

University research and teaching: an enriching and inseparable combination

By Roald Hoffman
SPECIAL TO THE GLOBE

A damaging misconception about modern universities is that research dominates and diminishes teaching.

Commentary

Defenders of the university argue that the two functions are complementary. I go further: I say research and teaching are, quite literally, inseparable.

A root of the error is thinking of learning in terms of place rather than audience. Places (classrooms, labs, library, carrels) are, indeed, circumscribed. But the audiences of learning (undergraduates, graduate students, faculty, our minds) always shift, overlap and enrich each other, like the colored-glass bits of a kaleidoscope.

As I reflect on the possibility of a separation of research and teaching, I look at my research group. We meet twice a week — four graduate students, four postdoctoral associates and I. One time we talk about the incredible, fertile literature of chemistry, while in the other session one of the people in the group reports on her work in progress. We also ask why marzipan pigs are popular in Denmark, explain to our foreign group members all those football and baseball metaphors in colloquial English, and try to guess who is likely to be the author of those scurrilous referees' comments on our last paper. In these group meetings, half the time I'm giving a monologue; the rest of the time, the hardy-shy rest of this research family speaks. Is that research; is that teaching?

I travel to Stanford to lecture about my work, about making and breaking bonds in the solid state. Ninety percent of the audience consists of graduate students, with a sprinkling of undergraduates. I talk to them. Is that research, is that teaching? I think the answer in both cases is yes. It's research and it's teaching.

Teaching helps the teacher

Interestingly, I am certain that I have become a better researcher, a better theoretical chemist, because I've had to teach undergraduates. When I began at Cornell, for instance, I thought I knew all about thermodynamics, all those beautiful partial differential equations that related the derivative of A with respect to B to C. But thermodynamics is a subject of great richness, with practical, common-sense roots (steam engines, the boring of cannon) and a mathematical structure of breathtaking sophistication. I had only followed the latter, and hadn't really understood the full empirical beauty of "thermo" until . . . I had to explain the subject to students *without* the crutch of mathematical apparatus. The more I taught beginning classes, the more important it became to me to explain. The rhetoric of pedagogy permeated my research.

In the beginning is research or discovery, a gleam of the truth, or of a connection, within an individual's mind. Actually, I've experienced such moments, and so have others, most often not in isolation, but in the course of discourse with another person. Or when I sit down to write a paper, before me the draft or progress report by one of my students.

In fact, understanding already formed in the inner dialogue between parts of me, me and an imagined ideal audience of one, or of a multitude, in the lonely dialogue with the voices of skepticism and self-doubt that are all me, all of me.

Deeper understanding

In the next stage, the audience expands to my research group. In the process of talking to them, the depth of my understanding of the discovery deepens, takes a stronger hold on reality. Then I write a technical paper. Now my audience is out of my control. Writing is the message that abandons, as Jacques Derida has put it. I can't grab that reformed reader in Poznan or Puna and tell him, no, you must read it that way, and not this way. It has to be all there, in the words with which I struggle. It has to be there — the substance of what I found, and the argument to convince him or her, the absent reader. And I write for that audience from a position of substantive ignorance about them — I don't know their preparation, their level of sophistication, their willingness to work to reach enlightenment! It begins to sound an awful lot like teaching.

The writing of a research paper to me is in no way an activity divorced from the process of discovery itself. I have inkings of ideas, half-cooked stories, a hint that an observation is relevant. But almost never do I get to a satisfactory explanation until I have to, which is when I write a paper. Then things come together, or maybe I make them come together.

A technical seminar at another university introduces another audience. Sure, I want to impress my colleagues, claim precedence, power, please real or constructed parents. Many things go on subliminally in the course of any talk. Yet, most of all I want to impart real, significant new knowledge. But the audience includes people of disparate backgrounds. The organic chemist may not know much about my present loves, which are surface and solid-state chemistry. Depending on their backgrounds, different parts of the audience may attach different meanings to the plain English words at my disposal. There are many graduate students here. I want to teach all, convince all. Remarkably, incredibly, we can do it, speak to many audiences at the same time. That's what teaching is all about.

The shifting audience

To me, the steps from a research seminar to teaching a graduate course, then an undergraduate one, are small moves in interacting with the continuous, overlapping spectrum of audiences. In the theater of the mind, the audience is always shifting, never constant. There are different strategies — call them tricks, the stuff of experience — that one applies with these audiences of young people and that one might not try in a research group meeting. But the similarities of pedagogical strategy across the spectrum of teaching/research far exceed the differences.

I wish to argue that the desire to teach others, enhanced by being obliged to teach others, leads to greater creativity in research. The rhetorical imperative operates to

make a scientist or scholar examine widely the potential responses (objections?) of his or her audience. Having to teach enlarges one's encounters with real audiences, therefore sharpens the imagined audience one engages in the inner dialogue in the course of research.

As my friend R. Preis has pointed out, following Aristotle, teaching is truly a cooperative art. It *works together* with the nature of the student as learner, knower, apprentice, in order to bring that nature to its perfection. Teaching is clearly also a rhetorical act. But it is more than mere persuasion, because of the empathetic, reflexive aspect of it being cooperative. The mind that faces up to the problem of teaching a novice something new and difficult cannot possibly avoid using the same strategies in explaining to itself something still more new, more difficult. Which is what people call research.

Much has been written about the ways in which state-of-the-art research enhances teaching. The evidence for a direct link is not clear to me; obviously the meld between teacher and student matters. How else could one explain the tremendous success of the graduates of City College in New York (which 60 years ago had little research activity) or the many small colleges that are the baccalaureate source of our best researchers. Nevertheless, I do think that there are certain ways in which education flourishes in the intellectual climate of a major university.

Living, thinking creature

First of all, it takes little to make a student aware that his instructor is not just reading an old set of lecture notes, but is a living, thinking creature in an active intellectual community. A small comment suffices, along the lines of: "I just heard in a seminar that this law we've been talking about, while in general quite reliable, is not universal. A group at Konstanz . . ." Or, "Incidentally, next week we have a seminar speaker from Harvard, Dick Holm, who is an expert on electron transport by metal clusters in biological systems. Those of you who are interested . . ."

Second, undergraduates take in not only the subject matter of their courses; they are also extraordinarily sensitive to the person of the professor outside the classroom. Do you realize what an effect it has on an undergraduate to go into a library to study on Saturday afternoon, everyone else at the football game, and see there his organic chemistry professor sit for two hours looking through, and taking notes on, the new journals that have come in that week? Or in the course of a summer job to sit in on research group meetings, hear the familylike banter, feel what it is like to learn that you've been scooped, sense the single-minded concentration on the new?

The usual advantages of the active researcher as teacher, often cited, are authoritativeness, proximity to the sources and a sensitivity to what is and is not important in the current state of the science. I think

the intangibles, a selection of which was given above, are equally important.

It seems an imperfect system, this concentration of research, scholarly and teaching functions at one place, the research university. It is also an idea that inherently generates stress for the individuals who make it go, with minimal financial encouragement. But what a place! The exciting, tense, productive research setting in which professors do their balancing act, the university, is correctly seen by most students as what it is, the world of mind and hands learning, teaching. Both. I wouldn't want to be anywhere else.

► *Ronald Hoffman, a Nobel Prize winner who teaches introductory chemistry at Cornell, wrote this piece for a faculty publication on undergraduate teaching.*

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