Direct Science Instruction Suffers a Setback in California - Or Does It? * ‡

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". . .I will look primarily at our traditions and practices of early schooling through the age of twelve or so. There is little to come after, whether of joys or miseries, that is not prefigured in these years."

David Hawkins in *The Roots of Literacy* (2000), p. 3.

On 10 March 2004, the California State Board of Education (CSBE), bending to intense pressure from teachers, scientists, and leaders of industry and higher education, made some amendments in the California Curriculum Commissions (CCC's) *Criteria For Evaluating K-8 Science Instructional Materials in Preparation for the 2006 Adoption*. The most startling amendment *reversed* the *Criteria's* demand that "instructional materials must compose *NO MORE* than 20 to 25 percent of hands-on activities" to read "instructional materials must compose *AT LEAST* 20 to 25 percent of hands-on activities." Although widely heralded as a setback for DI in California, I argue that *DI may continue to predominate in K-8 science classrooms* because instructional material adoptions will be heavily influenced by the DI-oriented CCC and CSBE. I list eleven objections to the *Criteria* that remain in force despite the amendments, and make three suggestions for loosening the stifling stranglehold of the CCC on K-8 science education: (1) replace the CCC's DI diehards, (2) rewrite the entire *Criteria* to insure *local* control of teaching practices and instructional materials, and (3) drastically upgrade teachers' salaries and working conditions.

I. Introduction

The *California Curriculum Commission* (CCC) has attempted to enact a *Criteria For Evaluating K-8 Science Instructional Materials in Preparation for the 2006 Adoption* that would prohibit the expenditure of state funds for K-8 science education instructional materials containing more than 25% hands-on activities. Such a draconian edict would reduce hands-on activities in most California schools, since all but the wealthiest are dependent on state funding for instructional materials. Because of its dire implications for science instruction in K-8 (and hence K-16) *nationwide* – text providers tend to publish only materials that can be sold in California, their largest market – the CCC's retrograde scheme has been reported in the news media [Strauss (2004), Galley (2004), *Mercury News* (San Jose) (2004)]; and has prompted letters of protest to the CCC and/or the *California State Board of Education* (CSBE) from (among others):

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(a) California state legislators [Goldberg (2003)];

(b) the *California Science Teachers Association* [Janulaw (2004a,b)];

(c) the *San Diego Science Alliance* [Winter (2004)];

(d) the *National Academy of Sciences* acting in concert with the *National Science Teachers Association* [Alberts & Wheeler (2004)];

(e) the *National Science Teachers Association* [Wheeler (2004)];

(f) leaders of *Genentech*, *Intel*, *Bechtel*, *Pixar*, *Lucasfilm*, *Adobe Systems*; the Presidents of the *University of California*, *Stanford*, and the *California Institute of Technology*; and all 10 Chancellors of the *University of California* [Levinson et al. (2004)]. A separate letter of protest was received from Richard Stephens (2004), president of the *Boeing Company*.

In addition, just before and during the first two months of 2004, Larry Woolf and I [Woolf & Hake (2004), Woolf (2004a-e), Hake (2003a,b; 2004a-q)] mounted a campaign that urged teachers, scientists, and educators to protest the CCC's regressive *Criteria.*

On 16 January 2004, despite an avalanche of objections, true to its myopic allegiance to direct instruction (DI), and in keeping with its typical disregard for external opinion, the CCC < **http://www.cde.ca.gov/cc/** > passed its *Criteria.*

On 5 March 2004, a meeting was called by Rae Belisle, executive director of the CSBE to address the outpouring of protests to the CCC's *Criteria*, a few of which are indicated above. According to a report by the *California Science Teachers Association* [CSTA (2004)], Belisle's workshop was attended by state board staff and CSTA executive director Christine Bertrand, K-12 teachers, CSU faculty, CSU deans, *California School Boards Association*, *California Teachers Association*, and representatives of Governor Schwarzenegger's office.

Certain amendments to the *Criteria* were crafted at Belisle's workshop for consideration of the *California State Board of Education* (CSBE) < **http://www.cde.ca.gov/board/** > at its meeting on 10 March. The most startling amendment *reversed* the *Criteria's* demand that "instructional materials must include ***NO MORE*** than 20 to 25 percent of hands-on materials" to read "instructional materials must include ***AT LEAST*** 20 to 25 percent of hands-on materials."

On 10 March, the CSBE unanimously accepted the March 5th amendments of Belisle's working group, thereby *seeming* to repudiate the anti-hands-on strictures of the *Criteria* that were written by the CCC, most of whose members had been appointed by the direct-instruction-oriented CSBE itself. According to a report by the *California Science Education Advisory Committee* [CSEAC: < **http://www.wested.org/werc/cseac.html** > (2004)], some of whom attended the meeting:

> In a rare show of unanimity, everyone involved in the issue testified in support of the revised criteria based on the March 5th negotiation. This testimony included those who had argued for this and other changes *as well as people who had written the original language restricting hands-on instruction*. . . . .[My *italics*.]

The *Criteria*, as amended, are online at < **http://www.cde.ca.gov/cfir/science/** >. The more important changes are shown below in **bold**:

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A. NEW LINES: 18-20:

Students should have the opportunity to learn science by direct instruction, by reading textbooks and supplemental materials, by solving Standards-based problems, and by doing lab investigations and experiments.

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B. NEW LINES: 25-29:

Some teachers may not have specialized in science and may not have an extensive background in science, while others may hold supplemental authorizations in life or physical science or have had extensive training in science content and pedagogy. The publishers shall develop and submit programs that offer the flexibility to meet the diverse needs of students and teachers with varying science backgrounds.

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C. PREVIOUS LINES 102-109:

[To be considered suitable for adoption, an instructional materials submission must provide] a table of evidence in the teacher edition, demonstrating that the California Science Standards can be comprehensively taught from the submitted materials with hands-on activities composing no more than 20 to 25 percent of science instructional time (as specified in the California Science Framework). Additional hands-on activities may be included, but must not be essential for complete coverage of the California Science Standards for the intended grade level(s), must be clearly marked as optional, and must meet all other evaluation criteria.

ARE REPLACED BY (changes are in **bold**):

NEW LINES 94-99:

[To be considered suitable for adoption, an instructional materials submission must provide] a table of evidence in the teacher edition, demonstrating that the *California Science Standards* . . . ["Science Content Standards for California Public Schools K-12,October, 1998, online as a 61 page 0.5 MB pdf at < **http://www.cde.ca.gov/standards/** >]. . . . can be comprehensively taught from the submitted materials with hands-on activities composing **at least** 20 to 25 percent of **the** science instructional **program** (*as specified in the California Science Framework*). **Hands-on activities must be cohesive, connected and build on each other to lead students to a comprehensive understanding of the California Science Content Standards.**

[Note that the italicized words indicate a need to revise the wording in the heretofore sacrosanct *California Science Framework* < **http://www.cde.ca.gov/cfir/science** > !]

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D. PREVIOUS LINES 156-157:

[To be considered suitable for adoption, an instructional materials submission must provide] a program organization that provides the option of pre-teaching of the science content embedded in any hands-on activities.

ARE REPLACED BY (changes are in **bold**):

NEW LINES 141-142:

[To be considered suitable for adoption, an instructional materials submission must provide] a program organization that provides the option of **preparing or** pre-teaching of the science content embedded in any hands-on activities.

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E. PREVIOUS LINES 299-300:

[To be considered suitable for adoption, an instructional materials submission must provide] suggestions for how to adapt each hands-on activity provided to direct instruction methods of teaching.

ARE REPLACED BY (changes are in **bold**):

NEW LINES 264–267:

[To be considered suitable for adoption, an instructional materials submission must provide] suggestions for how to adapt each hands-on activity provided to **other methods of teaching, including teacher modeling, teacher demonstration, direct instruction, or reading, as specified in the California Science Framework.**

The *National Science Teachers Association* [NSTA (2004)], The *California Science Teachers Association* [CSTA (2004)], the *California Science Education Advisory Committee* [CSEAC (2004)], Scott Hays (2004a,b), and Jerry Becker (2004) have all reported on the *apparent* 10 March setback for direct instruction. That *seeming* setback is primarily the *Criteria's* change from "instructional materials must include ***NO MORE*** than 20 to 25 percent of science instructional time" to "instructional materials must include ***AT LEAST*** 20 to 25 percent of science instructional time."

II. Will the 10 March *Apparent* Setback for Direct Instruction Have Any Substantive Effect on the California Adoptions Process for K-8 Science Materials?

I sincerely hope it will, but by playing the devil's advocate I hope to show that such optimism may be illusory. I list below two reasons to be doubtful that the amendments to the *Criteria* will affect the adoptions process.

A. Textbooks Containing More Than 20% Hands-On Material Will Probably *NOT* be adopted.

As indicated above, according to the CSEAC (2004):

> In a rare show of unanimity, everyone involved in the issue testified in support of the revised criteria based on the March 5th negotiation. *This testimony included those . . . people. . . .*[evidently members of the CCC]. . . *who had written the original language restricting hands-on instruction. . . . .* [My *italics*.]

Does this mean that the CCC has suddenly seen the light and will henceforth support hands-on instruction? The probability of such a radical conversion seems vanishingly small, considering past statements of its leaders [Metzenberg (1998, undated, 1999); Adams (2004)], and its demonstrated prior disregard for the opinions of California legislators, citizens, teachers, scientists, and educators (as witness the CCC's passage of its much-protested anti-hands-on *Criteria* on 16 January 2004).

To foresee the 2006 instructional materials adoption process, one can examine the last such process in the year 2000 as indicated at CSBE (2000). [My thanks to Larry Woolf for calling my attention to this reference]. There it is stated that:

> The materials that publishers submitted were thoroughly reviewed by the 52 members of the Instructional Materials Advisory Panel (IMAP) and 14 members of the Content Review Panel (CRP) *appointed by the State Board of Education. . . .* The Curriculum Commission held two well-publicized formal public hearings and included a change process for improving the accuracy of materials. The State Board of Education conducted a formal public hearing in February 2000. The State Board and the Commission appreciated the public interest in the resources submitted for adoption and carefully reviewed all the testimony. It should be noted that for purposes of this process, the *Curriculum Commission recommends and the State Board of Education adopts* only "basic instructional materials." Basic instructional materials are those resources that are designed for use by pupils as a principal learning resource and that meet in organization and content the basic requirement of the intended course. Supplemental resources, or resources covering less than an entire course content, are not adopted as part of this process. [My *italics*.]

I judge from the above that the adoption process in 2006 will be heavily influenced by the recommendations of the CCC. Regardless of the judgements of the CSBE-appointed IMAP and CRP, it seems likely that the CCC (just as it passed the anti-hands-on *Criteria* on 16 January 2004 in defiance of protests from teachers, scientists, and educators) will disregard all external input and reject hands-on-rich materials in favor of those that contain the *maximum* amount of direct instruction – 80% under the amended Criteria of 10 March 2004. This will satisfy the CCC's mantra to "teach 'em the 'facts' " [Metzenberg (1998)], "let 'em read a textbook" [Metzenberg (undated)], or "know the CONTENT " [Metzenberg (1999)]. From the CCC's standpoint, only direct instruction will facilitate the pouring of the full portion of the all important "facts" and "content" contained in the *California Science Standards* into the vacant vessels that comprise students' minds, without time-wasting hands-on activities.

Publishers, judging from their deplorable records [see, e.g., Roseman et al. (1999), Hubisz et al. (2001), Raloff (2001a,b)] will then tend to maximize their bottom lines by printing materials for CA (and the rest of the U.S) which satisfy the CCC's favored 20%. Most instructors will tend to teach from those hands-on-deficient textbooks. Judging from past history [Roseman et al. (1999), Hubisz et al. (2001), Raloff (2001a,b)], such commercial textbooks will, in addition to being light on hands-on activities, also be both scientifically and pedagogically inferior.

Although wealthier schools and school districts may be able to purchase with their own funds textbooks containing more than 20% of hands-on material, and therefore not approved by the CCC for state adoption, the *average* K-8 classroom will still be condemned to use hands-on deficient text books, resulting in lower quality science instruction for the *average* California student. We trust that the CSBE is aware that lower quality education for lower income students poses the threat of discrimination law-suits against the State [see e.g. Asimov (2001)], as has been pointed out by Woolf (2004c).

B. Exemplary Nationally-Developed, Research-Based, Hands-On Science Instructional Materials Will Probably *NOT* Be Adopted.

There are at least two reasons for this suspicion:

1. The first reason revolves around new lines 141-142 of the *Criteria* that read (changes are in **bold**):

> [To be considered suitable for adoption, an instructional materials submission must provide] a program organization that provides the option of **preparing or** pre-teaching of the science content embedded in any hands-on activities.

Leaving aside the ambiguous newly-added term "preparing," the fact that the "*pre-teaching of hands-on materials"* has evidently not been recognized as an *oxymoron* suggests that DI-blinders on both the CCC nor the CSBE prevent them from understanding the nature of the nationally-developed, research-based, hands-on science instructional materials. As an example, suppose the hands-on activity involves students simultaneously dropping a flat sheet of paper, a sheet of paper crumpled into a ball, and a lead ball. *After* lively discussion with their peers, the students write down their predictions of the sequence in which the three dropped objects will hit the floor. They then do the experiment. The nearly simultaneous arrival on the floor of the light crumpled sheet and the heavy lead ball will astonish most students. When challenged for an explanation by a teacher who knows enough to *shut up and listen to what students say*, students can be guided to exert the mental effort required to reach an interpretation approximating that of a professional physicist. When they do, lights will go on in their eyes – they will have gained some deep insight into the "Newtonian revolution."

Of course, if any pre-teaching (read DI instruction) occurs, students' eyes will remain glazed over both during the "pre-teaching" and during the now pointless hands-on exercise. Research [Sec. III (2)] , to which the CCC is apparently oblivious, has indicted time and again that the students will have learned essentially nothing.

Since the "pre-teaching" converts the hands-on activities to the CCC's gold standard (but-ineffective) DI, the CCC may well wonder why students should waste time going though preempted hands-on motions when they could be "learning the facts" [Metzenberg (1998)]. The CCC will, I suspect, *not* adopt nationally-developed, research-based, hands-on science instructional materials.

2. The second reason that exemplary nationally-developed, hands-on materials will probably *not* be adopted revolves around the unchanged lines 79-95 of the *Criteria*:

> [To be considered suitable for adoption, an instructional materials submission must provide] comprehensive teaching of all California Science Standards [CSS] at the intended grade level(s), as discussed and prioritized in the California Science Framework, Chapters 3 and 4. The only standards that may be referenced are the [CSS]. There should be no reference to national standards or benchmarks or to any standards other than the [CSS]. . . . Extraneous lessons or topics that are not directly focused on the standards are minimal, certainly composing no more than 10 percent of the science instructional time. . . . . A table of evidence in the teacher edition, demonstrating that the [CSS] can be comprehensively taught from the submitted materials . . . .

As Larry Woolf (2004e) has written in his unpublished *San Jose Mercury News* OpEd piece:

> Many research-based science instructional materials, often developed using National Science Foundation funding, are guided by the National Science Education Standards (NSES). . . . [NRC 1996] . . . . . and Benchmarks . . . .[AAAS (1993]. . . . . Yet, the mere presence of the forbidden words "national standards" or "benchmarks" in these science instructional materials will prevent them from being adopted. . . . .
>
> Nationally developed science instructional materials often contain more than 10% of topics considered "extraneous" at a given grade level by the *Criteria* because such topics *are* in the NSES, but are missing from the CSS. On the other hand, some topics required by the CSS for certain grade levels, e.g. "there are more than 100 different types of atoms, which are included in the periodic table of the elements" for third grade, *would not* be contained in materials written to satisfy the NSES because the NSES considers the periodic table to be a high school level topic. Thus, science instructional materials written to satisfy the NSES may not cover every California state standard at every grade level. This means that the *Criteria* will prevent the adoption of most nationally developed science materials based on the NSES.
>
> The restrictive criteria of the previous adoption resulted in only science textbooks being adopted for 2000 - 2006. Studies by the AAAS. . . .[Roseman et al. (1999)]. . . and the David and Lucile Packard Foundation. . . [Hubisz, J.L. et al. (2001)] . . . . of middle school science textbooks found them to be riddled with errors and ineffective – not one was rated satisfactory by the AAAS. Yet, our teachers are restricted to using these flawed materials. Districts should be permitted to purchase materials from different sources that best allow them to meet the state science standards. This approach follows the Business Roundtable's Principles for K-12 Education < **http://www.businessroundtable.org/document.cfm/467** > that "districts should have flexibility for their educational … innovation and instruction" and schools should use "world class educational materials." California science policy should not restrict teachers from obtaining the educational materials that will allow their students to excel.
>
> **The *Criteria* should be rejected**.

In regard to the *Criteria's* insular insistence that:

> The only standards that may be referenced are the California Science Standards [CSS]. There should be no reference to national standards or benchmarks or to any standards other than the [CSS]. . . . . Extraneous lessons or topics that are not directly focused on the standards are minimal, certainly composing no more than 10 percent of the science instructional time,

it should be mentioned that Johnny Lott (2004), President of the *National Council of Teachers of Mathematics* (NCTM), has written Governor Schwarznegger to express dismay over the *Criteria's* mathematics counterpart of the above stricture. Lott writes:

> Reading the guidelines in conjunction with a statement from a recent speech of State Superintendent Jack O'Connell gives many nationwide cause for alarm. His quote follows:
>
> > *...the majority of California's 1.7 million high school students simply are not reaching the academic levels needed to succeed, in the workplace, in college, or as effective citizens.*
>
> While recognizing that it is within the state purview of education to set any standards or guidelines that the state chooses, the proposed California criteria have national implications. These criteria state that subject matter in mathematics and science must reference only California standards at a time when your state superintendent acknowledges that California, with its standards adopted in 1997, has a massive number of students who are not succeeding.
>
> A major reason for national concern is that textbook publishers often cater to the California text market. If you choose to set criteria for textbook selection that limit reference of standards only to your state standards and limit principles of instruction only to those that reflect the current thinking in California, a bar is being set that severely limits not only your teachers and students but teachers and students nationwide. And this is being done at a time when Mr. O'Connell has noted that the majority of California's 1.7 million high school students are not succeeding. Instead of restricting the view espoused in the California *Criteria* that de-emphasizes problem solving, concept understanding, and "creative thinking," now should be the time for California's leadership to compare its standards to those of "high-performing states" and to other national standards. *This is a time to recognize that "narrow minds produce narrow views.*" [My *italics*.]

III. With the Reasonable Assumption (Sec. II) that the Amended *Criteria* Will Have No Substantive Effect on California Adoptions for K-8 Science Materials, All Previous Objections [see, e.g. Sec. I] to the *Criteria* Remain in Force.

I shall enumerate my own objections [an elaboration of my 1 March 2004 letter to the CSBE (Hake (2004q)] as numbers 1-11 below:

1. The *Criteria,* even as amended on 3/10/04, will seriously limit hands-on pedagogical methods in the average K-8 science classroom.

The reasons have been given above in Section II .

2. The *Criteria,* since they will allow adoption of science materials in K-8 that contain only 20% hands-on material, as indicated in Sec. II above, ignore scientific evidence demonstrating that hands-on guided inquiry methods are far more effective than direct instruction in K-8 science education.

There is a substantial amount of scientific research evidence [for discussions of what constitutes "scientific research evidence" in education see Shavelson & Towne (2000) & Burkhardt & Schoenfeld (2003)] that "hands-on guided-inquiry methods" [commonly called "inquiry" or "interactive engagement" methods] are far more effective than "direct instruction" for promoting student learning *in conceptually difficult areas* [for reviews see e.g., Hake (2004j); Doss-Hammel (2004); Lowery (2003); and the literature references in AAAS (1993, 2004), NRC (1996; 1997a,b; 1999, 2000, 2001, 2003), Bransford et al. (1999), and Donovan et al. (1999).

In Hake (2004j) I wrote:

> [The CCC] appears to inhabit a "private universe" [Schneps & Sadler (1985)], seemingly oblivious of the literature of cognitive science [see, e.g. Bransford et al. (1999)] and three decades of science-education research showing the superiority of hands- and minds-on pedagogy to direct instruction in conceptually difficult areas [see e.g., Karplus (1974, 1977, 1981); Arons (1960, 1972, 1974, 1983, 1985, 1997, 1998); Shymansky et. al. (1983, 1989, 1990); Halloun & Hestenes (1985a,b); McDermott & Redish (1999); Hake (1998a,b; 2002a,b); Lopez & Schultz (2001); FOSS (2001); Pelligrino et al. (2001); Crouch & Mazur (2001); Fagen et al. (2002); Fuller (2002)]; Redish (2003); and Belcher (2003).
> Note that none of the above research concerns unguided "discovery learning," an evident bugaboo of CCC's Stan Metzenberg and executive director Thomas Adams (2004).

Still other references showing the superior effectiveness of hands-on guided inquiry methods over direct instruction are Bredderman (1982, 1983, 1985), Kyle et al. (1988), Jorgenson & Vanosdall (2002), GLEF (2001), and Anderson (2002). In addition, the eleven K-12 science-education studies listed in Table 1 of Lipsey & Wilson (1993) (where the test group is characterized by reform methods) yield a total N = 888 students and average effect size <d> = 0.36 [Cohen (1988)]. Most of these studies include grades 4 or 6 to 12 with the effect size control group being traditional direct instruction and the measurement unit being "achievement" or "learning" (presumably as measured by tests). Cohen's rule of thumb – based on typical results in social science research – that d = 0.2, 0.5, 0.8 imply respectively "small," "medium," and "large" effects, but Cohen cautions that the adjectives "are relative, not only to each other, but to the area of behavioral science or even more particularly to the specific content and research method being employed in any given investigation." My own survey [Hake (1998a,b)] yielded a much larger effect size of d = 2.43 [Hake (2002a)] and such large differences in the effectiveness of interactive engagement vs direct instruction have been corroborated by many other physics-education researchers as discussed in Hake (2002a,b).

In sharp contrast there is, as far as I am aware, *ZERO scientific evidence* for the superiority (in conceptually difficult areas of science education) of "direct instruction" [in any of its many guises [see Sec. III (8) below and Hake (2004p)] to "inquiry" [operationally defined by Alberts (2000)] or "interactive engagement" [operationally defined by Hake (1998a,b)]. Of course, neither "inquiry" nor "interactive engagement" methods should be confused with the extreme "discovery learning" mode, researched by Klahr & Nigam (2004). Their research suggests that, not surprisingly, an *extreme* mode of "discovery learning," in which there is almost no teacher guidance, is inferior to "direct instruction" for increasing third and fourth grade children's effective use of the control of variables strategy, a so-called "process skill." It might be interesting for Klahr & Nigam to extend their study to more guided forms of "discovery learning" and to children's acquisition of "operative knowledge" [Arons (1983)]. In regard to the latter, Arons was fond of quoting:

> *Above all things we must be aware of what I will call 'inert ideas' – that is to say, ideas that are merely received into the mind without being utilized, or tested, or thrown into fresh combinations.*
>
> Alfred North Whitehead, *The Aims of Education* (1929).

3. The *Criteria*, since they will allow adoption of science materials in K-8 that contain only 20% hands-on material, as indicated in Sec. II above, are very strongly biased in favor of the relatively ineffective [see Sec. III (2) above] "direct instruction."

It seems ironic that the entire national K-8 (and hence K-16) science-education endeavor promises to be undermined by a few diehard extremists on the CCC and the CSBE who unscientifically refuse to consider:

(1) the overwhelming scientific evidence that direct instruction is ineffective for enhancing conceptual understanding of science [Sec. III (2)], and

(2) the vehement protests from (as indicated in Sec. I above):

(a) California state legislators [Goldberg (2003)];

(b) the *California Science Teachers Association* [Janulaw (2004a,b)];

(c) the *San Diego Science Alliance* [Winter (2004)];

(d) the *National Academy of Sciences* and the *National Science Teachers Association* [Alberts & Wheeler (2004)];

(e) the *National Science Teachers Association* [Wheeler (2004)];

(f) leaders of *Genentech*, *Intel*, *Bechtel*, *Pixar*, *Lucasfilm*, *Adobe Systems*; the Presidents of the *University of California*, *Stanford*, and the *California Institute of Technology*; and all 10 Chancellors of the *University of California* [Levinson et al. (2004)]; and the president of the Boeing Company. [Stephens (2004)].

4. The common argument that direct instruction methods must dominate science materials because some teachers do not have the requisite understanding of science or the facilities to utilize hands-on guided inquiry methods is, in my opinion, spurious.

As indicated in Sec. I, the Criteria, as amended on 3/10/04, contain the new lines 25 – 29:

> Some teachers *may not have specialized in science and may not have an extensive background in science,* while others may hold supplemental authorizations in life or physical science or have had extensive training in science content and pedagogy. *The publishers shall develop and submit programs that offer the flexibility to meet the diverse* needs of students and *teachers with varying science backgrounds*. [My *italics.*]

This wording is in consonance with the sentiments of Thomas Adams (2004) who is quoted by Strauss (2004) as follows:

> . . . . commission members are trying to balance the need for a comprehensive science curriculum with the limited science background of many K-8 teachers. Twenty to 25 percent of hands-on instruction seemed like the like 'the most reasonable amount of time for someone faced with the challenges of limited facilities and limited time,' he said. 'What we want are materials that all teachers can use,' Adams said. ' . . . *There are some people who are convinced that the only way that students learn is in a discovery method*.' " [My *italics*.]

The same concerns were raised by critics of the excellent 1960's hands-on *Physics Science Study Committee* (PSSC) program for high-school physics, who complained that some teachers did not have the requisite understanding of science or the facilities to use PSSC. The late Arnold Arons (1960) responded with a characteristic insightful zinger:

> I cannot escape the conviction that [such arguments are] entirely specious. The conventional course material. . . .[conventional high-school direct-instruction texts and recipe labs]. . . . is incompetent. It seems to me vastly preferable to put into the hands of our students competent material which might at first be incompetently handled by some teachers than to hold tightly to incompetent material, incompetently handled.

But because some members of the CCC and the CSBE believe that hands-on instruction may not be competently handled by some instructors, the present *Criteria* allow the adoption of K-8 science materials with 80% direct instruction, shown over and over again to be "incompetent material" (see Sec. III (2) above) that will, in some cases, be "incompetently handled."

In my opinion, instead of lowering the quality of science instruction to accommodate the least prepared and least effective teachers, the CSBE would better serve the state by working to attract outstanding teachers into California's classrooms. In Hake (2002d) I suggest that school boards treat K-12 teachers like the valued professionals they are by drastically upgrading their salaries (Heller 2001) and working conditions (Jones 2001) [especially in the inner cities (Kozol 1992)]. Ken Heller (2001) suggests that teachers be paid *at least as much as mechanical engineers*. Other concrete proposals to substantially increase salaries of K-12 teachers have been given by Don Langenberg (2000) and the Hart-Rudman Commission (2001b). For a review of the Heller, Langenberg, and Hart-Rudman proposals see Lesson #12i of Hake (2002a). For an analysis of incentives for attracting and retaining K-12 teachers by PACE (Policy Analysis for California Education) < **http://pace.berkeley.edu/** > see Laurence et al. (2002).

But where would cash-strapped California find money for upgrading teachers' salaries and working conditions? From the transcript of *First to Worst* (Merrow (2004):

> Foremost among [tough questions for California are] what to do about proposition 13. Gov. Schwarzenegger has made his position clear: "Additional taxes are the last burden that we need to put on the backs of the citizens and the businesses of California.". . . .[but see Salladay & Nicholas (2004)]. . . .

Regarding the governor's "No New Taxes" pledge, perhaps he might consider the implications for California of *Business Week's* (2004) claim that:

> Because the quality of a nation's workforce has such a huge influence on productivity, effective school reform could easily stimulate the economy more than conventional strategies, such as the Bush tax cuts. *Consider what would happen if the U.S. could raise the performance of its high school students on math and science to the levels of western Europe within a decade*. According to Eric A. Hunushek . . . . .
> [< **http://edpro.stanford.edu/eah/eah.htm** >]. . . . , a senior fellow at the Hoover Institution < **http://www-hoover.stanford.edu/** > at Stanford University, *U.S. gross domestic product growth would then be 4% higher than otherwise by 2025 and 10% higher in 30 years."* [My *italics*.]

Alternatively, Michael Kirst, professor of education, business administration, and political science at Stanford University, in the extended transcript of Merrow's interview at < **http://www.pbs.org/merrow/tv/ftw/transcripts/kirst.pdf** > (44kB) said:

> What we do need to do is to bring back a local source of revenue. Now, that could be the property tax or another tax. One proposal I've been thinking about is a local income tax surcharge. Ohio uses this, Pennsylvania uses this for example. You would just add on 10 percent, by a local vote of the people in that school district, to their state income tax. So we need some sort of local revenue base.

And John Mockler, former executive secretary of the CSBE, stated in his extended interview with Merrow < **http://www.pbs.org/merrow/tv/ftw/interviews.html** >:

> I think what you need to do [rather than try to repeal Prop. 13], and I think people are starting to talk about it, is this realignment of tax structures, state and local. Property tax is a stable tax. Even in this economic downturn, property taxes in the state are up seven, eight percent, even though state general fund revenues are down 10 billion, 12 billion. So asset taxes, city taxes, property taxes, need to be a better share of revenue. California spends almost more than any other state on state aid to schools. But we have such low property tax that our expenditures are less than other states. So by not having a local tax base, any volatility in the state system makes the local system volatile. So I think what you need to do is look at the whole tax structure. We used to spend, let's say, five-and-a-half, five . . . cents (sic). . . . [Mockler evidently meant "percent"]. . . . of our income on kids. Now they're now giving us 3.3 cents. So two percentage points less of their income go to schools. Well, one percent of personal income in this state is $11.5 billion. *So if the citizens of the state committed to their schools the same percent of their income as they did when Ronald Reagan was governor, we'd spend $23 billion more a year on the schools.* That being said, the last four or five years before this last recession, we made some progress. We moved from almost last in expenditures per kid up to around 35th. [My *italics*.]

5. The *Criteria* are focussed only on the California Science Standards and thus isolate California public education from the recommendations of most U.S. scientists and science educators.

The *Criteria* effectively isolate California's K-8 teachers and students from the thinking and recommendations of the Nation's most outstanding scientists and science educators [see, e.g., AAAS (1993, 2004); NRC (1996, 1997a, 1997b, 1999, 2000, 2001, 2003)], insisting that their attention be focussed solely on the *California Science Standards* ["Science Content Standards for California Public Schools K-12, October, 1998, online as a 61 page 0.5 MB pdf at < **http://www.cde.ca.gov/standards/** >]. The latter document is the product of a highly politicized and undemocratic process spearheaded by a few direct-instruction extremists as described by Schultz (1998), Woolf (1999), and Feder (1998a,b)]. As indicated above in Sec. IIB2, the exclusionary lines 79-95 read:

> [To be considered suitable for adoption, an instructional materials submission must provide] comprehensive teaching of all California Science Standards [CSS] at the intended grade level(s), as discussed and prioritized in the California Science Framework, Chapters 3 and 4. The only standards

> that may be referenced are the [CSS]. There should be no reference to national standards or benchmarks or to any standards other than the [CSS]. . . . .Extraneous lessons or topics that are not directly focused on the standards are minimal, certainly composing no more than 10 percent of the science instructional time. . . . . A table of evidence in the teacher edition, demonstrating that the [CSS] can be comprehensively taught from the submitted materials . . . .

Woolf's (1999) petition (as true today as it was in 1999) states that the California Science Standards:

> . . . are based on neither the spirit nor the letter of the National Science Education Standards developed by the National Academy of Sciences . . .[National Research Council NRC (1996)]. . . or the Benchmarks for Science Literacy. . .[AAAS (1993, 2004)]. . . .developed by the American Association for the Advancement of Science; many of the California Science Standards are incorrect, misleading, ambiguous, and age-inappropriate." The petition further states that "California Academic Standards Commission" has approved a policy that effectively prohibits the adoption of scientifically accurate, thoroughly tested, and highly regarded kit-based science curricula,. . . .(and) . . . has approved a policy that allows the adoption of materials that have never been thoroughly tested in classrooms. Woolf's petition was signed by 330 Californians, among them: Andrew Sessler & James Langer, past presidents of the American Physical Society; Jerry Pine, co-director of the Cal Tech Precollege Science Institute; Wendell Potter, vice chair of the Physics Dept., Univ. of California at Davis; Helen Quinn of the Stanford Linear Accelerator; Richard Shavelsohn, Professor of Education and Psychology at Stanford; J.M. Atkin, Chair of the Committee on Science Education K-12 at the National Research Council; Fred Goldberg, Professor of Physics, San Diego State University; Angela Stacy, Professor of Chemistry, Univ. of California-Berkeley; and many California science teachers and educators from elementary, middle, and high schools; colleges; and universities.

For some commentary on the "California Science Wars" see Feder (1998 a, b). For commentary on the parallel and similar "California Math Wars" see Jackson (1997), Sowder (1998), Becker & Jacob (2000), Wilson (2003), and reviews of the latter book from "traditionalist" Ralph Raimi (2004) and "reformer" Anthony Ralston (2003). Sowder (1998) wrote:

> I will discuss today the ways that I see these two sides differing: They hold different beliefs about what mathematics is, different beliefs about how mathematics is learned, different understandings of what it means to know mathematics, and different ways of interpreting what research has to tell us on these issues. In a nutshell, *they represent different value systems*. I believe that rational, reflective discussion and exploration of these issues can bring the two sides closer together. Thus, although the two sides may not reach total agreement, they can come to understand the issues better and find ways to compromise. *I am told that California schools educate one-seventh of the students in this country. There is too much at stake to continue the fighting*, to take a chance on sacrificing the mathematical education of our children by not reaching some agreement on what that education should be. [My *italics*.]

In my opinion, if "science" is substituted for "mathematics," then Sowder's comments apply equally well to the California "Science Wars." Some direct instructionists think K-8 science education should be about teaching the "facts," while some proponents of "inquiry" think K-8 science education should be about leading children to exercise careful observation and critical thinking. Surely both sides can, as Sowder writes, "come to understand the issues better and find ways to compromise."

6. The *Criteria*, since they will allow adoption of science materials in K-8 that contain only 20% hands-on material, as indicated in Sec. II above, dictate a one-size fits all pedagogy, thus foreclosing teachers' options in favor of edicts from the Sacramento bureaucracy.

To facilitate effective teaching and learning it is imperative to *leave teaching options open to the teachers in the trenches* and *not* allow the state bureaucracy to dictate one-size-fits-all methods that *must* be employed. Teachers, to be effective, need to use different approaches (e.g., didactic lectures, coaching, collaborative discussions, and Socratic dialogue) to fit the classroom occasions and diverse natures of their students. Each method has its strengths and weaknesses for each type of student, but in the hands of a *skilled teacher* each can be made to compliment the other methods so as to advance *every* student's learning. A skilled teacher might *lecture* on material that can be rote memorized [but s(he) might be better off using the *Gutenberg Method* (Morrison 1986, Hake 2002c) that recognizes the invention of the printing press], *coach* skills such as typing or playing a musical instrument, and use *Socratic dialogue* or *collaborative discussions* (or some other "interactive engagement" method) to induce students to construct their conceptual understanding of difficult counter-intuitive material such as Newton's Laws.

It should be noted that the new lines 18-20 in the *Criteria*, as amended on 3/10/04:

> Students should have the opportunity to learn science by direct instruction, by reading textbooks and supplemental materials, by solving Standards-based problems, and by doing lab investigations and experiments,

do not necessarily mean any diversion from "teach em the facts" direct instruction since:

(a) "reading textbooks and supplemental materials," if such only calls for rote memorization;

(b) "solving Standards-based problems," if such only require plug-and-chug algorithmic manipulation;

(c) "doing lab investigations and experiments," if such only require following a recipe;

are all forms of direct instruction.

Likewise the fact that in the *Criteria*, as amended on 3/10/04, the previous lines 299-300:

> [To be considered suitable for adoption, an instructional materials submission must provide] suggestions for how to adapt each hands-on activity provided to direct instruction methods of teaching,
>
> are replaced by lines 264–267: (changes are in **bold**):
>
> Suggestions for how to adapt each hands-on activity provided to **other methods of teaching, including teacher modeling, teacher demonstration, direct instruction, or reading, as specified in the California Science Framework,**

do not necessarily mean any diversion from "teach 'em the facts" direct instruction since:

> (a) The term "teacher modeling" is undefined and could mean simply a direct-instruction lecture on the application of a model to a scientific area. Or does "teacher modeling" refer to the "modeling program" of Hestenes et al. [see e.g. Wells et al. (1995)] ? If so, it requires more than just action on the part of the teacher, and it might be questioned why this program was given special priority over other "interactive engagement" methods [see e.g. Hake (1998b] .
>
> (b) Teacher demonstrations can be a deadening and ineffective form of direct instruction unless the students are interactively engaged.
>
> (c) "Reading," if such only calls for rote memorization, can again be an ineffective form of direct instruction.

7. Considering Sec. III (6) above, the *Criteria* run counter to the announced intentions of Governor Schwarznegger and Secretary of Education Riordan [see Helfand (2004)] *to move control of teaching practices from Sacramento to local teachers, principals, and parents* - in direct opposition to the apparent intentions of the CCC and the CSBE.

A strong proponent of local control is James Guthrie, a Professor of Public Policy and Education at *Vanderbilt University* and Director of the *Peabody Center for Education Policy* there. He was formerly a professor of education at the University of California, Berkeley, and is the co-founder of the Berkeley-based *Policy Analysis for California Education* (PACE). < **http://pace.berkeley.edu/** >. In the extended transcript of Merrow's interview at < **http://www.pbs.org/merrow/tv/ftw/transcripts/guthrie.pdf** > (56kB) Guthrie says:

> . . . [The] detrimental consequence of Proposition 13 isn't so much money, as it is how it changed the governance structure of California's education system. Proposition 13

centralized decision making. It made it a . . . inadvertently, unconsciously, mindlessly, [sic] its proponents didn't think of this. Or didn't think sufficiently about it. It changed California from a local school, a system of local schools, to a state system. And when that happened, the centralized decision making set it up to be the poster child for partisan politics, in the state. It set it up for state bureaucratic regulation. It set it up for a . . . vastly diminished local participation in decision making and engagement. . . . Proposition 13's governance system, has to be changed, in order to give local school districts an opportunity to gain purchase on their children's education.

8. The *Criteria* fail to meaningfully define "direct instruction" and "hands-on" activities. Unfortunately, neither "direct instruction" nor "hands-on" activities have been *meaningfully defined* in the *Criteria*. Here "*meaningfully defined*" means "operationally defined" [see, e.g. Holton & Brush (2001), Phillips (2000)] so that, e.g., any term "T" denoting some pedagogical method, is specified in terms of rigorous operations for distinguishing "T" from other methods U, V, W, X. . . . The undefined nature of the terms "direct instruction" [Hake (2004p)] and "hands-on" activities [Hake (2004m)] means that:

A. The CCC, in making decisions as to what instructional materials do or do not satisfy the *Criteria*, will be able to exercise their prejudices with no accountability to the CSBE, science teachers, principals, or parents.

B. "Direct instruction" and "hands-on activity" can and do mean different things to different people.

1. What does "hands-on activity" mean? In a discussion list post [Hake (2004m)] I wrote:

I suspect that "hands-on activity" means:

(a) "non-direct-instruction," to the CCC's Stan Metzenberg (1998);

(b) "discovery learning," to Thomas Adams (2004), executive director of the CCC;

(c) either "discovery learning," or "non-direct-instruction," to most members of the CCC;

(d) "interactive engagement" or "inquiry" or "hands-on guided inquiry" to most physics education researchers [including Woolf & Hake (2004)];

(e) "placing hands on ANY object (e.g., pencil, paper, book, candy)" to literalists.

The undefined nature of "hands-on" activities will, of course, lead to severe problems in deciding what is and what is not a "hands-on" activity. For example, to literalists direct instruction that requires students to handle a pencil, paper, or book would qualify as "hands-on." In my opinion, the problem of deciding what is and what is not a "hands-on" activity, and deciding the time taken up by a "hands-on" activity (is it occurring *only* when students' hands are in contact with some object?) should have been reason enough for Board to reject the vague 1/16/04 version of the CCC *Criteria* at its meeting on 10-11 March 2004.

2. What does "Direct Instruction" mean? In Hake (2004p) I wrote:

> I suspect that "direct instruction" means to:
>
> (a) *Mathematically Correct* < **http://mathematicallycorrect.com/science.htm** >: "drill and practice," "non-hands-on," "teach 'em the "facts" [Metzenberg (1998)], and "non-discovery-learning," where "discovery learning" means setting students adrift either in aimless play or ostensibly to discover on their own, say, Archimedes' principle or Newton's Second Law.
>
> (b) Physics Education Researchers (PER's): traditional *passive* student lectures, recipe labs, and algorithmic problem sets.
>
> (c) Cognitive scientists Klahr & Nigam (2004): "[. . .instruction in which] the goals, the materials, the examples, the explanations, and the pace or instruction are all teacher controlled," but in which hands-on activities *are* present. At least this is Klahr & Nigam's (KN's) definition of what they call "*extreme* direct instruction" (extreme DI), possibly having in mind the reasonable idea of a continuum of methods from extreme DI to extreme "discovery learning" (DL). In extreme DL, according to KN, there is "no teacher intervention beyond the suggestion of a learning objective: no guiding questions, and no feedback about the quality of the child's selection of materials, explorations, or self-assessments."
>
> (d) *Association of Direct Instruction* [ADI (1998, 2004)]:
>
> (1) teaching by telling (as contrasted by teaching by implying), or
> (2) instructional techniques based on choral responses, homogeneous grouping, signals, and other proven instructional techniques, or
> (3) specific programs designed by Siegfried Engelmann and his staff.
>
> Direct Instruction programs incorporate the above "2" coupled with carefully designed sequences, lesson scripting, as well as responses to anticipated children's questions as expounded in Englemann & Carnine (1982).

9. The *Criteria*, since they will allow adoption of science materials in K-8 that contain only 20% hands-on material, as indicated in Sec. II above, may mandate pedagogical restrictions that appear to conflict with *Standards of Quality and Effectiveness for Professional Teacher Induction Programs*.

Assembly member Jackie Goldberg et al. (2003) wrote:

> Since the current proposal now restricts methods of teaching science, it raises the question of conflicts with standards developed by the *California Teacher Credentialing Commission* following passage of SB 2042 (Alpert). These *Standards of Quality and Effectiveness for Professional Teacher Induction Programs* are designed to align teacher preparation with state adopted content standards. In this case, the restriction on pedagogy contained in the current draft appears to contradict:
>
> Standard 15: K-12 Core Academic Content and Subject Specific Pedagogy;
>
> Standard 16: Using Technology to Support Student Learning;
>
> Standard 17: Supporting Equity, Diversity and Access to Core Curriculum;
>
> Standard 18: Creating a Supportive and Healthy Environment for Student Learning;
>
> Standard 19: Teaching English Learners; and,
>
> Standard 20: Teaching Special Populations.
>
> For the above reasons we believe it is important that the Commission defer action on these proposed changes until such time as those who will be affected have been notified and given an opportunity to comment on this proposal.

The autocratic CCC *ignored* Goldberg's message (along with a flood of protests from science teachers, scientists, and educators) and passed the *Criteria* on 16 January 2004. So much for the influence of California legislators, citizens, teachers, scientists, and educators on the isolated CCC, shielded in its Sacramento sanctum from both citizen concerns and the results of three decades of science-education research [see Sec. III (2) above].

10. The *Criteria*, since they will allow adoption of science materials in K-8 that contain only 20% hands-on material, as indicated in Sec. II above, are antithetical to outstanding educational programs backed by the nation's leading scientists and science educators. According to the research referenced in Sec. III(2) above, the CCC's anti-hands-on brand of "direct instruction" is, for the most part, relatively ineffective in promoting conceptual understanding or process skills in science as compared to teacher guided "inquiry" and "interactive engagement" methods. It is also antithetical to the educational programs supported by:

a. most working scientists [including Nobelists such as Ken Wilson (Wilson & Daviss 1994) and Leon Lederman (2001)], thus calling into question the significance of Metzenberg's (1998) claim that Nobelist Seaborg approved direct instruction;

b. most science educators;

c. leaders of industry and higher education in California [Levinson et al. (2004)];

d. the *National Academy of Sciences* < **http://www4.nationalacademies.org/nas/nashome.nsf** >, [Alberts (2000), Alberts & Wheeler. (2004)];

e. the *National Research Council* < **http://www.nationalacademies.org/nrc/** > [NRC (1997a, 1997b, 1999, 2000, 2001, 2003)];

f. the NRC's *National Science Education Standards* (NRC 1996);

g. the *American Association for the Advancement of Science* < **http://www.aaas.org/** >, [AAAS (1993, 2004)];

h. the *American Association of Physics Teachers* < **http://www.aapt.org/** >, [AAPT/APS/AAS/AIP/ASA/AAPM/AVS (2003)];

i. the *American Physical Society* < **http://www.aps.org/** >, [AAPT/APS/AAS/AIP/ASA/AAPM/AVS (2003)];

j. the *American Chemical Society* (Education Section)
< **http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC= education\index.html >.**

See also WonderNet
< **http://chemistry.org/portal/a/c/s/1/wondernetdisplay.html?DOC=wondernet\index.html >**

featuring hands-on activities. Unfortunately, most of these would be disallowed by the California's direct-instruction-oriented *Criteria*;

k. the *National Association of Biology Teachers* < **http://www.nabt.org/** >;

l. the *National Science Foundation* < **http://www.nsf.gov/** >, [NSF (2004)];

m. the *National Science Teachers Association* < **http://www.nsta.org/** >,
[Wheeler (2004)], [NSTA (1990, 1998, 2002)];

n. the *California Science Teachers Association* < **http://www.cascience.org/** >, see especially K-8 Instructional Materials Adoption
< **http://www.cascience.org/IMCriteria.html** >, and [Janulaw (2004a,b)];

o. the *San Diego Science Alliance* < **http://www.sdsa.org/** >, [Winter (2004)];

p. insights of discerning teachers such as the late Arnold Arons
[Arons (1960, 1972, 1974,1983, 1997, 1998); see Hake (2003c) for a review].

11. The *Criteria*, since they will allow adoption of science materials in K-8 that contain only 20% hands-on material, as indicated in Sec. II above, undermine the general welfare of California and the Nation.

Even given the above ten reasons for rejecting the CCC's Criteria, why should the CSBE really care much about K-8 science education in California? Aren't reading and math the only really important subjects in K-8? In Hake (2004c) I wrote:

> . . . . If the *Criteria* are passed by the California State Board of Education < **http://www.cde.ca.gov/board/** > at its next meeting on 10 - 11 March, they may drastically effect the K-8 textbooks that publishers print for consumption, not only in California but *in the entire nation*, since publishers strive to satisfy their largest markets: California and Texas. It's quite possible that *only* relatively hands-off "direct instruction" K-8 science textbooks containing the minimum mandated California 20% hands-on material will be widely available in the U.S. after 2006.
>
> This could result in an even:
>
> a. greater turn-off of children from science;
>
> b. worse performance in NAEP and international testing programs [for the poor national ratings see < **http://www.aft.org/publications/on_campus/feb02/clips.html** >, for California's dismal performance see Pak (2002) and Merrow (2004)];
>
> c. larger number of unprepared students entering high schools, colleges, and universities;
>
> d. smaller pool of knowledgeable citizens;
>
> e. fewer competent teachers, engineers, scientists, technologists, and entrepreneurs, along with a less competent work force, resulting in:
>
> f. more astronomical state and national budget deficits and fiscal crises;
>
> g. *greater science illiteracy of the general population with consequent threats to effective democracy, the environment, and general well being.*

IV. Recommendations

In conclusion, I strongly urge the *California State Board of Education*, Governor Schwarznegger, Secretary of Education Riordan, State Superintendent of Public Instruction Jack O'Connell, and members of the California legislature to place the educational, social, technological, and business interests of California and the U.S. above a blind and unscientific faith in the efficacy of "direct instruction," and take immediate action to:

1. *Replace* the diehard direct instructionists appointed to the CCC by the CSBE. In my judgement, these few extremists are undermining the K-8 education of California and the Nation.

2. "*Develop a new set of criteria* that would allow each school district a much broader set of options for purchasing materials (both textbooks and hands-on inquiry-based instructional materials), and request an independent evaluation of the Draft Criteria that includes the rationale and research based evidence upon which they are based." [From Levinson et al. (2004)]

3. Attract outstanding teachers into California's classrooms by treating them as the valued professionals they are. This means giving them control of their own teaching materials & practices (rather than top-down dictation through adoption of only direct-instruction-oriented texts and materials), and drastically upgrading their salaries and working conditions.

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AAAS. 2004. *Project 2061*, online at < **http://www.project2061.org/default_flash.htm** > . Especially:
(a) "Research on Teaching and Learning" < **http://www.project2061.org/learning.htm** >,
(b) "Curriculum Materials" < **http://www.project2061.org/curriculum.htm** >,
(c) "Testing and Assessment" < **http://www.project2061.org/assessment.htm** >,
(d) "Middle School Textbook Evaluation" < **http://www.project2061.org/curriculum.htm** > .

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< **http://www.aps.org/educ/joint.cfm** >:

> The scientific societies listed [above] urge the physics community, specifically physical science and engineering departments and their faculty members, to take an active role in improving the pre-service training of K–12 physics/science teachers. . . . . *research indicates that effective pre-service teacher education involves hands-on, laboratory-based learning.* Good science and mathematics education will help create a scientifically literate public, capable of making informed decisions on public policy involving scientific matters. A strong K–12 physics education is also the first step in producing the next generation of researchers, innovators, and technical workers. [My *italics*.]

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> Thomas Adams, executive director of the curriculum commission, said critics are misrepresenting the panel's views. He said commission members are trying to balance the need for a comprehensive science curriculum with the limited science background of many K-8 teachers. Twenty to 25 percent of hands-on instruction seemed like the like "the most reasonable amount of time for someone faced with the challenges of limited facilities and limited time, " he said. "What we want are materials that all teachers can use, " Adams said. " . . . *There are some people who are convinced that the only way that students learn is in a discovery method*. " [My *italics*.]

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Alberts, B. & G. Wheeler. 2004. Letter of 4 March to California State Board of Education Members; online at < **http://science.nsta.org/nstaexpress/lettertocaliffromgerry.htm** >. Alberts & Wheeler write:

> Hands-on science is a core component of the National Research Council's *National Science Education Standards* (NSES) and the American Association for the Advancement of Science's (AAAS) *Science for All Americans*. The *NSES* state, "At all stages of inquiry, teachers guide, focus, challenge, and encourage student learning." The current criteria before the Board presume to tell teachers how to teach. If enacted, they would clearly prohibit many valuable science instructional materials from being adopted by the state and used by local districts, as well as limit the amount of hands-on instruction a teacher can offer, simply because there would be a dearth of quality hands-on instruction resources with which to do so. *Quite simply this language can, and will, significantly limit the way science can be taught in California*. [*Emphasis* in the original.] This is troubling and will have huge repercussions not only in California, but also for the thousands of scientists, administrators, and teachers who are working to incorporate effective hands-on inquiry strategies and related instructional materials into classrooms nationwide. *The current criteria clearly favor direct instruction approaches*. . . [my *italics*]. . . that undermine the authority of local districts to make basic instructional decisions and dismiss the expertise of teachers to understand and meet the specific needs of their students. The California board should not prescribe or limit the amount of time hands-on activities that should be allowed in the science classroom; it should instead provide teachers with a large array of effective tools to help them do their jobs.

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Arons, A.B. 1983. "Achieving Wider Scientific Literacy," *Daedalus*, Spring. Reprinted in Arons (1997) as Chapter 12, "Achieving Wider Scientific Literacy." Arons wrote:

> Researchers in cognitive development describe two principle classes of knowledge: figurative (or declarative) and operative (or procedural). "*Declarative knowledge*" *consists of knowing* "*facts*". . . . [cf. Metzenberg (1998)]. . . ; for example, that the moon shines by reflected sunlight, that the earth and planets revolve around the sun . . . . "*operative knowledge*", *on the other hand, involves understanding the source of such declarative knowledge* (How do we know the moon shines by reflected sunlight? Why do we believe the earth and planets revolve around the sun when appearances suggest that everything revolves around the earth? . . . .) and the capacity to use, apply, transform, or recognize the relevance of the declarative knowledge to new or unfamiliar situations. *To develop the genuine understanding of concepts and theories that underlies operative knowledge, the college student, no less than the elementary school child, must engage in deductive and inductive mental activity coupled with interpretation of personal observation and experience*. Unfortunately, such activity is rarely induced in passive listeners, but it can be nurtured, developed, and enhanced in the majority of students *providing it is experientially rooted and not too rapidly paced, and providing the mind of the learner is actively engaged*. [My *italics*.] See also Hake (2003c).

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> The authors tell the story of a powerful group of parents and mathematicians in California who manipulated information and played off of the public's perception of our 'failing schools' to acquire political clout. Through this telling, they hope that other states will be able to adopt a more rational course as they reconsider their policies.

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> . . . 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.

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> Robert Karplus (1927–90), who began his career as a brilliant theoretical physicist, switched to science education in the early 1960s. He made many substantial contributions to this field in addition to developing a complete K–6 hands-on science curriculum. Karplus provided his curriculum with a sound epistemological foundation, based on the work of Piaget. He developed an effective classroom teaching strategy, the learning cycle. He and his team used a scientific approach to curriculum development. They focused on teacher development. Karplus was committed to science for ALL students. Through science activities he sought to share the joy of discovery. A recent book . . .[Fuller (2002)] . . . . collects some of his important papers and enables you to examine his work for yourself and see what you discover.

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Sharon Janulaw is president of the California Science Teachers Association (CSTA).

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> Laboratory work must be inquiry dominated (the opposite of cookbook labs) and designed to illuminate concepts. . . . The three-year sequence must include a lot of process in addition to content. How does science work? How did we discover some of these things? Why is science such a universal culture? How do the traits of skepticism, curiosity, openness to new ideas, and the joy of discovering the beauty of nature affect the process of science? Long after all the formulas, Latin words, and theories are forgotten, the process will be remembered. The goal of teachers using the new curriculum would be to produce high-school graduates who will be comfortable with a scientific way of thinking.

Levinson, A.D. , *Genentech* CEO, along with leaders of Intel, *Bechtel*, *Pixar*, *Lucasfilm*, *Adobe Systems* and higher education, including the Presidents of the *University of California* (UC), *Stanford*, and the *California Institute of Technology*, and all 10 UC Chancellors. 2004. Letter of 5 March to Reed Hastings of the Board of Education. Online at *the George Lucas Educational Foundation* < **http://www.glef.org/** > as a 112 kB pdf < **http://www.glef.org/pdfs/Letter_from_GLEF_board.pdf** >. Levinson et al. write:

> We write on behalf of the leading institutions of higher education and industries in the State of California to convey our deep concern about the January 16, 2004 Draft Criteria for Evaluating K-8 Science Instructional Materials, and the limits and restrictions they would place on local school districts, schools, and teachers as they strive to improve the teaching and learning of science for all of our students. The California Curriculum Commission's (CCC) Science Subcommittee has developed Draft Criteria for use in grades K-8, subject to approval by the State Board of Education on March 10, 2004. Currently, the only approved materials for science are textbooks. If the Draft Criteria are approved, with their even tighter constraints, the present "textbook only" situation is almost certain to continue for the next adoption cycle: 2006-2012. US businesses and industry seek from today's high school graduates a high capacity for abstract, conceptual thinking, and the ability to apply that capacity to complex real-world problems. The Draft Criteria would greatly restrict access to nationally produced, widely acclaimed instructional materials for grades K- 8 that promote these skills and habits of mind. While acquisition of knowledge is essential, it is well known that students do not easily acquire scientific knowledge without, at the same time, learning to understand the facts by engaging in active experimentation. Thus, the Draft Criteria are counterproductive to the hope of expanding California's economy, and they will severely limit the opportunities for California's children to learn science and scientific methods.

Lipsey, M.W. & D.B. Wilson. 1993. "The Efficacy of Psychological, Educational, and Behavioral Treatment: Confirmation From Meta-Analysis," *American Psychologist* **48**(12): 1181-1209; online at < **http://www.vanderbilt.edu/cerm/MWL_web_bib.htm#methods%20and%20issues** > under "Program Evaluation, Methods for Intervention Research." See also Wilson & Lipsey (2001).

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

Lott, J.W. 2004. "Letter to Governor Arnold Schwarznegger," NCTM News & Media,, February 25; online at < **http://nctm.org/news/letters/2004_0225.htm** >.

Lowery, L. F. 2003. "Research on Hands-On Science Programs," online as a 572 kB pdf at < **http://www.fossworks.com/pdfs/HandsOnScienceResearch.pdf** >.

Maxwell, J.A. 2004. "Causal Explanation, Qualitative Research, and Scientific Inquiry in Education," *Educational Researcher* **33**(2): 3-11; online at < **http://www.aera.net/pubs/er/pdf/vol33_02/2026-02_pp03-11.pdf** > (88 kB). The abstract reads:

> [Shavelson & Towne (2002) has elicited considerable criticism from the education research community, but this criticism has not focused on a key assumption of the report—its Humean, regularity conception of causality. It is argued that this conception, which also underlies other arguments for "scientifically-based research," is narrow and philosophically outdated, and leads to a misrepresentation of the nature and value of qualitative research for causal explanation. An alternative, realist approach to causality is presented that supports the scientific legitimacy of using qualitative research for causal investigation, reframes the arguments for experimental methods in educational research, and can support a more productive collaboration between qualitative and quantitative researchers.

McDermott, L.C. & E.F. Redish. 1999. RL-PER1: Resource letter on physics education research. *Am. J. Phys*. **67**(9):755-767; online at < **http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html** >.

Mercury News. 2004. "Kids won't learn science if a lecture is all they get: Without hands-on labs the boring factor soars," *San Jose Mercury News*, Editorial, 8 March 2004; online on 9 March at < **http://www.mercurynews.com/mld/mercurynews/news/opinion/8133334.htm** >.

Merrow, J. 2004. "No More Tinkering: Remake the Schools," *Los Angeles Times*, 4 February; online at < **http://pqasb.pqarchiver.com/latimes/search.html** >, search for "Merrow." Merrow wrote:

> Where are the people who, 15 years from now, will be maintaining the planes we fly, processing our tax returns, distributing medications and changing our IV drips in hospitals, assembling our cars and teaching our children and grandchildren? In all probability they're attending public school. And that should be of grave concern to Californians because the once-impressive public school system here has declined precipitously since the late 1950s and early 1960s. *California hit bottom on the national assessment of educational progress tests in 1994, and today, despite several years of serious reform efforts, California students test ninth from the bottom among the states* [My *italics*.] Many California schools do not have adequate art, music or physical education classes; nor do they offer foreign languages, counseling or well-stocked libraries with full-time librarians. Many California schools are deteriorating, overcrowded and understaffed. California teachers have about 25% more students per class than the national average, while the typical California guidance counselor is responsible for a mind-boggling 960 students. *As John Mockler, who once ran the state board of education, says, "it's like Calcutta*." [My *italics*.]

John Merrow, is a Peabody Award winner. His documentary, *First to Worst*, aired during February and March on PBS stations. WestEd (a nonprofit research, development , and service agency) < **http://www.wested.org/cs/we/print/docs/we/home.htm** > features a summary of *First to Worst* at < **http://www.wested.org/cs/we/view/rs/731** >. The *First to Worst* website is at < **http://www.pbs.org/merrow/tv/ftw/** >. The *First to Worst* transcript is available as a 112 kB pdf at < **http://www.pbs.org/merrow/tv/ftw/transcripts/first_to_worst.pdf** >. Extended interviews of education and policy experts that are well worth reading are available at < **http://www.pbs.org/merrow/tv/ftw/interviews.html** >.

Metzenberg, S. 1998. Testimony before the U.S. House of Representatives; online at < **http://mathematicallycorrect.com/moremetz.htm** >. Metzenberg testified:

> The authors of the national documents. . .[AAAS (1993) "Benchmarks of Science Literacy" and NRC (1996) National Science Education Standards (NSES)]. . . might argue that they are building understanding in the students, while the California Standards ask simply for knowledge of isolated facts. To quote from page 20 of the NSES: "Emphasizing active science learning means shifting emphasis away from teachers presenting information and covering science topics. The perceived need to include all the topics, vocabulary, and information in textbooks is in direct conflict with the central goal of having students learn scientific knowledge with understanding." I vehemently disagree with their approach, because *understanding is built only upon a solid foundation of knowledge of facts*. . . .[My *italics*. Metzenberg appears to champion *declarative* knowledge with little appreciation for *operative* knowledge – see e.g., Arons (1983)]. . . . This is something that would be acknowledged by nearly every working scientist, but is an anathema to the educational reform movement. The California Standards are significantly different from the national standards because they were developed in a committee chaired by one of the most notable scientists of our century, Glenn T. Seaborg, who co-discovered ten transuranium elements (including Seaborgium which was recently named after him) and was awarded the Nobel Prize in 1951. I would recommend that the NSF consider his contributions very carefully, and reject the tenets of the educational reform movement.

[Metzenberg fails to mention Seaborg's enthusiasm for hands- and minds-on science activities (Woolf 2004b)].

Mertzenberg, S. undated. "Reading: The Most Important Science Process Skill," Antenna; < **http://www.youth.net/ysc/educnews/readscie.htm** >. Metzenberg wrote:

> It has become fashionable in science education to mold K-12 students around an "idee fixe" [obsession] of a modern scientist; formulating hypotheses, observing, measuring, and discovering through hands-on investigations. What has been left unsaid is that real scientists don't actually spend very much of their day 'observing' and 'measuring.' They read! Reading for understanding of content is the core process skill of science, and there is no substitute for practice at an early age. . . . Hands-on investigative activities ought to be sprinkled into a science program like a 'spice'; they cannot substitute for a 'main dish'. *The best 'Hands-on' program would be one in which students can get their 'Hands on' an informative textbook!* [My *italics*.]

Metzenberg, S. 1999. "Talk at the 1999 Conference on Standards-Based K-12 Education; online at < **http://www.csun.edu/~hcbio027/standards/conference.html/may21/metzenberg.html >.** Metzenberg said:

> The enabling legislation for the standards, Assembly Bill 265, set the course for the academic content standards, by calling for "Statewide academically rigorous content and performance standards that reflect the knowledge and skills that pupils will need in order to succeed in the information-based, global economy of the 21st century." Content standards were defined as "the specific academic knowledge, skills and abilities that all public schools in this state are expected to teach and all pupils expected to learn in each of the core curriculum areas, at each grade level tested." The words "specific academic knowledge" raise a point I would like to focus on, because the level of specificity of science standards is something that varies considerably between states. . . . If you look at the structure of the California Science Standards, you will see that the Commission struggled with this issue and resolved it in this reasonable way. . . . One thing that you may have noticed about the [CA] standard, is that it made use of the verb 'to know.' *In science you do not get very far if you don't know things* [my *italics*.]. . . . If you look at the science standards from different states, you will often see that the writers had a great deal of trouble having the students 'know' things . . . So how did the verb "to know" get such a bad reputation? I think it is because to some people, the verb "know" connotes memorization, or a type of rote repeating of something that has been said. In their view, if you ask a student to know something, you are only asking that they be able to parrot it back. On the other hand to be able "to explain" something is said to indicate a higher order form of thought. . . one of the first big surprises I had as a new faculty member here, reading essay exams, was that students can explain things without knowing anything at all. . . *This state has made a tremendous step forward by rejecting the content-free approaches to science education.* [My *italics*.]

Morrison R. 1986. "The Lecture System in Teaching Science," in *Undergraduate Education in Chemistry and Physics, Proceedings of the Chicago Conferences on Liberal Education*, No. 1, edited by R.R. Rice Univ. of Chicago, p. 50. See Hake (2002c) for excerpts from this *brilliant lecture*. I have recently learned that chemist Frank Lambert, whom Morrison credits as his guru and the father of the *Gutenberg Lecture Method*, first published his epiphany in Lambert (1963).

NRC. 1996. *National Science Education Standards*, National Academy Press; online in HTML at < **http://books.nap.edu/catalog/4962.html** >.

NRC. 1997a . *Introducing the National Science Education Standards, Booklet*, National Academy Press; online in HTML at < **http://books.nap.edu/catalog/5704.html** >.

NRC. 1997b *Science Teaching Reconsidered: A Handbook*, National Academy Press; online at < **http://books.nap.edu/catalog/5287.html** >. This is oriented towards postsecondary education, but its message that "inquiry' and "interactive engagement" methods are generally more effective that direct instruction applies to K-12. See especially Chapter 2, "How Teachers Teach: Specific Methods."

NRC. 1999. *Improving Student Learning: A Strategic Plan for Education Research and Its Utilization* , National Academy Press; online in HTML at < **http://books.nap.edu/catalog/6488.html** >.

NRC. 2000. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*, National Academy Press; online in HTML at < **http://books.nap.edu/catalog/9596.html** >. See especially Bruce Alberts' (2000) Forward: "A Scientists Perspective on Inquiry" for a good operational definition of the "inquiry."

NRC. 2001. *Classroom Assessment and the "National Science Education Standards,"* National Academy Press; online in HTML at < **http://books.nap.edu/catalog/9847.html** >.

NRC. 2003. *What Is the Influence of the National Science Education Standards?: Reviewing the Evidence, A Workshop Summary*, National Academy Press; online at < **http://books.nap.edu/catalog/10618.html** >.

NSF. 2004. "Instructional Materials Development." online at
< **http://www.ehr.nsf.gov/esie/programs/imd/imd.asp** >:

> IMD develops high-quality, research-based instructional and assessment materials for students that enhance knowledge, thinking skills, and problem-solving abilities of all students, as well as incorporate recent advances in disciplinary content, research on teaching and learning, and instructional technologies. IMD materials are intended to be implemented nationwide and address learning in diverse settings.

Unfortunately, most NSF-funded materials would probably not appeal to the California's direct-instruction-oriented CCC who appear to be the sole arbiters in recommending California's K-8 science instructional material adoptions to the CSBE.

NSTA. 1990. Position Statement on Laboratory Science; online at
< http://www.nsta.org/159&psid=16 >:

> "***A minimum of 60 percent of the science instruction time should be devoted to hands-on activities***, the type of activities where children are manipulating, observing, exploring, and thinking about science using concrete materials. *Reading about science, computer programs, and teacher demonstrations are valuable, but should not be substituted for hands-on experiences.*" [My *italics*.]

NSTA. 1998. Position Statement on *National Science Education Standards. . . .*[NRC 1996]; online at < http://www.nsta.org/159&psid=24 >.

NSTA. 2002. Position Statement on Elementary School Science; online at
< http://www.nsta.org/159&psid=8 >.

NSTA. 2004. Express Newsletter, 15 March, "California State Board of Education Votes Against Proposal to Limit Amount of Hands-on Instruction in Future Textbooks"; online at
< **http://science.nsta.org/nstaexpress/nstaexpress_2004_03_15.htm** >.

Pak, J. 2002. "California education receives low marks," *Silicon Valley/San Jose Business Journal*, 15 January; online at
< **http://sanjose.bizjournals.com/sanjose/stories/2002/01/14/daily23.html** >:

> California ranks near the bottom nationwide in nearly all elementary and secondary school indicators according to CyberEducation2002, a report released by the AeA and The Nasdaq Stock Market. . . . Only 18 percent of California's eighth-graders scored at or above proficient levels on the 2000 math National Assessment for Educational Progress test, up from 12 percent in 1990. Similarly, only 15 percent of eighth-graders scored proficient or above on the 2000 science NAEP, *placing California last in the country.*

Pelligrino, J.W., N. Chudowsky, R. Glaser, eds. 2001. *Knowing What Students Know: The Science and Design of Educational Assessment*, National Academy Press; online at
< **http://www.nap.edu/catalog/10019.html** >.

Phillips, D.C. 2000. *Expanded social scientist's bestiary: a guide to fabled threats to, and defenses of, naturalistic social science*. Rowman & Littlefield.

Raloff, J. 2001a. "Errant Texts: Why some schools may not want to go by the book," *Science News* **159** (11). March 17; online < **http://www.sciencenews.org/articles/20010317/bob9.asp** >.

Raloff, J. 2001b. "Where's the book? Science education is redefining texts." *Science News* **159**(12), March 24; online at < **http://www.sciencenews.org/20010324/bob12.asp** >, second in a two part series on middle-school science curricula.

Raimi, R.A. 2004. "Uncivil War," review of Wilson (2003) in *Education Next*, Spring, online at < **http://www.educationnext.org/20042/81.html** > .

Ralston, A. 2003. Review of Wilson (2003) in *Notices of the AMS*, November; online at < **http://www.ams.org/notices/200310/200310-toc.html** > / "California Dreaming - A Book Review," where "/" means "click on" or go directly to < **http://www.ams.org/notices/200310/rev-ralston.pdf** > (92 kB). See also the comments on Ralston's review at < **http://www.ams.org/notices/200403/200403-toc.html** > / "Opinion" where "/" means "click on," or go directly to < **http://www.ams.org/notices/200403/commentary.pdf** > (56 kB).

Redish, E.F. 2003. *Teaching Physics With the Physics Suite*. John Wiley.

Roseman, J., S. Kesidou, L. Stern, and A. Caldwell. 1999. "Heavy Books Light on Learning: Project 2061 Evaluates Middle Grades Science Textbooks," Science Books & Films, November/December 1999, v. 35 no. 6. Report on the *Project 2061* in-depth evaluation of middle grades science textbooks. The focus of this effort was to see textbooks had potential for helping students learn key ideas. *Not one of the middle grades science texts evaluated by Project 2061 received a satisfactory rating*. For a press release see at < **http://www.project2061.org/press/pr990928.htm** >. See also AAAS (2004d).

Salladay, R. & P. Nichols. 2004. "Tax Opposition May Be 'Wishful,' Gov. Says : "Gov. Arnold Schwarzenegger, with little cash on hand to close a $14-billion budget shortfall, reiterated Tuesday his opposition to new taxes but said it might be "wishful thinking"; *LA Times*, 31 March; online at < **http://pqasb.pqarchiver.com/latimes/search.html** >, search for "Salladay."

Schneps, M.H. & P.M. Sadler. 1985. "Private Universe Project" (Harvard -Smithsonian Center for Astrophysics, Science Education Department); information is online at < **http://cfa-www.harvard.edu/cfa/sed/resources/privateuniv.html** >. That video shows Harvard graduating seniors, evidently victims of direct instruction, confidentially explaining that the seasons occur because of the yearly variation of the distance of the Earth from the Sun (never mind that summer in the northern hemisphere is winter in the southern hemisphere) !

Schultz, T. 1998. "History of the Development of California Science Content Standards," online at < **http://www.sci-ed-ga.org/standards/history.html** >. See also the excellent articles by Lopez & Schultz (2001) and Schultz (2001). Schultz (1998) wrote:

> This. . .[the 1995-1999 CA Science Wars]. . . is an important story, but *none of the prominent newspapers really covered it*. The conflicting goals of the different approaches to science education, the evidence for each, the supporters of each, and the intensely political maneuvering behind the scenes have all been missed. And the Op-Ed pages have distorted the issues at best, totally misrepresented them at worst. Attempts to correct the wrong impressions, *to have as an op-ed piece a shortened version of the enclosed statement by the president of the National Academy of Sciences (who is also a renowned Bay Area scientist and a leader of the effort to improve science education in San Francisco), were rejected by three of the state's leading newspapers.* While people who care have been grossly misled, the development of the California Science Content Education has been hijacked, and California's science education is about to take a giant step backward. [My *italics*.]

A similar silence [Woolf & Hake (2004), Woolf (2004e)] has beset most California newspapers during the recent battle [Strauss (2004), Galley (2004), *Mercury News* (San Jose) (2004)] over the CCC's attempted limitation of hands-on science activities in California's K-8 classrooms.

Schultz, T. 2001. "K-8 Science Education through the Eyes of a Physicist," *APS Forum on Education Newsletter*, Summer; online at
< **http://www.aps.org/units/fed/newsletters/summer2001/schultz.cfm** >

> As a theoretical physicist who now devotes full time to promoting the systemic reform of K-8 science education to a hands-on, inquiry-centered approach, and to involving scientists in this process, I have found the environment and challenges in the worlds of physics and education, and the effects they have on physicists and educators, to be entirely different. Any physicist working in both worlds, or wishing to make a transition from one to the other, will have to learn about the differences. The observations presented here are intended to help that process along. . . . Physicists (and other scientists, engineers, and other technical professionals) can make important contributions to science education in many ways. But to do so, they must enter a very different culture. To make their involvement useful in any real sense, they must understand the underlying features of that culture and not assume those features are similar to those of their own culture. Educators will say that physicists will really understand this only when they have *constructed their own understanding of* the differences. The observations offered here are intended to aid in that constructivist process. [*Emphasis* in the original.]

Shavelson, R.J. & L. Towne, eds. 2002. *Scientific Research in Education*, National Academy Press; online at < **http://www.nap.edu/catalog/10236.html** > :

> The Committee argued that all the sciences, including scientific educational research, shared a set of epistemological or fundamental guiding principles, and that all scientific endeavors should:
>
> (a) pose significant questions that can be investigated empirically,
>
> (b) link research to relevant theory,
>
> (c) use methods that permit direct investigation of the questions,
>
> (d) provide a coherent and explicit chain of reasoning,
>
> (e) attempt to yield findings that replicate and generalize across studies, and
>
> (f) disclose research data and methods to enable and encourage professional scrutiny and critique."

For recent commentary on the hotly debated topic of "scientific" research in education see, e.g. :
(1) Maxwell (2004);

(2) Burkhardt & Schoenfeld (2004);

(3) Eisenhart & Towne (2003);

(4) *Educational Researcher* **32**(1), 2003, theme issue on "The Role of Design in Educational Research" < **http://www.aera.net/pubs/er/toc/er3201.htm** >;

(5) *Educational Researcher* **31**(8), 2003, theme issue on "Scientific Research in Education" < **http://www.aera.net/pubs/er/toc/er3108.htm** > [stimulated by (a) Shavelson & Towne (2002), and (b) recent federal legislation such as the *No Child Left Behind Act of 2001* and related federal policy initiatives that proclaim randomized clinical trials (RCT's) to be the gold standard of educational research];

(6) Slavin (2002).

Shymansky, J.A., W.C. Kyle, J.M. Alport. 1983. "The effects of new science curricula on student performance," *Journal of Research in Science Teaching* **20**(5): 387-404.

Shymansky, J. 1989. "What Research Says About ESS, SCIS, and SAPA," *Science and Children*, April.

Shymansky, J., L.V. Hedges, & G. Woodworth. 1990. "A Reassessment of the Effects of Inquiry-Based Science Curricula of the 1960's on Student Performance, *Journal of Research in Science Teaching* **27(**2**)**: 127-144.

Slavin, R. 2002. "Evidence-Based Education Policies: Transforming Educational Practice and Research," *Educational Researcher* **31**(7): 15-21; online at
< **http://www.aera.net/pubs/er/toc/er3107.htm** >. The abstract reads:

> At the dawn of the 21st century, educational research is finally entering the 20th century. The use of randomized experiments that transformed medicine, agriculture, and technology in the 20th century is now beginning to affect educational policy. This article discusses the promise and pitfalls of randomized and rigorously matched experiments as a basis for policy and practice in education. It concludes that a focus on rigorous experiments evaluating replicable programs and practices is essential to build confidence in educational research among policymakers and educators. However, new funding is needed for such experiments and there is still a need for correlational, descriptive, and other disciplined inquiry in education. Our children deserve the best educational programs, based on the most rigorous evidence we can provide.

Sowder, J.T. 1998. "What are the 'Math Wars' in California All About? Reasons and Perspectives" Phi Beta Kappa Invited Lecture; online at
< **http://mathematicallysane.com/analysis/mathwars.asp** >.

Stephens, R.D. 2004. Letter to the CA State Board of Education, 8 March; online at
< **http://www.cascience.org/IMCriteria.html** >. Richard Stephens is President of the Shared Services Group of the *Boeing Company*. He writes:

> Being the largest private employer in the State of California, we recognize that economic growth and stability for the State are dependent upon having a strong core base of profitable growing businesses. To ensure those businesses can sustain and continue to grow in the new marketplace, we must have a sufficient pool of people available with the skills and capabilities to innovate, create and invent products and services that respond to the market needs of a global economy. We were very concerned that there was a proposal under consideration that would reduce and/or limit the amount of time teachers would be allowed to incorporate certain materials for hands on experiments in the classroom. Such a proposal had the potential for a number of unacceptable implications.

Strauss. V. 2004. "Back to Basics vs. Hands-On Instruction: California Rethinks Science Labs." *Washington Post*, Tuesday, 3 February. page A12; online at
< **http://www.washingtonpost.com/wp-dyn/articles/A6944-2004Feb2.html** >. This report was stimulated at least in part by the wide internet disbursal of Woolf & Hake (2004), an OpEd piece rejected by the *San Diego Union Tribune*. As of 6 April 2004 there were 75 reader responses to this article on the site's "Message Board."

Wells, M., D. Hestenes, G. Swackhamer. 1995. "A modeling method for high school physics instruction," *Am. J. Phys*. **63**(7): 606-619; online at
< **http://modeling.asu.edu/R&E/Research.html** >.

Wheeler, G.F. 2004. Letter of 15 January to Thomas Adams, Executive Director of the California Curriculum Commission,; online at < **http://www.nsta.org/main/news/stories/nsta_story.php?news_story_ID=49065** >. Gerald Wheeler is Executive Director of the National Science Teachers Association.

Wilson, K.G. & B. Daviss. 1994. *Redesigning Education*. Henry Holt; description online at < **http://www.physics.ohio-state.edu/~kgw/RE.html** >. See e.g., page 178-179:

> Gardner . . .(1991) . . .and other constructivists argue that the old behaviorist format of lecture, recitation, and rote drills leaves far too many students incapable of bringing useful knowledge with them from the artificial setting of the classroom into the real world. Schools intent on seeing students master higher-order skills must explicitly confront and destroy the simplistic intuitive theories that linger from childhood. Otherwise those covert notions will remain - often undermining the results of typically superficial classroom education.

Wilson, S.M. 2003. *California Dreaming: Reforming Mathematics Education*, Yale University Press. Reviewed by Anthony Ralston (2003) and by Ralph Raimi (2004).

Wilson, D.B. & M.W. Lipsey. 2001. "The Role of Method in Treatment Effectiveness Research: Evidence from Meta-Analysis." *Psychological Methods* **6**(4): 413-429; online at < **http://www.vanderbilt.edu/cerm/MWL_web_bib.htm#methods%20and%20issues** > under "Program Evaluation, Methods for Intervention Research."

Winter, P. 2004. Letter to Members of the State Board of Education, 12 February. Patricia Winter is the Executive Director of the San Diego Science Alliance < **http://www.sdsa.org** >, a non-profit consortium of businesses, K-12 education, higher education, and scientific institutions, with over 250 members.

Woolf, L.D. 1999. "22 December 1999 Science Education Petition," online at < **http://www.sci-ed-ga.org/standards/petition.html** >. See also Woolf (2000).

Woolf, L.D. 2000. Letter of 17 February to California Secretary of Education Gary Hart in response to a letter by Stan Metzenberg who criticized Woolf's "Science Education Petition" [Woolf 1999] as "misleading and erroneous." Woolf sent cc's to State Senator Dede Alpert, Assemblymember Kerry Mazzoni, CSBE executive director John Mockler [see Section III (4) above], CA Superintendent of Schools Delaine Eastin, members of the CSBE, & Stan Metzenberg ; online at < **http://www.sci-ed-ga.org/standards/Metz.html** > / "Response by Dr. Larry Woolf to a letter by Dr. Stan Metzenberg. . . ." where "/" means "click on."

Woolf, L.D. 2004a. "Re: The End of Hands-On Science Activities in California's K-8 Classrooms?"; online at
< **http://lists.psu.edu/cgi-bin/wa?A2=ind0401&L=physhare&O=D&P=13211** >.
Post of 28 Jan 2004 22:45:53-0800 to PhysLrnR, Phys-L, Physhare, & POD.

Woolf, L.D. 2004b. "Testimony of 1/16/04 to the California Curriculum Commission regarding hands-on science limitation," online at < **http://www.sci-ed-ga.org/standards/index.html** > as a 52 kB pdf at < **http://www.sci-ed-ga.org/standards/12CA83.pdf** >.

Woolf, L.D. 2004c. "Briefing Regarding the January 16, 2004 Draft Criteria for Evaluating K-8 Instructional Materials for California's Students," online at
< **http://www.sci-ed-ga.org/standards/index.html** >.

Woolf, L.D. 2004d. Letter of 25 February to the Members of the State Board of Education; online at < **http://www.sci-ed-ga.org/standards/index.html** >.

Woolf, L.D. 2004e. OpEd, by invitation of the *San Jose Mercury News*; the editor decided at the last minute *not* to publish Woolf's piece, evidently because an OpEd favoring the *Criteria* by CCC science chair Sandra Mann was suddenly withdrawn; online at
< **http://www.sci-ed-ga.org/standards/** >.

Woolf, L.D. & R.R. Hake. 2004. "The End of Hands-On Science Activities in California's K-8 Classrooms?" online at
< **http://lists.psu.edu/cgi-bin/wa?A2=ind0401&L=physhare&O=D&P=4583** >.
Post of 12 Jan 2004 16:57:42-0800 transmitted to (a) the discussion lists AERA-K, AP-Physics, BIOPI-L, CHEMED-L, PHYS-L, PHYSLRNR; and (b) to the members and staff of the CCC. This post was intended as an OpEd piece for the *San Diego Union Tribune* but was rejected by the editor as being written too much for "insiders." Also "letters to the editor" by Woolf and Hake were immediately tossed into the circular files of the *LA Times*, *the San Francisco Chronicle*, and the *Sacramento Bee*. Is it bad writing, bad editing, or a topic of no public interest? The 75 lively responses (as of 6 Sept. 2004) to Strauss (2004) suggest that it is *not* the latter. According to Schultz (1998), California newspapers similarly failed to adequately cover 1995-1999 "California Science Wars" [Woolf (1999, 2000), Feder (1998a,b)].