

Physics First: Precursor to Science/Math Literacy for All? *†

Richard R. Hake

I. "Physics First"

The Lederman (1999; 2001a,b) "Physics First" brigade appears to be attracting recruits: e.g., two sessions on "Physics First" at the January 2002 AAPT meeting in Philadelphia; recent pro-"Physics First" editorials by AAPT leaders (Chiaverina 2002, Khoury 2001, Hubisz 2001a); a "Physics First" website (Livanis 2000); and "more than a hundred schools around the country. . . that have switched the sequence to the rational order" (Lederman 2001b). Lederman (1999) writes:

*Our reform thrust, in military metaphor, is toward a weak section of the barriers to change that surround the school systems. We have observed that 99 percent of our high schools teach biology in 9th (or 10th) grade, chemistry in 10th or 11th grade, and, for survivors, physics in 11th or 12th grade. This is alphabetically correct, but by any logical scientific or pedagogical criteria, the wrong order. A standards-based science curriculum must contain at least three years of science and three years of mathematics. And the coherent order begins with 9th grade physics, **taught conceptually** and exercising only the math of 8th and 9th grade; then chemistry, building on the knowledge of atomic structure to study molecule; then the crowning glory of modern, molecular-based biology We stress that this is a design for **ALL** students, work bound, liberal arts-college-bound, or science-and-technology-bound. The schools that are "doing it right" report greatly expanded enrollments in fourth-year electives and Advanced Placement science courses. **Thus, a solid, core curriculum will enlarge rather than . . .** (diminish the pool of) . . . **future scientists.** (My emphasis.)*

II. Precursor to "Science/Math Literacy for All"?

But does K-12 education need "Physics First" or "Physics For All"? I agree with Hubisz (2001a) that *both* are desirable. However, considering the appallingly low level of science literacy among the general population, and society's need to solve the monumental science-intensive problems (economic, social, political, and environmental) that beset it (see, e.g., Lederman 1999, Hake 2000), I would rate "Physics For All" or, more generally, "Science/Math Literacy for All," as being by far the more important.

*Partially supported by NSF Grant DUE/MDR-9253965.

† Submitted to the *APS Forum on Education Newsletter* on 31 May 2002. A more complete illustrated version of this paper, titled "Physics First: The Opening Battle in the War on Science/Math Illiteracy?" in online as reference 18 at < <http://www.physics.indiana.edu/~hake> >.

© Richard R. Hake, 5/31/02. Permission to copy or disseminate all or part of this material is granted provided the copies are not made or distributed for commercial advantage, and the copyright and its date appear.

Viewed from that perspective, Lederman's "Physics First" reform thrust could be *an important precursor* for more systemic reform such as that envisaged by "Project 2061" (AAAS 1989, 1993, 1997, 2001, 2002), a long-range effort designed to achieve "Science/Math Literacy for All." As indicated in AAAS (1989, p. 11), Project 2061 "was started in 1985, a year when Comet Halley happened to be in the earth's vicinity. That coincidence prompted the project's name, for it was realized that the children who would live to see the return of the comet in 2061 would soon be starting their school years." But I would submit that "2061" could also designate the earliest year by which scientific literacy as defined in *Benchmarks for Science Literacy* (AAAS 1993) might characterize a *majority* of Americans (even despite the thorough and thoughtful efforts of Project 2061). My pessimism reflects the formidable roadblocks to education reform (Section III), and the monumental inertia of the U.S. educational system.

Considering only the *physics* aspects of "Science/Math Literacy for All," the cogent arguments of Hugh Haskell (2001) for "Physics for All," *starting in the very early grades* are worth pondering:

*I have been saying for years that physics can be taught earlier than the 12th grade, and it should be, but just dumping physics into the ninth grade isn't the solution either. . . . It isn't that we have to "dumb down" physics so that it can be taught as a terminal course to ninth graders; we need to teach the early concepts to kids starting as early as they can be expected to grasp them . . . They need to start learning to ask the question "How do we know that?" . . . (Arons 1983). . . and they need to start learning some of the vocabulary of science. They can also start learning how to draw a graph, and how to collect things--how to choose what fits into a desired category, how to decide on categories, in other words, how to look systematically at the world . . . In this way, we can expect that the students will be able to do certain things when they get to the ninth grade, and even more by the time they get to the twelfth grade. **But we have put them on a ramp to understanding and not a cliff.** Keeping the cliff but just making it lower because the kids are starting in the ninth grade is no improvement. . . . it involves much more than just reversing the order of presentation . . . **it involves a major rethinking of the philosophy of science education in the pre-high school years.** (My **emphasis.**)*

Haskell's arguments are in consonance with:

- A. The AAAS Project 2061 as indicated above.
- B. The *National Science Education Standards* (NRC 1996).
- C. Mahajan & Hake (2000) and Hake (2002a,b).
- D. The "Revolutions in the Goals and Methods of K-12 Science Education" (Lopez & Schultz 2001).

III. Systemic Roadblocks to Science/Math Literacy

Among important roadblocks to science/math literacy are, in my opinion, the following:

A. *High-stakes state-mandated tests of reading and mathematics* (see, e.g.; AAAS 1997e; Heubert & Hauser 1998). Will these crowd out K-8 science education?

B. *State science standards that are antithetic to the National Science Standards (NRC 1996) and the AAAS (1993) "Benchmarks for Science Literacy."* An outstanding example is the California science standards (Feder 1998, Woolf 1999).

C. *An antiquated and dysfunctional K-12 science/math curriculum* (AAAS 1997c).

D. Science textbooks that are *overstuffed, uninformed by education research, and often riddled with scientific errors* (see, e.g., AAAS 2001; Hubisz 2001b).

Attempts to overcome roadblocks "A" – "D" will require considerable educational redesign (Wilson & Daviss 1994) as well as grass-roots political effort. In my view those four roadblocks, challenging as they are, will be far easier to overcome than the fifth and most formidable:

E. *The dearth of effective K-12 science/math teachers* (APS 2001, AAPT 2000).

IV. Conclusions

The reports of the Glenn (2000) and Hart-Rudman (2001) Commissions; as well as the NSF (1996); AAAS (2002); AAPT (2000); APS (2001); and the "No Child Left Behind Act" (U.S. Congress 2001); all testify to the current national interest in improving pre-college teaching and education. On the other hand, there exist very serious systemic *roadblocks* to improving K-12 science/math education that may take sixty years or so to overcome. In the meantime, Lederman's "Physics First" regime, while not the ideal *ramp* to science/math literacy, might – if vigorously supported – be adopted by thousands of U.S. school systems within the next decade. This would auger well for the eventual attainment of the goal of "Science/Math Literacy for All" by demanding that serious attention be paid to the several roadblocks that are common to both "Physics First" and "Science/Math Literacy for All," most importantly, *the dire shortage of effective science/math teachers*. In particular, physics departments might help to overcome this roadblock and at the same time enhance their numbers of physics major and graduate students, through programs designed to provide a large corps of teachers capable of *effectively* teaching physics to vast numbers of students in the "Physics First" schools: ALL ninth-graders plus those taking twelfth-grade honors and AP physics courses. Then to, once ninth graders have experienced the excitement of well-taught conceptually oriented physics they will doubtless flock to enroll in twelfth grade and undergraduate physics classes, many of them as physics majors.

Richard Hake spent 40 years researching superconductivity and magnetism at the University of Illinois, North American Aviation, and Indiana University; together with 25 years teaching physics and researching physics education at the latter institution. He is now retired and living in California. He can be reached at <rrhake@earthlink.net>, < <http://www.physics.indiana.edu/~hake> >, and < <http://www.physics.indiana.edu/~sdi> >.

References and Footnotes

AAAS. 1989. *Science for All Americans*. AAAS Press; online at < <http://www.project2061.org/tools/sfaaol/sfaatoc.htm> >.

_____. 1993. *Benchmarks for Science Literacy*. Oxford University Press; online at < <http://www.project2061.org/tools/benchol/bolframe.htm> >.

_____. 1997. *Blueprints*; especially (a) Research, (b) School Organization, (c) Curriculum Connections, (d) Materials and Technology, (e) Assessment, (f) Teacher Education, (g) Higher Education; online at < <http://www.project2061.org/tools/bluepol/blpframe.htm> >.

_____. 2001. *Project 2061 Textbooks Evaluations*: middle grades mathematics, middle grades science, algebra, high-school biology; online at < <http://www.project2061.org/newsinfo/research/textbook/default.htm> >.

_____. AAAS. 2002. Project 2061; online at < <http://www.project2061.org/> >.

AAPT. 2000. *White Paper on Teacher Preparation*, L.M. Adair & C.J. Chiaverina, "The Preparation of Excellent Teachers at All Levels," online at < <http://www.aapt.org/governance/> >.

APS. 2001. American Physical Society, "Policy Statement on K-12 Science and Mathematics Education"; online at < <http://www.aps.org/apsnews/0201/020101.html> >.

Chiaverina, C. 2002. "Physics First: Some Personal Observations," *AAPT Announcer* **32**(1): 4.

Feder, T. 1998. "California's Science Standards Slammed for Demanding Too Much, Too Early," *Physics Today* **51**(11): 54.

Glenn Commission. 2000. *Before it's too late: A report to the National Commission on Mathematics and Science Teaching for the 21st Century*; online at < <http://www.ed.gov/americaaccounts/glenn/toc.html> >.

Hake, R.R. 2000. "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University," *AAPT Announcer* **30**(2): 105 (2000); online as ref. 11 at < <http://www.physics.indiana.edu/~hake/> >.

Hake, R.R. 2002a. "Lessons from the physics education reform effort." *Conservation Ecology* **5**(2): 28; online at < <http://www.consecol.org/vol5/iss2/art28> >.

Hake, R.R. 2002b. "Comment on 'How do we know if we're doing a good job in physics teaching?' by Robert Ehrlich [Am. J. Phys. **70**(1), 24-29 (2002)]," *Am. J. Phys.*, accepted for publication.

Hart-Rudman Commission. 2001. [United States Commission on National Security/21st Century], *Road map for national security: Imperative for change, Phase III Report*; online at < <http://www.nssg.gov/> >.

Haskell, H. 2001. "Re: Physics for Ninth Graders?" Phys-L post of 25 Sep 2001 20:51:32-0400; online at < <http://lists.nau.edu/cgi-bin/wa?A2=ind0109&L=phys-l&P=R36757> >.

Heubert & Hauser, eds. 1998. "High Stakes: Testing for Tracking, Promotion, and Graduation," Committee on Appropriate Test Use, National Research, National Academy Press; online at < <http://www.nap.edu/catalog/6336.html> >.

Hubisz, J.L. 2001a. "Physics? Yes, but when?" *AAPT Announcer* **31**(4): 8.

Hubisz, J.L. 2001b. "Report on a Study of Middle School Physical Science Texts," *Phys. Teach.* **39**(5): 304-309.

Khoury, B. 2001. "Physics First, Physics for All, Physics for the Best," *AAPT Announcer* **31**(4): 6.

Lopez, R.E. & T. Schultz. 2001. "Two Revolutions in K-8 Science Education." *Physics Today* **54**(9): 44-49; online at < <http://physicstoday.org/pt/vol-54/iss-9/p44.html> >.

Lederman, L.M. 1999. "A science way of thinking." *Education Week*, 16 June; 1999 < <http://www.edweek.org/ew/1999/40leder.h18> >.

Lederman, L. 2001a. "Physics First," *APS Forum on Education Newsletter*, Spring 2001; online at < <http://www.aps.org/units/fed/spring2001/index.html> >.

Lederman, L. 2001b. "Revolution in Science Education: Put Physics First." *Physics Today* **54**(9): 11-12; online at < <http://physicstoday.org/pt/vol-54/iss-9/p11.html> >.

Livanis, O. 2000. *Physics First Home Page*; online at
< <http://members.aol.com/physicsfirst/> >.

Mahajan, S. & R.R. Hake. 2000. "Is it time for a physics counterpart of the Benezet/Berman math experiment of the 1930's?" *Physics Education Research Conference 2000: Teacher Education*; online as ref. 6 at < <http://wol.ra.phy.cam.ac.uk/sanjoy/benezet/> >.

NRC. 1996. National Research Council, *National Science Education Standards*. National Academy Press < <http://books.nap.edu/catalog/4962.html> >.

NSF. 1996. Advisory Committee, *Shaping the future: new expectations for undergraduate education in science, mathematics, engineering, and technology*; online at
< <http://www.nsf.gov/cgi-bin/getpub?nsf96139> >.

U.S. Congress. 2001. Public Law PL 107-110, *No Child Left Behind Act of 2001*; online at
< <http://www.ed.gov/legislation/ESEA02> >.

Wilson, K.G. & B. Daviss. 1994. *Redesigning Education* (Henry Holt, 1994); description online at < <http://www-physics.mps.ohio-state.edu/~kgw/RE.html> >.

Woolf, L. 1999. *Science Education Petition of 22 December 1999*; online at
< <http://www.sci-ed-ga.org/standards/> > / "22 December 1999 Science Education Petition," where "/" means "click on".