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An educational moment?

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This is a time of extraordinary opportunity for the US physics community. We have successively been urged by reports from Congress, the business community, the National Academy of Sciences,[1] and the executive branch to expand innovation in the physical sciences, with the eventual goal of improving the economy. The proposed effort has two arms: increased research accomplishments and enhancement of Americans' educational attainments in mathematics and physical sciences. The first goal can be approached by reversing the decline in federal and industrial funding of research in the US. Here I make a few suggestions for how physicists might help improve education in the sciences and allied areas.

US weaknesses

First, look at the problem. In contrast to people in places like China, India, Korea, and Eastern Europe, many Americans have a limited view of the possible advantages of education. Being a sports star or a self-made man or having street smarts is regarded as preferable to book learning, and as a surer and better road to social and economic advancement. For many, the purpose of going to school or college is found in sports, social life, and making contacts. Teachers, teaching, and learning are all given a very low status in popular mythology. Think, for example, of the classic American movie *The Wizard of Oz*. One character morphs from nasty schoolteacher into wicked witch. Another is given a diploma to make up for his lack of brain. Attitudes like the ones displayed in this film steer potential students away from learning and discourage our best students from becoming teachers.

The outcome of the educational process is correspondingly disappointing. US students, who match up to the best in the world in early grades, fall behind in middle school and find themselves rather poorly trained in science and mathematics in their high-school years. Comparisons of achievement scores in various developed countries make US achievement look mediocre. In a listing of national averages, our 15-year-olds sit a little below the middle,[2] with, for example, the Netherlands, Canada, and France well above us. We fall into the same middling category as the Slovak Republic, Spain, and Italy. This picture is not awful. Countries in the middle and lower categories have many excellent scientists. However, the US does not stand anywhere near the world leaders: Finland, Japan, and South Korea—all countries in which high educational attainment matches their very considerable export of technology and technological goods. Quick changes are unlikely. Achievement tests[3] show that the science knowledge of US 17-year-olds has not improved over the past decade.

Part of the difficulty lies with the training of schoolteachers for elementary and middle schools. Many of those teachers have gotten "only a meager introduction to basic physics concepts."[4] Anecdotal evidence suggests that elementary schoolteachers are often uncomfortable with even simple math. At the high-school level, the US has a substantial shortage of qualified physics teachers.[5] In addition, many high schools are too small or too poor to employ someone who has been properly prepared to teach physics.[4] Of course, these problems are worst in the most economically stressed school districts.

Other scientific subjects suffer from complementary difficulties. For example, biology boasts a larger proportion of fully qualified teachers, but they are often shackled by rules and policies that prevent them from presenting a full picture of their science. Most of biology is closely tied to evolutionary theory, which provides a framework for integrating the specific knowledge in biology. Many states, school districts, and parents' associations discourage the teaching of modern evolutionary knowledge because it conflicts with strongly held religious beliefs. The activities of the Dover, Pennsylvania, school board have been closely examined because of a lawsuit about board strictures against the teaching of evolution.[6] Judge John Jones's decision in that lawsuit noted, with opprobrium, that the board's interference was related to a quasi-political effort by the intelligent design movement. That movement contains a wide variety of enthusiastic believers opposed to the dissemination of knowledge about evolution. Many adherents of ID are even opposed to scientific discussions about the age of the universe. Thus, religion-based conflicts can impede a full education in science.

Students, professors, professionals

Many opportunities exist for the improvement of education. The UTeach program at the University of Texas in Austin is particularly aimed at improving teacher training in mathematics and the sciences. (Michael Marder, one of the founders of UTeach, was a postdoc in my field at the University of Chicago.) The program description says:

> Through UTeach's academic program, participants get rigorous preparation and training in math and science in regular academic departments while also receiving the opportunity to take education courses and obtain hands-on experience in the school of education. The program is open both to undergraduates, who can complete the program over the course of four years, and to graduates with degrees in math, sciences, or computer science, who are eligible to complete the program in three semesters.

The work begins with two courses on education and continues with extensive training in school classrooms. Those learning experiences are all led by classroom professionals chosen for their skill in teaching pre-college students and for their ability to explain their teaching methods. Thus school-based knowledge is brought to a university audience. In addition, the UTeach curriculum contains rigorous science and educational theory, all taught by the appropriate academics. So the students get plenty of hard work. Apparently they eat it up. About 75 students graduated from the program last year and were certified as teachers, with their academic achievement at or above the high level usual for UT Austin graduates. Certified teachers of such high quality may be expected to make a significant impact upon education in Texas if they can remain insulated from the usual mess of Texas politics.

The use of pre-college teachers for college instruction is also built into the Physics Teacher Education Coalition (PhysTEC). This effort, supported by government and donors, is aimed at training more and better physics teachers. Led by the American Physical Society, the American Institute of Physics, and the American Association of Physics Teachers, PhysTEC coordinates work of eight different localities, each containing a collaboration among a physics department, an education college, and local schools. Each collaboration is cemented by a professional teacher borrowed from the local school district who spends a large proportion of his or her time working with the college or university. The program's main goals are to increase the number of highly qualified high-school physics teachers and to improve the quality of physical science preparation for all teachers. PhysTEC seeks to train enough fully qualified teachers so that every high-school physics course is taught by a person with solid knowledge of physics and a full competence in teaching techniques.

For the last four years, a museum administrator, a social scientist, a computer scientist, and I have provided leadership for a program at the University of Chicago that brought graduate students into the educational programs of local science museums. Social scientists and humanists were equally mixed with scientists. The grad students were paid for 10 hours a week for three quarters. That workload was picked so that the students' scholarly work could go on almost unimpeded alongside their outreach activities. The latter included producing preliminary designs for museum exhibits and designing and performing scientific demonstrations within the museums. The university and NSF provided stipends for the science students. Some academic instruction came from university scientists, but the bulk of the training was provided by professionals—both those hired by the university and those working for the cooperating museums. (By "a professional" I mean a person who has spent considerable time presenting science to a broad public, often in a school or museum context.) The students seemed to like the program very much. They enjoyed meeting people from other disciplines, getting away from the regular work of producing a thesis, and getting involved in helping young people learn science.

The programs I've mentioned, and a similar NSF program called GK-12, emphasize bringing the best of our young people into science education. Many of the people so trained will become professionals in science education or outreach. Many will not. But they will all benefit from an experience broader than usual, and especially from learning how to communicate ideas to people with backgrounds and attitudes unlike their own. Excellent and unusual students are often drawn into programs like the ones I've mentioned.

Bringing in the professors

Recruitment of undergrad and grad students is relatively easy. Recruitment of professors is much harder. Working in education and outreach will not help a person build a reputation for research accomplishment. Instead, these programs must depend on uncommon (and usually tenured) individuals with a perspective extending beyond the world of research. The payoff for their work will likely not be monetary. Nonetheless, I fully believe that scientists will increasingly devote themselves to education on all levels.

To see why, we must look at the meaning and value of science. Our work is particularly valuable not for the wealth or power it produces; there are quicker roads to wealth and power. Instead science provides a method for generating evidence-based arguments aimed at finding provisional truths. We scientists have the opportunity to develop evidence and to say things about nature that are very likely to be true: Atmospheric CO_2 can trap heat; photons tend to clump in the same state; the universe is billions of years old, and so on. Those observations can provide the hard facts upon which others may build the reliable instruments of our polity, or our economy, or our view of the world. That is the scientist's true value to the community. We can also serve as examples to show how others might, in their own lives, reach conclusions by careful assessment of evidence. The best scientific work stands in contrast to the self-seeking and evidence evasion characteristic of many people, high and low, in public life.

Educational activities enable us to communicate our professional values to the next generation. We can do that by the careful training of undergraduate and graduate students. Some of us also have the opportunity to organize and add to other kinds of educational processes aimed at informal education, teacher training, and the broad dissemination of science to young people and the public. Each of us, acting individually and through our professional associations, should consider seizing these opportunities above and beyond the usual consideration of "what's in it for me."

In the long run, there is something in it for all of us. Education aimed at the evidence-based pursuit of truth can help the community gain tools for a better understanding of the world. Evidence-based argumentation can help scientists, engineers, business people, national leaders—everyone—make better decisions.

I have received helpful advice from many colleagues in our University of Chicago Museum Program, and from fellow participants in several proposals for further museum and educational work. In addition, I have had helpful discussions with Michael Marder, Panos Oikonomou, Jerry Gollub, Michael Neuschatz, Ronen Mir, and Ted Hodapp. Financial support has been received from the University of Chicago and its Materials Research and Engineering Center and Flash programs.

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