CRITIQUE OF PROPOSED CALIFORNIA SCIENCE CONTENT STANDARDS

Education Department, American Physical Society, August 21, 1998

There are many aspects of the proposed California Standards that one may criticize. Below, we point out a number of the most glaring problems. For each issue, we provide some brief background, evidence for the defect (you may find the full text of the California standards at http://www.ca.gov/goldstandards/), and some implications if applied to the classroom.

If you wish to register your opposition to these standards, please write a letter to the California State Board of Education, 721 Capitol Mall, Rm. 532, Sacramento, CA 95814, to reach them by Friday, September 4. Please also send a copy to Dr. Ramon Lopez, American Physical Society, One Physics Ellipse, College Park, MD 20740, so we can be sure your letter is not ignored. In your letter, we suggest that you begin by stating that these standards are not acceptable, then mention any number of the points below or other objections you might wish to raise, ands finally endorse the APS proposal to have a group of distinguished scientists ("the Scientists' Standards Panel") who are representative of the scientific community direct a revision of the standards.

1. The proposed standards are overstuffed

Background: Traditional science teaching places greater emphasis on factual knowledge than on conceptual understanding. It relies heavily on rote memorization of facts and formula. The inquiry-centered approach that is advocated by both the *National Science Education Standards* and the *Benchmarks for Science Literacy* relies on students learning science by discovery, i.e. by doing experiments and analyzing the results to achieve real understanding. Discovery, analysis, and understanding take more time than learning by rote.

Evidence for this defect: Readers of this document will be amazed by the amount of very specific material that has been included. In the high-school physical science section on waves, phenomena such as diffraction, refraction, polarization, and interference and beats are all called out as standards. While these are important concepts, are they things that we should expect *all* students to understand? Throughout the document, there is a strong bent toward including every aspect of a subject, often in considerable factual detail.

Implications of this defect:

a) Teachers will be forced to teach subjects in a superficial manner in order to "cover" the material. This will lead to an emphasis on rote learning and will leave little time for examining the larger scientific concepts or building conceptual understanding.

b) Publishers will include everything mentioned in the standards in their textbooks because the California market is so important. This will reinforce the pressure on teachers to "cover the material" and will impact science education in other states. We shall continue to have a curriculum that is a mile wide and an inch deep.

c) Children will ultimately know much less. When learning by rote, children don't really learn, they just remember, and this is usually for only a short time. Later, they forget most and misunderstand much of the rest. The long-term effect is little or no understanding of science.

d) Children will cease being the wonderful scientists they are in their earliest years and will learn to dislike science. Because of having too many facts to learn, children will have much less if any time to discover, to learn how to satisfy their curiosity in more

and more subtle ways, to ask the good questions which is the very essence of being a scientist. When given a choice, children taught this way usually choose not to study science, because most of them don't like to memorize a bunch of facts. Of course, children who like their studies learn much more than those who don't.

2. **The proposed standards ignore what is known about the cognitive development of children**.

Background: What we know about cognitive development is far more than we knew even ten years ago, far more than we knew when the parents and grandparents of today's children went to school. It simply is not correct that we can teach young children anything at any age if we do it with enough skill. Since the goal is general scientific literacy, we should be guided by cognitive studies that provide insights into what most children can do and understand and not focus on the select few who will become scientists themselves.

Evidence for this defect: The atomic nature of matter and the periodic table are introduced in the 3rd grade. These concepts involve significant abstractions well beyond a child's ability to experience concretely, and the periodic table involves at least two independent and several dependent variables. This kind of reasoning is way beyond the ability of young children.

Implications of this defect:

a) Children simply won't learn what is intended that they learn.
b) They may learn some rules with no understanding of what they mean or they may develop misconceptions that are based on these failures to understand, misconceptions which are amazingly persistent and which seriously impede further learning.
c) Children will often become confused, impatient, and frustrated, and then turn off.

3. **The proposed standards lay too much stress on knowing facts, not enough on understanding concepts, the processes of doing science, or scientific habits of thinking**

Background: Scientists almost uniformly say they want children to have real understanding in preference to knowing a lot of isolated and disconnected facts. Of course, one must know facts to have understanding, because otherwise there's nothing to understand. But there is a belief by some that the more facts one knows, the easier it is to learn still more. Unfortunately, as any scientist knows, in science knowing more and more facts doesn't carry with it, *ipso facto*, understanding. This is also true for children, especially if there is no attempt, or no time, to teach for understanding. In traditional ways of teaching science, facts are taught and are to be accepted (either because they are made plausible or because they come from authorities like the book and teacher) and experiments, when done, are means to verify the facts, not investigations into the nature of the real world.

Evidence for this defect: At the high-school level, one standard reads "chemical bonds between atoms in molecules such as H2, CH4, NH3, H2CCH2, N2, Cl2 and many large biological molecules are covalent." Is this a piece of information that is really crucial and relates to a big picture?

Implications of this defect:

a) Facts are easily forgotten, so knowing a lot of facts may leave a small residue.
b) Facts without connections (i.e. without understanding) are of limited value, so even though a student may retain many facts (and thus do well on tests that measure simple

recall), he/she may never gain (or possess) any real understanding.

c) Students will miss their best opportunity to develop scientific habits of thinking. They may grow up uncritical of "facts". At best, when a question arises, they will answer it by "looking it up" or "asking an expert" rather than mixing this with "thinking it through". And as adults, they will encounter many issues for which they can't look up the answer.

4. The proposed standards are for elite children, not for all students

Background: Historically, academic science learning was geared to produce children who might go on to study science at the university. "Everyday science" was learned from real life experiences, on the farm or in the kitchen or wherever young people had to do things for themselves. The "average" student today learns less and less science outside of the classroom, while the demands for basic scientific knowledge and understanding on the part of the average citizen have grown dramatically. In the revolution in science education of the sixties (which was driven by Sputtnik and a felt need for more scientists), the emphasis was on the elite student, the future scientist; today, the emphasis of both the *Benchmarks* and the *NSES* is on the average student. The key phrase, coined by the AAAS and the title of the first book of their Project 2061, is "Science for *All* Americans".

Evidence for this defect: The proposed California Science Content Standards attempt to carry students far too far along academic pathways in the study of various areas of science (one could say that they are somewhat watered-down treatments of the same science in each field that a major in that field would study at the university). As a result, they totally miss areas that would be of great interest and importance to the average student, to all Americans. For example, they have almost nothing about applications of science, about technology, or about the role of science and technology in society. They also have almost nothing about the history of science. This is in sharp contrast to the *NSES* and *Benchmarks*, with which the proposed standards are so badly aligned.

Implications of this defect:

a) At the high-school level, only children taking four years of science would come close to meeting the standards. These will be the college-bound students (and not even all of them). And what about the rest? Science standards should be seen as a floor, not a ceiling, and all students should have a reasonable chance of meeting them.

b) At all levels, science education according to the proposed standards would short-change most students where they need it the most, in understanding the many ways that science and technology will confront them during their lives.