MY CONVERSION TO THE ARONS-ADVOCATED METHOD OF SCIENCE EDUCATION[1,2]

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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 perspective 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. To make matters worse, in a student evaluation given shortly after the exam, some students rated me as among the worst instructors they had ever experienced at our university. Knowing something of the teaching effectiveness of my colleagues, I was severely shaken.

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. 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 standard 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 (e.g., Arons, 1972; Arons, 1974) and was deeply impressed. I tried to construct several laboratory write ups to promote the Arons-advocated method and found that such "Socratic-Dialogue-Inducing" (SDI) labs were quite effective in advancing the conceptual understanding of physics among elementary education majors.

Of course, other professors who followed me in the elementary teachers' course quickly returned to the time-honored lecture method. As with most one-shot professorial instructional innovations, my efforts would have silently passed into oblivion but for another chance occurrence several years later. As "payment" for the privilege of teaching a highly sought after quantum mechanics course, I was assigned to teach the physics course most dreaded by both students and faculty: the large-enrollment non-calculus-based introductory course for science (but not physics) majors. (This is the notorious course for captives who, by virtue of their majors, must take physics.) I lectured primarily to students in the second semester (P202) on electricity and magnetism, optics, and modern physics. These students had already passed the first semester (P201) on Newtonian mechanics, waves, and thermodynamics. It soon became apparent that P201, as taught at our university in the standard research university mode (didactic, large-class professorial lectures followed by graduate-student-led discussions and labs) had imparted near-zero knowledge of the Newtonian mechanics needed to comprehend charged-particle motion in electric and magnetic fields. The science majors of P201-2 (future doctors, health professionals, chemists, biologists, and high-school science teachers) were still back in the Aristotlian or medieval worlds, understanding little more of Newtonian mechanics than had the earlier prospective elementary teachers subjected to my initial useless lectures.

About the same time, Halloun and Hestenes (1985) published a careful study using massive pre- and post-course testing of students in both the calculus and non-calculus based introductory physics courses at Arizona State. Their conclusion that "the student's initial qualitative, common-sense beliefs about motion and its causes have a large effect on performance in physics, but conventional instruction induces only a small change in those beliefs" dramatically reinforced my own experience and that of many researchers in physics education (e.g., Clement, 1982; McCloskey, 1983; McDermott, 1984). With this impetus I resolved to develop further the hands-on interactive engagement SDI labs I had initiated for the elementary education majors and to try them out on large-enrollment introductory courses for science majors.

Thus began a research program at Indiana University designed to bring the Arons-advocated method to the masses through SDI labs (Hake, 1987),[3] and to assess[4] their effectiveness by 1.) demonstration interviews (Roychouhury, 1990); 2.) evaluations by students and professors as physics students (Tobias & Hake, 1988); and 3.) Halloun-Hestenes (1985) pre- and post-course tests of conceptual understanding. All of this recent work (Hake, Roychoudhury, & Gabel, 1990) with the Arons-advocated method (Arons, 1990) has convinced me that it is extremely effective. I would recommend it not only to university introductory-course physics teachers but to science teachers in all grades. Indeed, even professors (Tobias & Hake, 1988) can benefit.

Notes

1. Supported by NSF Grant MDR-8955073.

2. The reference for this article is R.R. Hake, "My Conversion To The Arons-Advocated Method Of Science Education," *Teaching Education* **3**(2), 109-111 (1991). Except for the correction of a few minor typos, this web version is identical to the original except for referencing updates at [***Ed. note (5/18/00****:* ……….].

3. Four recently prepared SDI lab manuals (Newton's First and Third Laws, Newton's Second Law, Circular Motion and Frictional Forces, and Angular Momentum) are available on request. [***Ed. note (5/18/00***): these labs and others (along with various ancillary materials) are now available online at <http://www.physics.indiana.edu/~sdi>.]

4. [***Ed. note (5/18/00****):* for more recent evaluation of interactive-engagement methods see R.R. Hake:

(a) "Interactive-engagement vs traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.* **66**(1), 64-74 (1998); on the web at <http://physics.indiana.edu/~sdi/>.

(b) "Interactive-engagement methods in introductory mechanics courses," submitted on 6/19/98 to the *Physics Education Research Supplement to AJP* (PERS); on the web at <http://physics.indiana.edu/~sdi/>.

(c) "Towards Paradigm Peace in Physics-Education Research," presented at the annual meeting of the American Educational Research Association, New Orleans, April 24-28, 2000; on the web at <http://physics.indiana.edu/~sdi/>. Lists recent research which is consistent with "a" and discusses the complementarity of quantitative and qualitative research in physics education.

(d) "What Can We Learn from the Physics Education Reform Effort?", ASME Mechanical Engineering Education Conference: *Drivers and Strategies of Major Program Change*, Fort Lauderdale, Florida, March 26-29, 2000; on the web at <http://physics.indiana.edu/~hake/> as a pdf document, and as HTML plus video at <http://hitchcock.dlt.asu.edu/media2/cresmet/hake/>.]

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