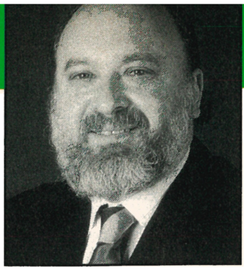

GREATS

Leo P. Kadanoff

I had a tiny idea that I thought might improve physics education a bit. It is neither original nor profound but I thought it might be helpful. I suggest that all of us, when asking for continued financial support for existing programs, state what became of the people previously supported on similar grants or contracts. We would name them and describe the first jobs, and, where appropriate, the second or even third.

I brought the idea to the dinner table and pointed out that it might help the Federal agencies evaluate proposals better. Some schools have claimed they had exceptionally good records in job placement. Maybe someone could look at those claims and help put the money for training graduate students, postdocs and undergraduates into the places that had proved most effective. My wife wondered whether this suggestion would be good for me. The change might, she suggested, be really bad for my own grant renewals. After all, some of my young coworkers got pretty unconventional jobs: in banking or in a Japanese government lab or in a hospital or (going back a little in time) in the atomic energy program of a nonaligned nation or as an administrator in a Soviet university, or . . . . In fact, a very large majority of the people whom I might have described under this proposal were doing something quite distant from the topic of their supported research. How should I evaluate my own accomplishments as a mentor? What kind of outcome should I count as a success and what kind as a failure for an undergraduate physics program?

My next occasion for thinking about this topic arose on a visit to Haverford College, an excellent institution with serious students and a particularly good undergraduate research program. Jerry Gollub, my host, showed me a list of professions pursued by the school's physics-major alumni. Doctor, lawyer, captain of industry . . . every profession under the sun, with only a small minority in physics and allied fields. Should this outcome be counted as a failure for an undergraduate physics program?

I do have a strong opinion about the purposes of undergraduate education in physics: I am in favor of it. (Surprise, surprise!) I think that we physicists have a lot to offer to many different kinds of people who wish to become educated. Specifically, an undergraduate education in physics potentially offers the following benefits to students.

Physics teaches that many problems can be well enough formulated so that they have answers. In our field, there is a distinction between correct and incorrect. A main goal of any education should be to teach that truth is not relative. (A wise student might recognize that a distinction between right and wrong applies also to other aspects of life.)

Physics teaches some concepts that should be part of the knowledge of every educated human. In studying physics we learn that events in the natural world occur through the working out of laws of nature and that many aspects of these laws are accessible to human intelligence. One sees that the development of the universe or the Earth or a piece of granite is the result of natural law. As a corollary, one begins to understand that humans are also part of the natural world and subject to nature's laws. The existence and ubiquity of law is the primary lesson, and the exact subset of laws learned less significant.

But even more important than any set of facts is the basic fabric of science itself, with its major components: curiosity about the world. The belief that problems can often be isolated and understood. The importance of successful predictions. The damning importance of unsuccessful ones. Problem isolation and prediction form the keystone of all science, indeed of most thoughtful human endeavor, and they appear in their purest form in physics. (Correspondingly, the weakness of physics as an educational tool is that our problems are too pure, too clean, and do not partake of the messiness of many real world conundrums.)

In addition the student of physics might learn technique and method. On the most basic level, physics method consists of problem isolation, the building of (often mathematical) models, the deduction of results from the models and the generalization of these results. A student may also learn the importance of more specific tools: laboratory technique, computer technique, mathematical analysis.

Finally the student will begin to see and understand a connected body of knowledge. Physics is a beautiful and complex intellectual creation, with an intricate interconnection among its parts.

So what kind of education do we wish to design for our students? What do we wish them to carry away? To where? So far, I have focused most on undergraduate education; next I turn to graduate education.

A PhD student should learn enough so that he or she will be able to find a first job that makes use of some portion of the skills and knowledge gained in grad school. Most students will directly use what they have learned about problem isolation, modeling, generalization and maybe some technique (perhaps use of computers) rather than any specific information close to their PhD theses. Nonetheless the thesis, if done right, will be the crucial learning experience in which they bring their technique and knowledge to bear on a real problem and advance, incrementally, some field of human knowledge. As the new PhDs enter the job market, they should be deeply and broadly enough trained so that they can make the expected switches from one career area to another. We uni-

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versity people should be pleased if our students have learned enough to start out in materials development, switch to the analysis of financial markets, and perhaps switch again to management or science writing. Any student should expect and be prepared for one or two major switches in the course of a career. Teachers should be pleased to see any previous student who is using his or her intellect fully and enthusiastically on work with some real value. Conversely we should be disappointed with a student who doggedly followed a straight-line career path in the direction of diminishing utility and diminishing rewards.

Many students can go in a straight line; few students can be flexible. Our graduate teaching should encourage the latter and discourage the former. Every student should have an opportunity to see the full range of a problem, from problem isolation to generalization. Through it all, the student and the teachers should keep their eyes on the two significant goals: Learn the right things to get a productive first job, and learn to learn so that one can switch fields as needed. (The professors may find they will need that skill too!)

Thus in graduate education we should give up narrow professional training and aim for flexibility and breadth. Correspondingly, on the undergraduate side, we should mostly give up thinking about the education of professional physicists. Instead we should try to develop a curriculum that exposes people who have a reasonably wide range of abilities and interests to the genuinely worthwhile, culturally valuable parts of our physics tradition. We should not aim to teach all of physics but merely representative portions of it, so that the student can see how it, and we, work. The particular portion taught might depend upon the resources of a particular institution. These portions should include considerable material from "applied" fields—astrophysics, geophysics, materials science—so that the student may see ideas interact with the real world. Broadly useful techniques should be stressed: more spreadsheets and small computer methods, less fancy mathematics; more model-building, less quantum mechanics.

In undergraduate education our goal should be to produce people who appreciate the capabilities of science, who might understand a discussion about global warming or the likely value of astrology. Our goals should not be narrowly professional, and we should certainly not judge the outcome on the number of people who go on to graduate school in physics. We might wish to ask something about what fraction of the students we have trained go on to productive lives independent of their field of activity.

So after having thought it over, I am reasonably happy that our former students chose such diverse careers. It would appear that most of the students have learned, and branched out, and it seems that their minds have found worthy tasks.

But, the reader might ask, what does the title of this piece have to do with all of this? During the high period of the British Empire, its public servants were largely given a classical education (Greek and Latin). "Greats" was the name for one portion of this funny education, which seemed in part to work. We need to inquire into the appropriate education for our time. ■

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