistry. When you understand something, it's hard to see what other people won't understand. That's a major problem with science writing. People specialize, and they don't have any idea how to write an abstract that other people can understand. This is a common problem for us all whenever we write about anything.

Dudley Herschbach, the Nobel Prize–winning chemist at Harvard, has a great idea that was never adopted as far as I know. He suggested that in order to get your PhD, you should have to write a two-page introduction to your dissertation that your grandmother could understand. And there would be a "grandmother" teaching you how to write. I think that was a great idea because it makes an important point. If you can't communicate to people outside your field, then quite often your science isn't understood by those who need to use it.

Q: What's the role of scientific education when it comes to politically charged subjects, such as climate change? A: Scientists have to be respectful of what we know now, with the understanding that it's not going to be absolutely true in the future. In my field of cell biology some things we thought we knew are absolutely wrong. Scientists always do terribly in news programs where one guy is a climate scientist and the other person absolutely knows that climate change is wrong. The scientist has to say, "Well, it's 95% certain that the earth is going to warm," and the other person says, "But we know it's a fraud!"

This is part of what science education must address. Everybody should recognize why scientists say that something is 95% certain and why the public should go along with that consensus. If somebody told you it was 95% certain that your house was going to burn down next year unless you changed your electrical wiring, you'd probably change it, at least if you're a rational person! And climate change is much worse than your house burning down.

Q: Are you optimistic about the future of science education? A: Long-range future, I'm optimistic, but even though we have a good vision now, our country is much too short ranged in its thinking. What we have is a vision for

Bruce Alberts delivering the 2015 Ullyot Public Affairs Lecture at CHF.

how to make real progress over the course of the next 10 years, but school districts live in a political world. They try to pretend that they can solve problems and change things in two years. Of course, they're bound to fail because they have to retrain their teachers if they want to improve science education in the long term. Not all teachers will be able to teach well. They can't teach kids how to think like a scientist if they're not able to do it themselves, which is why we need better, specific strategies.

A smart thing to do is try to train all of our teachers to teach differently, and then hope that half of them will be able to do it and have those teachers share classes with the ones who can't. That's the scientific approach, right? But it's not politically acceptable to say that. We need to bring much more realism to the effort. It is critical that we empower our best teachers to continuously improve our schools and school systems. The public school system is a terrible place to work for the many outstanding teachers, who have pressures coming from on high to have their students perform better on some stupid test or to do things that don't make any sense because of various rules.

I'm a big advocate for empowering our best teachers to have a much larger say in policies at all levels, all the way from schools and school districts to states and nations. There needs to be a cultural change, but that takes time. I can be patient, but I'm impatient with the fact that a critical part of our population has discounted public schools when they're really the lifeblood of the future for the country. Our nation can't be successful in the future without excellent public schools.

Q: There's a painting of you hanging in the National Academy of Sciences' Keck Center. Your tie is covered in smiley faces, you're grinning a little, and your hands are raised as if you are explaining something. What does that painting say about you? A: I wore that tie to many events in Washington because I thought people were taking themselves too seriously. It's not just smiley faces; there are also sad faces. But it was my favorite tie. I got letters from chemists saying the painting was a disgrace. They wanted someone to at least paint the tie black or put the whole portrait in the basement so nobody sees it. I suppose that will happen soon.

Arrogance gets scientists nowhere. We're well known for being arrogant. Teachers and the public think we're often arrogant, which is not a way for scientists to be successful in society; nobody wants to interact with you if they think you think that you're superior because you did better in science class. People are good at different things. You can't measure intelligence on a single scale. The art of teaching, of course, is to find out what people are good at and encourage that. D

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