# Millikan Lecture 1997: Is there a text in this class?

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I'll propose a physicist's answer to Stanley Fish's impudent question, and offer some thoughts about the role of text(book)s in the teaching and learning process. Also—with a view to offending as many listeners as possible—I will indulge in some gratuitous curmudgeonly remarks about the reform movement in physics education. 

I'm not at all sure what I'm supposed to say today. Maybe you're expecting a grand philosophy of education. But I learned very early as a parent that almost any philosophy of childrearing is worse than no philosophy at all, and I am inclined to think the same applies to teaching. The process is simply too rich, subtle, and complicated to allow for easy packaging. A technique that works wonderfully for one instructor or student fails miserably for others. So I'm afraid what you're going to get is a collection of loosely related and sometimes contradictory thoughts about teaching and learning physics.

In 1980 Stanley Fish—then a Professor of English at Johns Hopkins—published a delightful little essay[1] entitled ''Is there a text in this class?'' It seems this question had been addressed to a colleague on the first day of the semester by a former student of Fish's. The colleague naively assumed the query pertained to text *books*, and responded that they would be using Norton's Anthology of Literature. But Fish is a very sophisticated man, and his student has learned her lessons well: The question, it transpires, has nothing to do with *books*, but rather with the underlying assumptions—the common language—that the course might (or apparently might *not*) presuppose. ''No, no,'' she says, ''I mean in this class do we believe in poems and things, or is it just us?'' This misunderstanding invites Fish to ruminate on the communal interpretive norms that make communication possible, and without which no sentence (he maintains) has a determinate meaning. Such are the weighty matters that occupy the energies of English professors.

I am very honored, of course, to be given the Millikan medal. But I must tell you that I feel like a charlatan accepting it. The purpose of the award is to recognize ''notable and creative contributions to the teaching of physics.'' The list of previous winners includes many who have made fundamental contributions to the reform and revitalization of physics education. These are people whose ideas have affected every institution in the country, including those that have not explicitly adopted their programs. In their company I feel like a stodgy conservative—not a posture I find congenial in *any* context—and I am called upon to ask myself, and confess to you, why I have not joined the reform movement.

I'll begin with a facile rationalization. It is striking (and perhaps ironic) that most of the reform programs place heavier demands on the textbook, since less of the basic material is presented in class. And writing textbooks seems to be my niche, so perhaps I can claim to have played at least a supporting role in the reform movement. Incidentally, although it may not be in my best interest to say so, I view with some alarm the increasing reliance on textbooks. Many perfectly competent students do not learn well from the written word, and some concepts that are easy to convey verbally or at the blackboard rest awkwardly on the page. There's a lot of theatre involved in good teaching, and no substitute for a live performance. A book, at best, is static and one dimensional, but a good lecture exploits the much richer resources afforded by the temporal domain. Of course, I'm not talking about somebody standing at a podium like this and reciting a prepared text, or flipping through a stack of transparencies. When I give a lecture I want my students to know that something is happening in real time—that I am thinking through the argument as it is delivered, and responding continually to feedback, verbal and otherwise, from the audience. Personally, I never bring notes to a lecture unless I am egregiously ill-prepared, for they break a very delicate and important bond of trust with the listener: If $B$ *really* follows from $A$, how come he has to refer to his notes?

The reform efforts are based on the proposition that either the physics curriculum or our teaching methods (or both) are seriously flawed, and I am not persuaded by either claim. It is true that the very first semester can be rough, if students are mathematically ill-prepared, and there is widespread confusion (which I share) about the appropriate subject matter for the second year; but apart from that I think the physics curriculum as practiced in this country since about 1960 is not too bad. When Reed College hires a new faculty member in, say, German or Political Science, we are obliged to rewrite the catalog of course offerings, to accommodate that individual's personal interests or some current fad in the field. It makes you wonder how any self-respecting discipline can accept such a volatile and arbitrary curriculum. I am proud that we as physicists have a relatively sound, stable, and well-considered notion of what our students need to learn. I don't mean to be complacent—obviously our curriculum should be subject to vigorous and continual review. But on the whole I think it's pretty good.

Nor do I believe our traditional instructional methods are hopelessly flawed. I love Dean Zollman's story[2] about the time he and his 8-year-old daughter passed a large lecture hall full of motionless bodies. ''What are all those people doing?'' she asks; to which he replies ''They're learning physics!'' The girl is perplexed: ''Do they just sit there?'' A painful question, for someone who has devoted a lot of his life to lecturing. But I do not agree with those who conclude that the lecture method itself is to blame. I would concede that 80% (maybe 95%) of the lectures I attended as an undergraduate were a waste of time (and about 20% were *worse* than that). The fact is, most physicists don't know how to give a decent lecture. But there are a few (Norman Ramsey, Edward Purcell, and Sidney Coleman, in my own student experience) who prove that lectures can be brilliantly effective, efficient, and entertaining pedagogical instruments, in the right hands. Now, you may well respond that it is dangerous to rely on a technique that succeeds only for rare individuals. I shall have more to say about this in a moment, but I must point out right away that most of the reform proposals also presuppose extraordinary talent and commitment on the part of the instructor. How many of us could pull off the inspired performance of Eric Mazur, for example, and what will become of Priscilla Laws' Workshop Physics under the direction of a mediocre instructor in a hurry to get back to his research (or the golf course). I believe practically *any* pedagogical method requires a good teacher, and good teachers are extremely rare.

Now, the proponents of reform and revitalization—including Robert Hilborn, who is at this moment is trying to determine whether there is some way to take back the award he has just given me—argue that whatever one may think about it in principle, the demonstrable fact is that undergraduate physics instruction as presently practiced is not working. They cite two pieces of hard evidence: (1) repeated studies demonstrating that students in introductory physics courses are not mastering the most basic concepts, and (2) declining enrollments.

We have occasionally administered the Hestenes test (or ''Force Concept Inventory'') at Reed, and—as elsewhere—have been dismayed at how poorly our students do, and how slight is the improvement afforded by a year of instruction. The obvious conclusion (that our course is a failure) seems inescapable. And yet, as I look through the questions and recollect my own confusion at a similar stage, I begin to have second thoughts. I vividly recall my first exam as a freshman, in which we were asked to calculate the proper banking angle for a roadway. I drew a ''free-body diagram,'' in which I carefully indicated the centrifugal force: $mv^2/r$. The grader gave me a zero for the problem, even though I got the correct answer. For the first and last time I went in to complain about a grade. I was subjected to a patronizing harrangue about the nonexistence of centrifugal forces, and informed that I did not understand the most basic principles of mechanics. In retrospect I agree with the TA, and I have often found myself making the same impassioned speech to equally uncomprehending students. But at the time his objections seemed to me tediously pedantic and abstract. I knew how to get the right answer; why was he being so fussy about my reasoning?

The truth is, I did not really understand the point until much later. Does this mean that my freshman class was a waste? I don't think so. The learning process is mysterious and imponderably complicated. I personally learn by what Albert Baez used to call the ''spiral'' approach, in which the same subject recurs again and again, and one's comprehension deepens with every pass. I don't think we should expect perfect understanding on the first encounter, and I do not believe a bad score on the Force Concept Inventory proves that the student has not—at some level—''learned'' the material.

I am also skeptical about the reliability of multiple-choice tests. There are a thousand ways to get a problem wrong—not all of them bad—and many ways to get a problem right—not all of them good. The Hestenes tests I have seen are very skillfully designed, and the implications of poor student performance are important and disturbing, but I wonder if we are not reading a little too much into them. I'm sure they measure *something*, but I'm not convinced they measure what we would like to believe they do. The entire current reform movement derives in very large measure from concern over the Hestenes results. That concern is entirely appropriate, but I also believe some caution is in order. I have no doubt that one can design a course that leads to much better results on such tests. But as my doctor once remarked, there is no such thing as intervention without side effects, and I would like to know what we are (perhaps inadvertently) sacrificing when we teach to the Force Concept Inventory.

I am more persuaded by Hilborn's second concern: declining enrollments. He cites reports that the number of bachelor's degrees in physics has fallen for six consecutive years, and has now reached a 37-year low. This is a complicated sociological phenomenon, but I think some of the causes are clear. Undergraduates are acutely aware of the dismal job market for Ph.D.'s, and a lot of them simply see no future in the field. You and I may believe that the physics major—even as presently constituted—is an outstanding platform for a wide variety of careers, from business and law to engineering and medicine. But this is hardly self-evident, and we have done a poor job of convincing our students that it is so. Moreover, despite all our promises that physics is interesting and fun and beautiful, the fact is it's also very damn difficult and frustrating at times. With the hurdles so high, and the rewards uncertain, Psychology and Economics start to look very attractive.

And there's a related factor that I mention with some trepidation, though I happen to think it is very significant. It's the thing that came closest to driving *me* out of the field, and I believe it is the main reason why so few women choose physics: As a group, physicists are notoriously harsh on one another and arrogant toward others. There is a nasty competitive quality to much of our professional discourse—a kind of school-yard ranking—that is as demoralizing, to some, as it is distasteful. Pauli was, I suppose, the all-time master of the withering put-down (never mind that he was frequently wrong), but it's a disease we all share to some degree, when we declare a problem ''trivial'' or show off ''back-of-the-envelope'' calculations we have carefully rehearsed. Carleton College consistently produces a large number of outstanding physics students, a strikingly high proportion of whom are women. I have asked them how they do it, and the answer seems to be that they have managed to create an atmosphere in which the study of physics is a supportive communal activity, not an arena for exercising infantile machismo—and they have done so without sacrificing the rigor and discipline of their program.

For nonmajors a substantial contributor to declining enrollments has surely been the erosion of distribution requirements. At Reed we require just one year of science (one-*fifteenth* of a typical student's program), and I am deeply ashamed to say that we have no real mathematics requirement. Gerald Holton[3] reports that 40% of American undergraduates never study any science at *all*. Somewhere in the sixties and seventies American higher education lost its nerve, and the result has been a generation of intellectually stunted college graduates. We need to reinstate serious distribution requirements, especially in math and science.

But I believe enrollments would have held up in spite of all these influences, were it not for the abysmal quality of physics instruction, especially at our large research universities. The main reason for poor teaching is perfectly obvious: none of us was really *trained* to teach, and precious few professors are hired or promoted on the strength of their teaching performance. Most of us are *amateurs*, when it comes to teaching, and whereas amateurs can occasionally be very good, in our system this is rare and accidental. Worse: We have created a culture which largely denies that teaching is a worthy activity at *all*. Even Liberal Arts colleges now fancy themselves miniature MITs—just read their job notices, which call for absurdly specialized research interests and a demonstrated ability to attract fat grants, but never mention teaching effectiveness as a qualification. (For a refreshing exception check out Rex Adelberger's ads for Guilford College. No pretensions there: he's looking for great teachers, and he is not afraid to say so.) A colleague of mine in Chemistry likes to boast that ''anyone can teach; the important thing is to attract good researchers.'' I think it's exactly the reverse: Competent research physicists are a dime a dozen, but good teachers are few and far between. Please don't misunderstand: I've got nothing against research—I do a certain amount of it myself, and I think it goes hand in hand with good teaching. But I regard myself as a professional teacher, and an amateur researcher, whereas most physicists are professional researchers but amateur teachers, and it shows. In my opinion by far the most effective thing we can do to improve the quality of physics instruction—much more important than modifications in teaching technique—is to hire, honor, and promote good teachers.

But finally, why do we *care* if enrollments in physics decline? There are, of course, self-interested reasons, such as preserving our jobs. And there is the practical motivation of producing informed citizens who will vote for worthy scientific projects (and against boondoggles like the Office of Alternative Medicine and the Space Station). Moreover, in a technology-based society it is certainly a good idea for people to have some notion of how things work. But if all we're concerned about is developing a more sophisticated electorate, I think the study of History and Economics is far more important than Physics. People who believe in UFOs and astrology are, on the whole, merely pathetic, but those who think you can run a modern society without taxes are downright *dangerous*.

What bothers me more is that so few students are exposed in any serious way to the greatest achievements of the human mind. I think it's *tragic* that vast herds of undergraduates squander their college years practicing arcane rituals of literary analysis—skills most of them will never use again, skills that do not lend themselves to other areas of human activity, skills without, as far as I can discern, any broader intellectual interest. If English majors learned to write beautifully—or even competently—that would be *something*, but they manifestly do *not*. No doubt they acquire a more sophisticated appreciation for Shakespeare (at any rate, they *used* to); but physicists are not altogether deprived of access to Shakespeare, whereas the overwhelming majority of American students are absolutely deprived of access to Schrödinger, by an educational system that regards such ignorance as perfectly acceptable.

Above all, I think studying science—and especially physics—is a tremendously *liberating* experience. I don't happen to know how a carburetor works; I'm not even sure what a carburetor *does*; let me be frank: I don't know what a carburetor *looks* like. But I *do* know that the behavior of carburetors is perfectly rational; *somebody* understands them, and if I really wanted to I'm sure I could understand them too. For I have confidence, grounded in the study of physics, that the world is rationally intelligible, and this, to me, is the most important—and most profoundly *liberating*—idea in human experience. The universe is *comprehensible*; we are *not* at the mercy of mystical forces or arbitrary deities; this is the real lesson of science. Yes: there *is* a text in this class. We believe in reason, and laws, and carburetors. It's *not* ''just us.''

[1]Stanley Fish, *Is There a Text in This Class? The Authority of Interpretive Communities* (Harvard U.P., Cambridge, MA, 1980), Chap. 13.
[2]Dean Zollman, ''Millikan Lecture 1995: Do they just sit there? Reflections on helping students learn physics,'' Am. J. Phys. **64**, 114–119 (1996).
[3]Gerald Holton, *Einstein, History, and Other Passions: The Rebellion against Science at the End of the Twentieth Century* (Addison–Wesley, Reading, MA, 1996), p.41.

**WHAT NEWTON LEFT OUT**

CHLOË: The future is all programmed like a computer—that's a proper theory, isn't it?

VALENTINE: The deterministic universe, yes

CHLOË: Right. Because everything including us is just a lot of atoms bouncing off each other like billiard balls.

VALENTINE: Yes. There was someone, forget his name, 1820s, who pointed out that from Newton's laws you could predict everything to come—I mean, you'd need a computer as big as the universe but the formula would exist.

CHLOË: But it doesn't work, does it?

VALENTINE: No. It turns out the maths is different.

CHLOË: No, it's all because of sex.

VALENTINE: Really?

CHLOË: That's what I think. The universe is deterministic all right, just like Newton said, I mean it's trying to be, but the only thing going wrong is people fancying people who aren't supposed to be in that part of the plan.

VALENTINE: Ah. The attraction that Newton left out. All the way back to the apple in the garden. Yes. Yes, I think you're the first person to think of this.

Tom Stoppard, *Arcadia* (Faber and Faber, London, 1993), pp. 73–74.