PRESIDENT'S Column

Why Is Teaching Good for Research?

This President's Column is written by guest columnist and ASCB Council member David Botstein.

It has become conventional wisdom in the scientific community that teaching, especially by younger faculty, is something to be avoided. Teaching, beyond a few token specialized lectures a year, is said to be a distraction that will impede, rather than enhance, the development of a scientific career. Faculty mentors, with the best of intentions, now advise junior faculty to minimize teaching and service, long understood to be normal, even essential, activities for someone with the title of "Professor." Negative attitudes toward teaching have become enshrined in the recruitment and development practices of many institutions of higher learning. This is especially the case at institutions prominent in scientific research. Such institutions tout minimal (or zero) teaching as inducements to young faculty; they thereby have abandoned the expectation that their successful researchers will ever teach more than a handful of specialized lectures. Consequently, teaching in many of these institutions has descended to a low level, both in quantity and quality, to the point that the rubric "institution of higher learning" is becoming an oxymoron. Alarmingly, the major U.S. scientific research funding agencies (National Science Foundation [NSF] and National Institutes of Health [NIH]) have limited or even forbidden teaching, especially by predoctoral and postdoctoral trainees. This development no doubt makes a bad situation even worse, and, as I show below, denies the origins of the modern academic research funding system. Fortunately, there is some indication that the National Institute of General Medical Sciences may be reconsidering its restrictive policy.

Photo Credit: Frank Wojciechowski

David Botstein

My thesis is that advice against teaching, so earnestly given, is actually bad advice. I believe that teaching and research are synergistic for the individual researcher-teacher as well as the institution and its students. The intellectual effort that serious teaching requires is, in my experience, amply repaid in enhanced intellectual breadth, mental sophistication, and clarity of scientific vision. These are the qualities that help young scientists to come up with the original and nonincremental scientific ideas required to drive a truly creative research career.

In support of this thesis I offer below examples from my own career. However, I begin with a historical perspective, which many may find more convincing than any number of anecdotes. The pervasive dismissive attitude toward teaching is actually a new phenomenon. The visionaries who established the NSF, NIH, and the modern academic tenure system came from a scientific community that thought exactly the opposite.

Teaching and the Origins of the Modern Academic Research Environment

The modern science funding and academic promotion systems originate from the period just after World War II. The scientific leaders of that era (notably Vannevar Bush, James Shannon, and James B. Conant) based their policies on their experience in leading the massive and remarkably successful research and development efforts that produced radar, sonar, atomic weapons, and modern computing machines. They found that the best outcomes were obtained with active scientists recruited from the universities. At that time, there were virtually no important research scientists who were not also important teachers.

For example, J. Robert Oppenheimer, who led the Manhattan Project at Los Alamos, had spent most of his career teaching physics. His reputation among physicists rested far more on his brilliant teaching than on his research. He was anything but single-minded about his personal research program in quantum mechanics. He was chosen, and he was successful, precisely because he 1) was a polymath who knew and understood broadly and deeply what was known in all of the

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physical sciences, and 2) could communicate this to virtually anybody at a sophisticated level. Many of his recruits were his seniors; most were experts in fields far removed from quantum mechanics per se—making the bomb was a deeply interdisciplinary endeavor. Oppenheimer was, in the full meaning of the word, a "professor": both a teacher and a scholar. The same could be said about Bush, Conant, and Shannon.

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In 1945 Vannevar Bush published an essay entitled "Science, the Endless Frontier" that historians credit with leading to the establishment of the NSF (and, more indirectly, the ultimate form of the NIH under Shannon). In it he wrote:

> Publicly and privately supported colleges and universities and the endowed research institutes… are uniquely qualified by tradition and by their special characteristics to carry on basic research. They are charged with the responsibility of conserving the knowledge accumulated by the past, imparting that knowledge to students, and contributing new knowledge of all kinds. It is chiefly in these institutions that scientists may work in an atmosphere which is relatively free from the adverse pressure of convention, prejudice, or commercial necessity. At their best they provide the scientific worker with a strong sense of solidarity and security, as well as a substantial degree of personal intellectual freedom. All of these factors are of great importance in the development of new knowledge, since much of new knowledge is certain to arouse opposition because of its tendency to challenge current beliefs or practice.

Bush and his contemporaries believed in a fundamental synergy between research and teaching: academic science (which included serious teaching) offered the best hope for progress in basic research. The funding and academic system they put in place became the envy of the world: a professor's dual mandate to *teach* the science and to *do* the research, simultaneously serving two masters (the university and the funders, respectively), was its central feature.

This belief persisted well into the early 1960s, when I was a student at Harvard, Massachusetts Institute of Technology, and the University of Michigan. Beginning with my very first undergraduate courses, my teachers were also leading researchers in physics, chemistry, and biology. They included several who ultimately received Nobel Prizes. They clearly valued their teaching, and they made clear to their students that they believed teaching and research should go hand in hand. I should add that their teaching loads were, by modern standards, very substantial. For example, Konrad Bloch taught the entire introductory biochemistry course personally, year after year. He had only a graduate student to help grade the exams. Further, my recollection is that it was not the only course he taught. Famously, Jim Watson, as an assistant professor, taught, solo, an introductory course for freshmen and a popular course on viruses every year. He clearly understood his dual role as a professor. He went on to write a textbook, *The Molecular Biology of the Gene.* Many believe the success of this book marks the true beginning of molecular biology as an academic subject.

When I was appointed assistant professor at MIT, it was not because of my research program (which focused on P22, an obscure bacteriophage even then). Rather it was because I had, as an instructor, helped devise a Project Laboratory course that the department believed had great promise. It is still taught at MIT, and I teach a version at Princeton. When it came time for me to be evaluated for tenure, the major emphasis, then as now, was on my research accomplishments, for which the bar was high, as opposed to teaching, for which the bar was lower. Yet nobody ever advised me (or anybody I know of) in that period that we should shirk teaching. We all taught, and by and large we profited from it out of proportion to the time we spent on it. I certainly did.

What Researchers Gain from Teaching

At this point the reader may well ask: What exactly is the nature of this profit or synergy? I see four major elements.

First, I think that teaching, especially at the introductory level, requires a level of thought and understanding of science not required to make incremental progress in a tiny specialized area. I have taught basic genetics for most of my career, and each year I find I understand the subject better and over a broader span. It's painful now to remember how easily students could come up with questions I could not satisfactorily answer in my salad days. I was embarrassingly naïve about many things, not least how genetics connects to other sciences.

It was precisely these questions, in both lecture and laboratory courses, that made me study and read widely outside my immediate research specialty. This benefited my research even more than my teaching.

For example, it was a student question in the late 1970s that first led me to study Bayesian probability seriously. Gerry Fink (my partner in that course) and I devised problems that illustrate Bayesian reasoning largely because we became so impressed with its importance, which still has not penetrated deeply into the standard genetics curriculum. This subject is now at the core of my current research (it underlies all modern gene mapping and microarray analysis). It has also become a linchpin for our undergraduate and graduate curricula in quantitative biology at Princeton.

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Second, through teaching and service at MIT, Stanford, and Princeton, I forged relationships with faculty in other disciplines. These relationships resulted in successful research collaborations that led, serendipitously, in directions I would never have undertaken on my own. Teaching with others is still the best and most reliable way to avoid the intellectual isolation that comes of thinking only about one's own current research.

Third, I profited from my teaching by attracting able students, either undergraduate or graduate, to my laboratory early in their careers. Teaching the younger students provided intellectual contact with those who, if they became interested, were free to join my group. As I look back on my career, I'm persuaded that it was the large number of really outstanding students who chose my lab instead of the labs of more senior and more famous colleagues that made it possible for me to achieve as much as I did.

Fourth, it is quite easy, if one sets one's mind to it, to organize courses around subjects that directly aid one's research while teaching fundamentals to students. This is most obvious in laboratory courses. Screens of mutants have been organized around courses, with students providing hands as well as minds, since the earliest days of fly genetics. The number of truly groundbreaking experiments begun in courses at Cold Spring Harbor or Woods Hole is legion; examples from Woods Hole include the Meselson-Stahl experiment and the discovery of cyclins. At Cold Spring Harbor, Max Delbrück and Salvador Luria spent their summers teaching courses. They were rewarded doubly by the recruitment of outstanding new colleagues as well as with the design and outcome of new experiments that changed their field. On a less grand scale, university laboratory courses not infrequently result in research results of real value. At MIT results obtained by undergraduates resulted in publications nearly every time I taught my Project Laboratory course; this is happening again at Princeton.

I want to conclude with a slogan I use in my laboratory: "Science is not primarily a motor activity." By this I mean that the execution of experiments, while important, is secondary to the mental efforts required to design them properly in the first place, and then to analyze and interpret the results intelligently afterward. Time spent teaching is time spent thinking about the most basic ideas of our science and how our science fits in with the rest of what is known about the real world. Time spent teaching is spent in intellectual activity both foundational and highly relevant to research. It is not "lost."

To conclude, my advice is to aim for a good balance between intellectual and motor activities in research. Teaching is an outstanding way to achieve this balance. Achieving such a balance is good for the individual scientist, for the institutions, for students, and for the scientific endeavor as a whole. Treating the teaching of the intellectual foundations of science with disdain in the name of focus on research alone damages our profession and its future. Restoring the balance between teaching and research is the best way to guarantee steady progress in both realms. ■

—David Botstein, Princeton University

Comments are welcome and should be sent to president@ascb.org.

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