choose to work on projects that, if successful, will be highly significant; and their research proposal is based on ideas not heard before.

Paul Roman claims that the foundations of quantum theory are not neglected and then proves my point by mentioning a list of people who are either dead or close to the end of their careers. Were the field well supported, he would be able to name important contributors in their twenties and thirties. In fact, young people are contributing important new results and ideas to the foundations of quantum theory, but none are working at US research universities. Let me name a few of them: Chris Fuchs, Lucien Hardy, Rob Spekkens, Antony Valentini, and David Wallace.

As to the absence of statistical evidence for an outflow of researchers from the US, the point is not quantity but quality. Quantum gravity and foundations of quantum theory are small fields, and not long ago most of the key ideas and results came from physicists and mathematicians at US universities. That is no longer the case. Work on quantum gravity was initiated mainly in the US by pioneers such as Peter Bergmann, Stanley Deser, Bryce DeWitt, James Hartle, Charles Misner, and John Archibald Wheeler. There were at one time active groups working in quantum gravity and mathematical general relativity at the Universities of California at Berkeley and Santa Barbara; the Universities of Chicago, Maryland, North Carolina, Pittsburgh, Texas, and Wisconsin; and Princeton, Syracuse, and Yale universities. Many groups are now working in string theory and a reasonable number are working on LIGO (the Laser Interferometer Gravitational-Wave Observatory) and numerical relativity. But only two universities—Maryland and Pennsylvania State—have more than one faculty member active in quantum gravity. Were the field dying intellectually, the scarcity would be warranted, but the opposite is true: Recent progress is impressive and rapid, with major new results coming from loop quantum gravity, Planck-scale phenomenology, causal dynamical triangulations, and causal set models. The only major country where support for this field is shrinking is the US. Abroad, the field of nonstring quantum gravity is flourishing. A recent international meeting on nonstring approaches to quantum gravity, the Loops '05 meeting, had more than 150 participants from around the world. But only 6 out of 80 speakers were from the US. France, Germany, the UK, and Canada were each better represented than the US.

I appreciate William Carter's point that important novel ideas and results do come from people at any age. But I do not think the issue of journals is key, now that we have the arXiv e-print server.

To T. J. Blasing's observation that anti-intellectualism in American culture may be a contributing factor, I add that some countries—France and the UK, for example—seem to have an intellectual culture that values independent and iconoclastic thinkers; one can see the results in a more diverse and critical scientific culture.

Burke Ritchie points out why someone like Einstein could do great work in a patent office—he was immune from pressure that even tenured professors and career researchers in government labs suffer to ensure that their research is funded. But I do not think the answer is to let our most independent and creative physicists work in patent offices. The case to be made, then, is that the progress of science requires a variety of minds and of scientific personalities. Many contribute by doing relatively low-risk mainstream work and following the big, clearly defined research programs. But equally important are those few who go their own way and follow their own unease with foundational issues by generating and developing their own ideas. What is needed is an understanding that scientific funding and hiring are not games to identify those who excel at clever solutions to narrowly defined questions. They are both about ensuring the progress of science, which requires making various kinds of investments, within which the high-risk, high-payoff work done by foundational thinkers has a small but absolutely necessary place.

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Discussing (or Not) Our Nuclear Future

A potentially enormous change in the way the US manages its nuclear weapons program is playing out with very little discussion.

Several books have been published this year on Robert Oppenheimer and Los Alamos. They remind us that even when Manhattan Project scientists were working flat out to develop and build the bombs, most of the scientists kept discussing the larger issues of national policy and how the bombs were to be used. Contrast that with today.

At present the major medium of discussion of the future of the Los Alamos National Laboratory and by implication the nation's nuclear weapons program seems to be the LANL blog (http://lanl-the-real-story.blogspot.com/). Discussion there of the impending change in laboratory management ranges from apprehension about benefits to character assassination of those figuring in recent Los Alamos controversies. Few comments have addressed the larger issues, and responses to them have ranged from nonexistent to derisive.

Few people now working at the lab recall, or know those who recall, the Manhattan Project and the dispirited days after World War II. Fascinatingly, some of the blog blather resembles withdrawal behaviors that were manifested 60 years ago in reaction to the new and dreadful reality of the bomb.

Most of today's adults were born and educated without having to learn to dive under their desks in case of nuclear attack, during which time we could contemplate the futility of that little action in the face of megaton weapons. Understanding of the danger of nuclear weapons is being lost as they are being conflated with chemical and biological agents as weapons of mass destruction. The reality is that there are nuclear weapons and then there is everything else.

The management of one of the nation's design laboratories by a private contractor reflects a change in US nuclear weapons policy. The possibility of a private contractor directing nuclear weapons design work was a subject of intense discussion at various times during the history of the weapons laboratories. It is now a done deal.

Other changes may follow. The reliable replacement warhead is under consideration for funding by Congress. The Overskei Report[1] describes one possible future: a single-site weapons development and manufacturing complex, with decreased competition between the design laboratories.

During the Manhattan Project, Los Alamos had a single, clearly-defined purpose. It then went through a period of drift and confusion until the decision was made to develop thermonuclear weapons. During the latter part of the cold war, additional projects were accreted without adequate planning. As a result, Los Alamos now comprises many kinds of scientists and engineers doing many kinds of research and development. Consequently, there are many voices—and those voices need to be talking to each other and asking the big questions. How might a profit-making, business-expanding mindset affect the nation's nuclear policies? Conversely, can such a mindset support necessary basic research?

Los Alamos and the physics community should be engaging the nation in discussing those questions. What kind of nuclear future do you want?

Reference

1. Secretary of Energy Advisory Board, *Recommendations for the Nuclear Weapons Complex of the Future*, final report, US Department of Energy, Washington, DC (13 July 2005), available at http://www.seab.energy.gov/publications/NWCITFRept-7-11-05.pdf.

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Teaching Students How to Learn

I agree with everything Jerry Gollub had to say in his excellent Reference Frame piece (PHYSICS TODAY, May 2005, page 10), but I have a little to add. I am a retired industrial physicist teaching outreach classes, in whatever subjects need teaching, for Colby Community College in northwestern Kansas. In particular I teach classes in chemistry, statistics, algebra, calculus, survey of math, and critical thinking. Classes are generally very small and are limited to 20 students.

Most of my students have been beaten up in one way or another. Some are single moms, some are workers displaced by downsizing or those discovering they cannot survive on minimum wage, and nearly all are dropouts. These students make up in motivation what they lack in preparation. Most are trying to rebuild their lives, but they also have the maturity to really want to learn.

The first thing I require of my students is that they keep a notebook. Most of them have never taken notes in class before. The notebook must contain notes from the lectures, the textbook, and possibly TV shows or personal experiences, anything that they consider pertinent to the class. A grade of "A" goes to students who demonstrate sufficient interest to find outside sources. The notebook accounts for 50% of a student's grade. Tests are all with open notes. The notebook grade is based on an oral "notebook defense."

Every week I generally give a half-hour test, which serves more as a teaching tool than as a grading tool. The student takes the test in ink and "erases" with a single strike-out line so I can give partial credit when appropriate. In the second half-hour of the session, we go over the test in detail and the student corrects it in a different color ink. The student receives half-points for every proper correction, and after I've graded the test, it, with all its corrections, becomes an integral part of the notebook and a resource for later tests or life experiences. I rarely have multiple choice or true/false questions. Instead, I do "match the phrases" and "fill in the blanks" questions for part of the test. Half of the test requires that the student demonstrate use of the subject matter.

It is virtually impossible to cheat on the tests because they demonstrate ability to use the material. Having open notes eliminates attempting to memorize, but by the time the student has filled out the notebook, the material is familiar anyway. Many of my students do not test well, and frequent testing helps overcome that. The class includes lots of board work, and I try to give at least two major exams orally to accommodate the students who do not test well. The tests and follow-up discussion make up 25% of the grade.

The classes, particularly college algebra, are often heterogeneous. Roughly 50% of the students in those classes are still in high school and have good math and science preparation. The other 50% usually have been out of high school for several years and have virtually no preparation in science and mathematics. I encourage the students to work together. The haves, those with preparation, become designated helpers. The have-nots serve, too, by providing a mechanism for the haves to sharpen their knowledge and abilities by explaining material unfamiliar to the have-nots. The end result is usually a class full of haves, and teams that have developed into long-term friendships.

Health problems that prevent me from using the standard lecture format have proved serendipitous. Each student takes a turn as my chalkboard scribe while I dictate the material. I let the scribes stop after a short session to update their own notes too.

The desks are arranged in an open circle with the board at the gap. I sit at a desk in the circle, so that I can interact with the students directly. It is amazing how they pay much more attention to one on their level than to a teacher with thunder and lightning flashing from all fundamental orifices. I include as much hands-on work as the subject allows. Many of my students have put in a full day's work, taken care of children, and done housework and the like by the time they come to class. A traditional lecture format would put them to sleep within minutes.

The final exam provides the last 25% of the class grade. I use the same format as for the other tests: half the session for the text and the second half for discussing and correction. The final exam is my last chance to teach the students something. Once again the emphasis is on using knowledge rather than remembering it. My students wake up five years later with vivid dreams of the material covered—it doesn't just disappear 15 minutes after the exam.

Gollub's emphasis on critical thinking is paramount. The issue is freedom. People with both knowledge and wisdom are hard to conquer. People without them can be easily enslaved.

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Corrections

October 2005, page 54—In the photograph, the man identified as Doyle Northrup is Carl Romney, who was then an assistant technical director in charge of the geophysics division at the Air Force Technical Applications Center.

November 2005, page 33—The Leiden Observatory, mentioned in the caption for figure 1, is located in the Netherlands. ■