typical educational background, lives, and challenges?

▶ What should students know more or better? Is physics more important for all than English, geography, or music? What is the evidence? CEOs, Cabinet officials, and media stars seem to do well with essentially no clue about physics. In what way would they improve by learning physics?

▶ As a scientist, have you reviewed the enormous amount of available literature on these topics from our university colleagues in education?

Let me provide a reference to some baffling and scary data relevant to our hopes and ambitions. Rent or purchase copies of the videos *A Private Universe* and *Minds of Their Own* from the Annenberg Project series. Watch them and answer this question: Will your reform improve the performance of these students? If not, what value do you perceive in putting physics in ninth grade for all students?

The students in those videos are graduating seniors of Harvard University and MIT, most with superb high-school experience. Yet more than 90% thought that the reason Earth had summer and winter was that it came closer to (or farther from) from the Sun. Even more could not identify photosynthesis as the mechanism by which a tree accumulates mass. The same percentage of MIT engineering graduates in their caps and gowns could not light a bulb with a battery and one wire.

I've concluded that less than 10% of the American populace can handle any kind of abstraction. Fortunately, almost 100% can learn by using other senses and right-brain pathways. Hence my recent focus, and my recommendation to those who want to get more students into physics, is to start with reality and touch: touch-science. This recommendation builds on the unchangeable reality of the sequence of human sensory development, which starts with touch in the womb. The hands-on approach puts students in touch with such real sciences as agriculture, Earth, health, and materials. And as data from the University of Washington show,[1] using materials as the gateway to abstract science is valuable to both citizens and protophysicists. Out of the many who become interested spring more, and possibly better, physicist-citizens.

Reference

1. T. Stoebe, G. Whittaker, K. Hinckley, *Jour. Mat. Ed.* (in press). Electronic copies available from Thomas Stoebe, stoebe@u.washington.edu.

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Lederman replies: It is a pleasure to assist Rustum Roy, who is equally renowned as a science educator and a materials scientist. Roy has usefully summarized the criteria that scientists should satisfy in order to be effective in the K–12 domain.

The reform of science education must be for all high-school graduates, future citizens, consumers, family members, and voters. Perhaps never before has this nation needed voters with the qualities of a science way of thinking (see my Reference Frame column "Revolution in Science Education: Put Physics First," PHYSICS TODAY, September 2001, page 11).[1] Therefore, I work on a core science curriculum designed for *all* K–12 students. The goal is a seamless math–science curriculum, for

students from pre-kindergarten through grade 12, taught by a well-trained, well-paid, and well-respected teacher corps.

Roy insists that scientists know something about the students they want to educate. Teaching Physics 101 to graduates of the Chicago high schools helps me, as has helping organize the Teachers Academy for Math and Science, a K–8 teacher development program, for the past 14 years. TAMS has learned that if it stays with teachers for three years (some 200 hours of science, math, and technology), the K–8 student scores on standardized math tests zoom up. This is true for deep urban Chicago. We may not know how the children get to school daily, but we know that they *can* be successful high-school graduates. Better nutrition, health care, home nurturing, and such do help, but schoolchildren also need good, lively, provocative teaching.

Genetically optimistic, I believe the K–12 system can be fixed so that it produces a science-literate population (see PHYSICS TODAY, May 1992, page 9, and April 1995, page 11).[2] Roy and I agree that this is the goal of high schools and that, if the goal is achieved, many "apparently average" students will become stars and cure senility and find grand unification. There are just too many examples of successes in urban poor schools not to believe.

Roy makes the point that physicists are so parochial that they would replace English and music with theoretical astrophysics and quantum string theory. Oh, come on!

Scientists, Roy insists, must take the time to absorb the vast literature produced by education professionals. One can start with Johann Pestalozzi, proceed to Jean Piaget, John Dewey, Robert Gagne, Jerome Bruner, Theodore Sizer, and pause at Howard Gardner. Useful? Yes. Essential? I'm not so sure.

I share Roy's alarm at the state of US science literacy. I argued that the near future may leave all children behind but that ultimately the mandate will be to give the highest priority to the war on ignorance and pay the cost of providing a 21st-century liberal arts education to all children. Roy's neuro-nonsensical pessimism is where he and I part company, but we can't be expected to agree on everything.

References

1. See also L. M. Lederman, *Education Week* **18**(40), 44; L. M. Lederman, *Interciencia* **27**, 66; G. E. DeBoer, *A History of Ideas in Science Education: Implications for Practice*, Teachers College Press, New York (1991).
2. See also L. M. Lederman, M. Bardeen, *Science* **281**, 178 (1998).

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Ronald Richter, Genius or Nut?

I remember Juan Roederer (see his article in PHYSICS TODAY, January 2003, page 32), his wife, and newborn child quite well from their 1953 visit to the Max Planck Institute for Physics in Göttingen, where I was working toward my PhD under Werner Heisenberg. Even though I had heard the sensational news that Argentine scientist Ronald Richter had achieved controlled fusion, I never asked Roederer what he knew about the project. Through Wolfgang Meckbach, who later became the director of the Bariloche research center and who married my cousin, I got a much better insight into Richter's work. My understanding differs substantially from Roederer's account. Putting together the different pieces, I got the following picture.

Primarily through the work done in Germany on electric arcs, Richter likely had known that, with the water-vortex–confined arcs (Gerdien arcs), temperatures of ~50 000 K had been achieved, still much too low for thermonuclear reactions to take place. But he also must have known that with plasma resistivity dropping rapidly as temperature rose, resistive heating alone was insufficient to reach the necessary high temperatures. To overcome that problem, he proposed—for the first time, I believe—using ion-acoustic heating by surrounding an arc with many powerful loudspeakers that focused intense sound waves on the arc. To reduce the heat conduction losses into the surrounding medium, he placed the arc in a strong axial magnetic field. That temperatures of 100 000 K can be reached by that technique was later rediscovered by scientists from the Max Planck Institute for Plasma Physics in Munich. So what went wrong with Richter's project?

First, although he was apparently quite familiar with electrical discharge physics, Richter must have been unfamiliar with nuclear physics. Second, he did not, or was not permitted to, publish his research. Had he published, the US likely would have declassified its controlled fusion research much earlier. Richter's work was not far off from what was done in the US, and some of his ideas—like ion-acoustic plasma heating—were actually new. Third, Roederer says that the Argentine scientists sought the opinion of Karl Wirtz, a codirector of the Max Planck Institute for Physics, rather than asking such outstanding physicists as Fritz Houtermans, who reportedly had left the institute because Wirtz was difficult to get along with and knew little about plasma physics.

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Roederer replies: Friedwardt Winterberg gives Ronald Richter too much scientific credit. He seems unfamiliar with the literature that is available—unfortunately only in Spanish—particularly Mario Mariscotti's meticulously documented book,[1] and reports available on the Internet; for example, see ref. 2 for a succinct answer to "what went wrong."

Richter wanted to do his thesis at Prague University on "Earth rays" but was persuaded to choose another subject. His only research jobs before going to Argentina were a six-month stint working on explosives and a few postwar commercial contracts. Richter never published a scientific article or technical report because there just was nothing to publish. And according to José Balseiro, founder of the Bariloche research center, Richter showed "a surprising lack of knowledge of the physics relevant to his own project" (ref. 2, p. 9).

True, Richter was interested in certain types of electric discharges and what he called "self-confining balls of plasma excited with sound waves" (ref. 1, p. 146), which was indeed the subject of an early stage of his "experiments" on Isla Huemul. As for Karl Wirtz, I stated that it was not scientists, but doubters among Juan Perón's entourage, who sought Wirtz's opinion (Heisenberg was contacted first, but he deferred the task to Wirtz.)

It is difficult to determine whether Richter was a clever impostor or a scientific nut. A 1956 quote from Edward Teller (ref. 1, p. 278)