Educational Activities (1979 – 2003) *‡§◊

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My educational activities have been primarily concerned with five areas:
(1) development and dissemination of Socratic Dialogue Inducing (SDI) labs,
(2) assessment of introductory high-school and college-level physics instruction,
(3) concerns with K-12 education,
(4) work on gender issues in science and physics education, and
(5) promotion of more effective educational use of the internet.

I. Socratic Dialogue Inducing (SDI) Labs

As indicated in "My Conversion To The Arons-Advocated Method Of Science Education," [Hake (1991b)], my present concern with undergraduate science education began in the early fall of 1980 when, being assigned by happenstance to teach a physics class for prospective elementary teachers, I gave the first examination. The results showed quite clearly that my brilliant lectures and exciting demonstrations on Newtonian mechanics had passed through the students' minds leaving no measurable trace. Seeking advice on efficacious physics pedagogy for future elementary teachers, I telephoned around the country with little success until the late Robert Karplus at Berkeley advised me to call "the only person in the country who understands the problem," Arnold Arons at the University of Washington.

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‡ The reference is: Hake, R.R. 2003. "Educational Activities (1979 – 2003)"; online as reference 32 at < **http://www.physics.indiana.edu/~hake** >.

§ For a brief bio and listing of research articles on condensed-matter physics (1956-1989) click on [VITA-052200.pdf, 48K] on page 1 of < **http://www.physics.indiana.edu/~hake** >.

◊ Downloading of articles at < **http://www.physics.indiana.edu/~hake** >.requires the free Adobe Acrobat "Reader," bundled on most modern browsers; also downloadable at < **http://www.adobe.com/products/acrobat/readstep2.html** >. .

In a watershed 30-minute telephone conversation, Arons, speaking from 12 years of hard-won experience with elementary education majors (Arons, 1977), recommended that *I abandon the traditional passive student lecture*. He patiently explained his physics education method: hands-on laboratory experience with concrete physical systems, repeated interactive engagement at increasingly sophisticated levels, emphasis on operational definitions, and Socratic dialogue. Seeking to learn more about this unorthodox approach, I studied some of Arons' insightful articles and books [e.g., Arons (1972, 1974, 1977)] and was deeply impressed. Since then Arons has authored many guides to physics education [e.g., Arons (1981, 1990, 1993, 1997)].

After my 1980 telephone conversation with Arons, I tried to construct several laboratory write ups to promote the *Arons-Advocated Method* [Hake (2003d)] and found that such "Socratic-Dialogue-Inducing" (SDI) labs were quite effective in advancing the conceptual understanding of physics among not only elementary education majors but also premeds, health professionals, and science (including physics) majors. It is gradually being discovered by physics teachers [see e.g., Mazur (1997, p. 4)] that the latter groups often hide their ignorance of basic concepts by their ability to solve exam problems by algebraic manipulation of rote-memorized algorithms. Starting in 1987, I published many SDI lab articles, commentaries, lab manuals, and teacher's guides [Hake (1987, 1991a,b; 1992; 1994; 1998a; 2002a; 2003a,b; Tobias & Hake (1988); Hake & Wakeland (1997)].

The age-old Socratic method of guidance (leading students into thinking and forming insights while not giving everything away) has been employed successfully in many high-school and college-level "interactive engagement" programs such as Arizona State University's "Modeling" [Wells et al. (1995)] and the Univ. of Washington's "Physics by Inquiry" and "Tutorials in Introductory Physics" [McDermott (2003)] . The Socratic method would seem to be an ideal way to structure some (but not all) K-8 science classes. Although not easy to apply and often misunderstood [Hake (2002g)], it can be very effective when used by skilled teachers with research-based material, as clearly demonstrated in my SDI program at Indiana University. There the average normalized gains $<g>$ on tests of conceptual understanding of mechanics during the years 1987-1995 were between 0.54 and 0.65 [Hake (1998c, Table IIc)], as compared with the average $<g>$ of 0.48 for 48 interactive engagement courses in my survey (Hake 1998b,c; 2002b).

II. Assessment of Physics Instruction

Regarding that survey, I have played a prominent role in the assessment of introductory high-school and college-level physics instruction [Hake & Swihart (1979), Hake (1987, 1998b,c; 2000a, 2002b,c,d,e,f,h). My pre/post-test survey provided convincing evidence that "interactive engagement (IE) methods" [i.e., "heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors" (Hake (1998b)], are far more effective [a nearly two-standard-deviation difference (Bloom 1984)] than traditional methods (passive-student lectures, recipe labs, and algorithmic problem sets) in enhancing students' conceptual understanding and problem-solving abilities. Since that time many other physics education researchers [for reviews see Hake (2002b,e)] have measured normalized gains for reform and traditional courses that are consistent with my results [Hake (1998b,c; 2002b)] .

The effectiveness of IE-induced brain activation for learning is consistent with the views of most cognitive scientists. For example, Bransford et al. (1999, page 106) write: ". . . synapse addition and modification are lifelong processes, driven by experience. In essence, the quality of information to which one is exposed and the amount of information one acquires is reflected throughout life in the structure of the brain. This process is probably not the only way that information is stored in the brain, but it is a very important way that provides insight into how people learn."

Along with the early work of: (a) Halloun & Hestenes (1985a,b) in developing the *Mechanics Diagnostic* test (precursor to the much-used *Force Concept Inventory* (FCI) [Hestenes et al. (1992)]); (b) Saunders (1991) in economics; (c) Sundberg & Moncada (1994) in biology; (d) Milford (1996) in chemistry; and (e) Zeilik (1997) in astronomy; my work has stimulated efforts to use valid and consistently reliable such as the FCI in a pre/post mode so as to formatively measure the need for and the result of reform methods in:

(1) physics [for reviews see Hake (2002b,e)];
(2) biology [e.g., Anderson et al. (2002), Klymkowsky et al. (2003), Roy (2001, 2003) , Sundberg (2002), and Wood (2003);
(3) chemistry [e.g., Bowen & Bunce (1997), ASU (2003), Gonzalez et al. (2003)];
(4) engineering [e.g., Evans et al. (2003)]; and
(5) computer science [e.g., Almstrum (2003)].

III. Concerns With K-12 Education

As a consequence of my 25-year effort (1970-1995) to promote physics understanding among often sadly underprepared pre-meds, science majors, and prospective teachers (all innocent victims of deficient K-12 education), I have devoted considerable attention to pre-college schooling and the dearth of *effective* K-12 science/math teachers [Hake (1989, 1990, 2000b,c,d; 2002b,i,j,k); Mahajan & Hake (2000)]. In that work, I have often expressed the view (unpopular among most university faculty and administrators) that the severe shortage of *effective* teachers is partially due to the failure of U.S. university science and math departments to adequately prepare teachers for America's schools [Goodland (1990, 1994); Goodlad & Keating (1994)]. In my opinion [Hake (2002 j,k)] (a) that shortage poses severe problems for Leon Lederman's (2001) controversial "Physics First" plan to teach physics to ALL the ninth grade students, but (b) "Physics First" may serve as a needed wake-up call to drastically improve K-8 science/math education.

IV. Work on Gender Issues in Science and Physics Education

My compilation with Jeffrey Mallow of "Gender Issues in Physics/Science Education (GIPSE) – Some Annotated References" [Mallow & Hake (2002)], has received favorable attention in many quarters, has been noted in *The Physics Teacher's* "WebSights" column of September 2003, and appears on the American Physical Society's *Committee on Status of Women in Physics* (CSWP) web page < **http://www.aps.org/educ/cswp/** > "links" where "/" means "click on." Plans are now underway to publish a version of GIPSE in the *American Journal of Physics* as a "Resource Letter." My interest in gender issues was enhanced during my collaboration with feminist author and educator Sheila Tobias [Tobias & Hake (1988)]. In that paper we analyzed the reactions of non-physical-science "professors-as-students" to their instruction in my regular university introductory physics class.

V. Promoting Effective Educational Use of the Internet

As indicated on pages 8-10 of "Education Articles, Materials, & Posts (1979 – 2003)" [Hake (2003c)], I have been a frequent contributor (about 800 posts since 1995) to internet discussion groups in diverse areas: physics, physics & society, chemistry, biology, mathematics, assessment, evaluation, psychometrics, medical education, after-school programs, oganization & development, educational psychology, and philosophy. As indicated in Hake (1999, 2000e,f), I think that (a) the internet might provide the intedisciplinary synergism required to promote progress in in solving the severe educational problems that beset the U.S. [see e.g. Jungck (1998); NSDL (2002, 2003); NRC (1999, 2001)], and (b) discussion-lists sorely need [paraphrasing Roschelle and Pea (1999)] "to move beyond forums for exchanging tidbits and opinions, to structures which rapidly capture knowledge-value and foster rapid accumulation and growth of the community's capability . . . providing tools to allow contributors to share partially completed resources, and enable others to improve upon them."

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Hake, R.R. 1999. "REsearch, Development, and Change in Undergraduate Biology Education (REDCUBE): A Web Guide for Non-Biologists" online at < **http://www.physics.indiana.edu/~redcube** >. This Adobe Acrobat portable document file (pdf) gives non-biologists (and even biologists) a point of entry into the vast literature and web resources relevant to research, development, and change in undergraduate biology education. The 9/8/99 version contains 47 biology-educator profiles; 446 references (including 124 relevant to general science-education reform); and 490 hot-linked URL's on
(a) Biology Associations,
(b) Biology Teacher's Web Sites,
(c) Scientific Societies and Projects (not confined to Biology),
(d) Higher Education,
(e) Cognitive Science and Psychology,
(f) U.S. Government, and
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The references and URL's may be generally useful to teachers and education researchers, and may provide some ideas for hastening education reform.

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Hake, R.R. 2000c. "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University," *AAPT Announcer* **30**(2): 105; online as ref. 11 at < **http://www.physics.indiana.edu/~hake/** >. Based on an earlier libretto with the leitmotiv: "The road to U.S. science literacy begins with effective university science courses for pre-college teachers." The opera dramatizes the fact that the failure of universities *throughout the universe* to properly educate pre-college teachers is responsible for our failure to observe any signs of either terrestrial or extraterrestrial intelligence.

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