Should the Culture of University Science Education Be Changed? *†

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In a recent *Science* article "Changing the Culture of Science Education at Research Universities" [Anderson et al. (2011)], thirteen biology research scientists, all Howard Hughes Medical Institute Fellows, deplore the prevalent university reward systems that "heavily weight efforts of many professors toward research at the expense of teaching." They advocate seven initiatives that might help to address "widespread concern about educating enough scientists and scientifically literate citizens."

Of primary concern in this essay is Initiative #1. "Educate faculty about research on learning. . . ." This is especially important if faculty are to play a prominent role in adequately educating prospective K-12 teachers, who might then, in turn, enhance the science/math literacy of the general population.

In that regard, I review an essay "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University" [Hake (2000)] based on an earlier libretto *The Science Illiteracy Crisis: A Challenge for the University* [Hake (1989)], with the leitmotiv: "The road to U.S. science literacy begins with effective university science courses for pre-college teachers." The opera dramatizes the fact that the failure of universities *throughout the universe* to properly educate pre-college teachers is responsible for our failure to observe any signs of extraterrestrial intelligence.

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*The reference is: Hake, R.R. 2011. Invited talk, "Should the Culture of University Science Education Be Changed?" Southern California Section of the AAPT, 14 May 2011, Pierce College, Woodland Hills, CA; online as reference #63 at <http://bit.ly/b2UsK6>.

† This article borrows from the following previous unpublished material: (a) "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University" [Hake (2000)]; (b) "Can Scientific Research Enhance the Art of Teaching?" [Hake (2007)]; and (c) "SET's Are Not Valid Gauges of Students' Higher-Level Learning #2" [Hake (2011g)].

Prologue

This article is a reaction to "**Changing the Culture of Science Education at Research Universities"** [Anderson et al. (2011)]. The thirteen authors are all leading biology researchers and "Howard Hughes Medical Institute" HHMI <http://www.hhmi.org/> Fellows. For photos and thumbnail bios see HHMI News (2010a) <http://bit.ly/alXrgy>. According to the HHMI News (2010b):

> "The HHMI Professors Program supports a small group of leading research scientists who are committed to making science more engaging to undergraduates. Thirteen HHMI professors . . . . .[[the authors of Anderson et al. (2011)]]*. . . . . will receive a total of $9 million over four years **to focus on solving important problems facing science education**,* such as how best to bring research into the classroom, **teach large introductory science courses**, and encourage students from diverse backgrounds to become scientists."

Anderson et al. (2011) advocate seven initiatives for "Changing the Culture of Science Education at Research Universities." They wrote (slightly edited):

> "Although many ideas we present here are not new, the context in higher education has changed because of widespread concern about educating enough scientists and scientifically literate citizens [*Rising Above the Gathering Storm* (National Academies, 2007)] and because resources that enable change have improved markedly in recent years [*Scientific Teaching* (Handelsman, Miller, & Pfund, 2007); Education Resources Information Center (ERIC, 2011); and Multimedia Educational Resource for Learning and Online Teaching (Merlot, 2011)]."

This talk is concerned primary with the **first** initiative proposed by Anderson et al.:

> "**Educate faculty about research on learning**. No scientist would engage in research without exploring previous work in the field, yet few university educators read education research. Universities can demonstrate that they value teaching by treating it as a scholarly activity, such as through faculty training in teaching that is predicated on evidence-based approaches [*Scientific Teaching* (Handelsman, Miller, & Pfund, 2007), 'Innovations in Teaching Undergraduate Biology and Why We Need Them' (Wood, 2009)]. Training should address education theory, tested practices, and methods to assess learning. . . . . **These practices must include strategies to engage students in introductory courses, arguably the highest-impact change that could be made** [Handelsman, Miller, & Pfund (2007); Wood (2009); 'Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education' (Fairweather, 2008); 'Peer Instruction: From Harvard to the Two-Year College' (Lasry, Mazur, & Watkins, 2008)]."

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* Here and throughout this article, quotes are in blue text and within those quotes: (a) my own emphasis is indicated in **bold text**, and (b) my inserts are indicated by ". . . .[[insert]]. . . . ".

1. *Carl Wieman's Words*

Regarding introductory course students, physics Nobelist Carl Wieman (2007) <http://en.wikipedia.org/wiki/Carl_Wiemanin> in "Why Not Try a Scientific Approach to Science Education?" wrote:

"The purpose of science education is no longer simply to train that tiny fraction of the population who will become the next generation of scientists. **We need a more scientifically literate populace** to address the global challenges that humanity now faces and that only science can explain and possibly mitigate, such as global warming, as well as to make wise decisions, informed by scientific understanding, about issues such as genetic modification."

2. *Traditional Introductory Science/Math Courses*

How effective are traditional undergraduate introductory physics courses? From "Interactive-engagement vs traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses" [Hake (1998a)]:

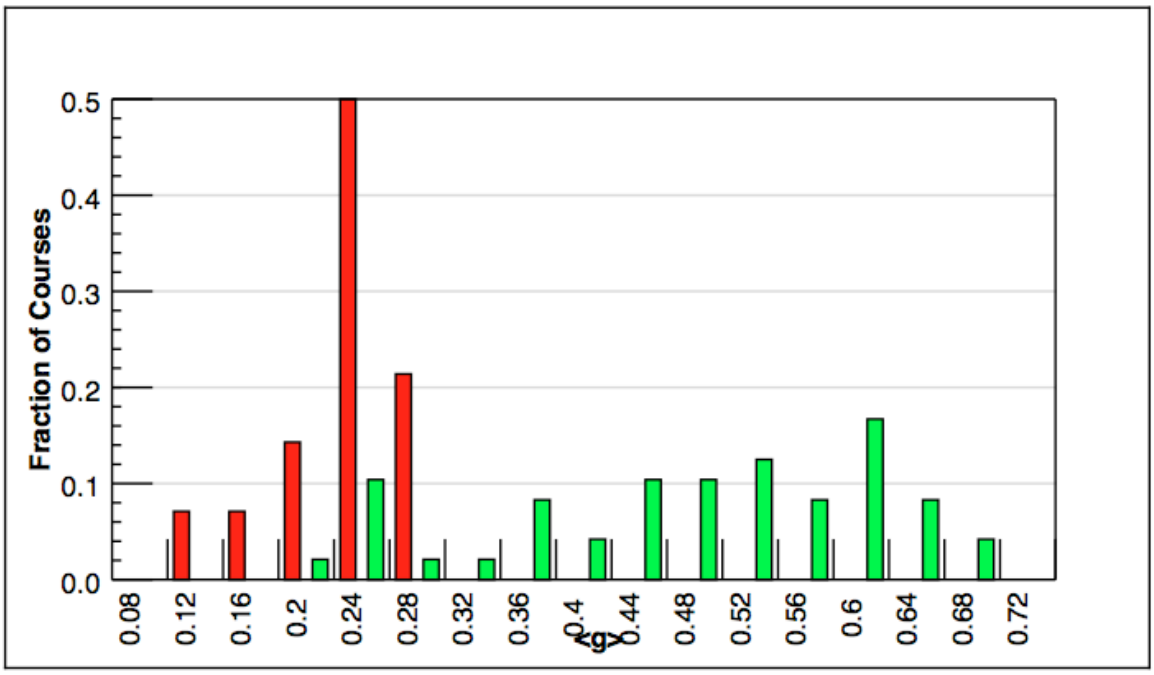


Fig. 2. Histogram of the average normalized gain <g> on the *Force Concept Inventory* or its precursor, the *Mechanics Diagnostic Test*: dark (red) bars show the *fraction* of 14 traditional courses (N = 2084), and light (green) bars show the *fraction* of 48 interactive engagement courses (N = 4458), both within bins of width δ<g> = 0.04 centered on the <g> values shown.

Who cares if student learning in traditional introductory physics courses (red bars) is near zero?

I suspect that traditional passive-student-lecture *science/math* courses *generally* are as ineffective as traditional passive-student-lecture *physics* courses in promoting higher-level learning. But so what? – can't we get all the science/math geeks we need from overseas?

Unfortunately, some of the students in U.S. universities are prospective K-12 teachers. They will have learned little from their university science/math courses and will teach as they have been taught thus leading to:

3. *"The General Population's Ignorance of Science-Related Societal Issues: A Challenge for the University"*

What follows is an updated version of an article [Hake (2000)] of the above title, which was in turn based on *The Science Illiteracy Crisis: A Challenge for the University* [Hake (1989)], an unpublished libretto for a Wagnerian musical drama to be presented under the stars in the open-air Santa Fe Opera Theater:

an annotated interweaving of classic themes and original work. The leitmotiv was: "*The road to U.S. science literacy begins with effective university science courses for pre-college teac*hers."

OUTLINE

I. Introduction: The Cosmic Connection

II. What is Science Literacy? Arons' Twelve Hallmarks

III. Evidence for Scientific Illiteracy

IV. Ineffective Introductory Science Courses in the Universities Generate Scientifically Illiterate Leaders

V. Time Chart

VI. Some Life-Threatening Science-Related Societal Problems

VII. University Reform – Needed But Unlikely

VIII. Why Do We Find No Evidence for Extraterrestrial Intelligent Life? Resolution of Fermi's Paradox: "Where is Everybody?"

I. Introduction: The Cosmic Connection

A. The *Fermi Paradox*: An operatic tenor, singing to the starlit sky in the role of Enrico Fermi <http://en.wikipedia.org/wiki/**Fermi_paradox**> plaintively inquires:

Where Is Everybody?

Most experts* agree there is no good evidence that extraterrestrials:

a. are now somewhere on Earth (even despite the *National Enquirer*),
b. have at some earlier time visited the Earth,
c. exist somewhere in the Universe.

Ammonia ! Ammonia!

R. Grossman; New Yorker, 1962

B. I Shall Argue that:

There's no evidence for extraterrestrial intelligent life because:

UNIVERSITIES *THROUGHOUT THE UNIVERSE* HAVE FAILED TO PROVIDE EFFECTIVE INTRODUCTORY SCIENCE/MATH COURSES FOR PRE-COLLEGE TEACHERS

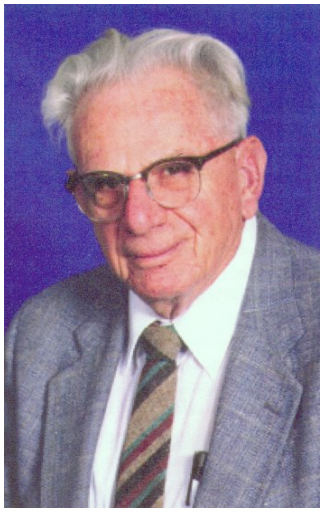
Throughout the Universe there exits:

From Gary Larsen

Math Anxiety *Chemistry Conniptions* *Physics Floundering*

*See e.g., *The Search for Life in the Universe* [Goldsmith & Owen (2001)]

II. What is Science Literacy? Arons's Twelve Hallmarks [Quoting the late A.B. Arons, *Teaching Introductory Physics* (Wiley, 1997), Chapter 12, "Achieving Wider Scientific Literacy"(my *italics*)]



Arnold Boris Arons (1916-2001)

"1. Recognize that scientific concepts ..... are invented (or created) by acts of human intelligence and are not tangible objects or substances accidentally discovered, like a fossil, or a new plant or mineral.

2. Recognize that to be understood and correctly used such terms require careful ***operational*** definition. . . . . .[[see e.g., 'Education Research Employing Operational Definitions Can Enhance the Teaching Art' (Hake, 2010d); 'Helping Students to Think Like Scientists in Socratic Dialogue Inducing Labs' (Hake, 2011h)]]. . . . .rooted in shared experience and in simpler words previously defined; to comprehend, in other words, that a scientific concept involves an idea *first* and a name *afterwards*, and that *understanding does not reside in the technical terms themselves*.

3. Comprehend the distinction between observation and inference and to discriminate between the two processes in any context under consideration.

4. Distinguish between the occasional role of accidental discovery in scientific investigation and the deliberate strategy of forming and testing hypotheses.

5. Understand the meaning of the word 'theory' in the scientific domain, and to have some sense, through specific examples, of how theories are formed, tested, validated, and accorded provisional acceptance; to recognize, in consequence, that the term does *not* refer to any and every opinion, unsubstantiated notion, or received article of faith and thus, for example to *see through the creationist locution that describes evolution as 'merely a theory.'*

6. Discriminate, on the one hand, between acceptance of asserted and unverified end results, models, and conclusions, and, on the other, understand their basis and origin; that is to recognize when questions such as ***How do we know***....? ***Why do we believe***...? ***What is the evidence for***.....? have been addressed, answered, and understood, and when something is being taken on faith.

7. Understand, again through specific examples, the sense in which scientific concepts and theories are mutable and provisional rather than final and unalterable, and to perceive the way in which such structures are continually refined and sharpened by processes of successive approximation.

8. Comprehend the *limitations* inherent in scientific inquiry and *be aware of the kinds of questions neither asked nor answered*; be aware of the endless regression of unanswered questions that resides behind the answered ones.

9. Develop enough basic knowledge in some area (or areas) of interest to allow intelligent reading and subsequent learning without formal instruction.

10. Be aware of at least a few specific instances in which scientific knowledge has had direct impact on intellectual history and on one's own view of the nature of the universe and of the human condition within it.

11. Be aware of at least a few specific instances of interaction between science and society on moral, ethical, and sociological planes.

12. Be aware of very close analogies between certain modes of thought in natural science and in other disciplines such as history, economics, sociology, and political science; for example, forming concepts, testing hypotheses, discriminating between observation and inference (i.e., between information from a primary source and the interpretations placed on this information), constructing models, and doing hypothetico-deductive reasoning."

III. Evidence for Scientific Illiteracy (a few of many examples)

A. Table 7-4, p. 7-19, *Science and Engineering Indicators 2010* (NSB, 2010)

Correct answers to scientific literacy questions, by sex: 2008

Question	Percent Correct Male	Percent Correct Female
PHYSICAL SCIENCE		
The center of the Earth is very hot. (True)	88	80
All radioactivity is man-made. (False)	74	67
Lasers work by focusing sound waves. (False)	64	34
Electrons are smaller than atoms. (True)	59	47
The continents have been moving their location for millions of years and will continue to move. (True)	82	73
Does the Earth go around the Sun, or does the Sun go around the Earth? (Earth around Sun) *How long does it take for the Earth to go around the Sun?* (One year). Data represent composite of correct responses to both questions. Second question only asked if first question answered correctly	58	44
BIOLOGICAL SCIENCE		
It is the father's gene that decides whether the baby is a boy or a girl. (True)	53	71
Antibiotics kill viruses as well as bacteria. (False)	47	60
A doctor tells a couple that their genetic makeup means that they've got one in four chances of having a child with an inherited illness. (1) Does this mean that if their first child has the illness, the next three will not? (No); *(2) Does this mean that each of the couple's children will have the same risk of suffering from the illness?* (Yes) Data represent a composite of correct responses to both questions.	66	63
Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many of them experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug? Why is it better to test the drug in this way? (The second way because a control group is used for comparison)	37	39

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology (2001); University of Michigan, Survey of Consumer Attitudes (2004); and University of Chicago, National Opinion Research Center, General Social Survey (2006, 2008). See appendix tables 7-9 and 7-10 for factual knowledge questions. See NSB (2010) for the references.

B. "Biological design in science classrooms" [Scott & Matzke (2007)]: The abstract reads:

> "Although evolutionary biology is replete with explanations for complex biological structures, scientists concerned about evolution education have been forced to confront 'intelligent design' (ID), which rejects a natural origin for biological complexity. The content of ID is a subset of the claims made by the older 'creation science' movement.
>
> Both creationist views contend that highly complex biological adaptations and even organisms categorically cannot result from natural causes but require a supernatural creative agent. Historically, ID arose from efforts to produce a form of creationism that would be less vulnerable to legal challenges and that would not overtly rely upon biblical literalism.
>
> Scientists do not use ID to explain nature, but because it has support from outside the scientific community, ID is nonetheless contributing substantially to a long-standing assault on the integrity of science education."

C. Jerome Epstein (1997-98) in "Cognitive Development in an Integrated Mathematics and Science Program" wrote (my **emphasis**):

> "While it is now well known that large numbers of students arrive at college with large educational and cognitive deficits, many faculty and administrative colleagues are not aware **that many students lost all sense of meaning or understanding in elementary school**. . . . . .
>
> In large numbers our students . . . . . [[at Bloomfield College (NJ) and Lehman (CUNY)]]. . . . cannot order a set of fractions and decimals and cannot place them on a number line. Many do not comprehend division by a fraction and have no concrete comprehension of the process of division itself. Reading rulers where there are other than 10 subdivisions, basic operational meaning of area and volume, are pervasive difficulties.
>
> Most cannot deal with proportional reasoning nor any sort of problem that has to be translated from English. **Our diagnostic test*, which has been given now at more than a dozen institutions shows that there are such students everywhere**."

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* Teachers and researchers may obtain copies by request to Jerry Epstein <jerepst@att.net>.

D. Factoids from *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* [National Academies (2010)]:

1. Sixty-nine percent of United States public school students in fifth through eighth grade are taught mathematics by a teacher without a degree or certificate in mathematics [NCES (2003)].

2. Ninety-three percent of United States public school students in fifth through eighth grade are taught the physical sciences by a teacher without a degree or certificate in the physical sciences [NCES (2003)].

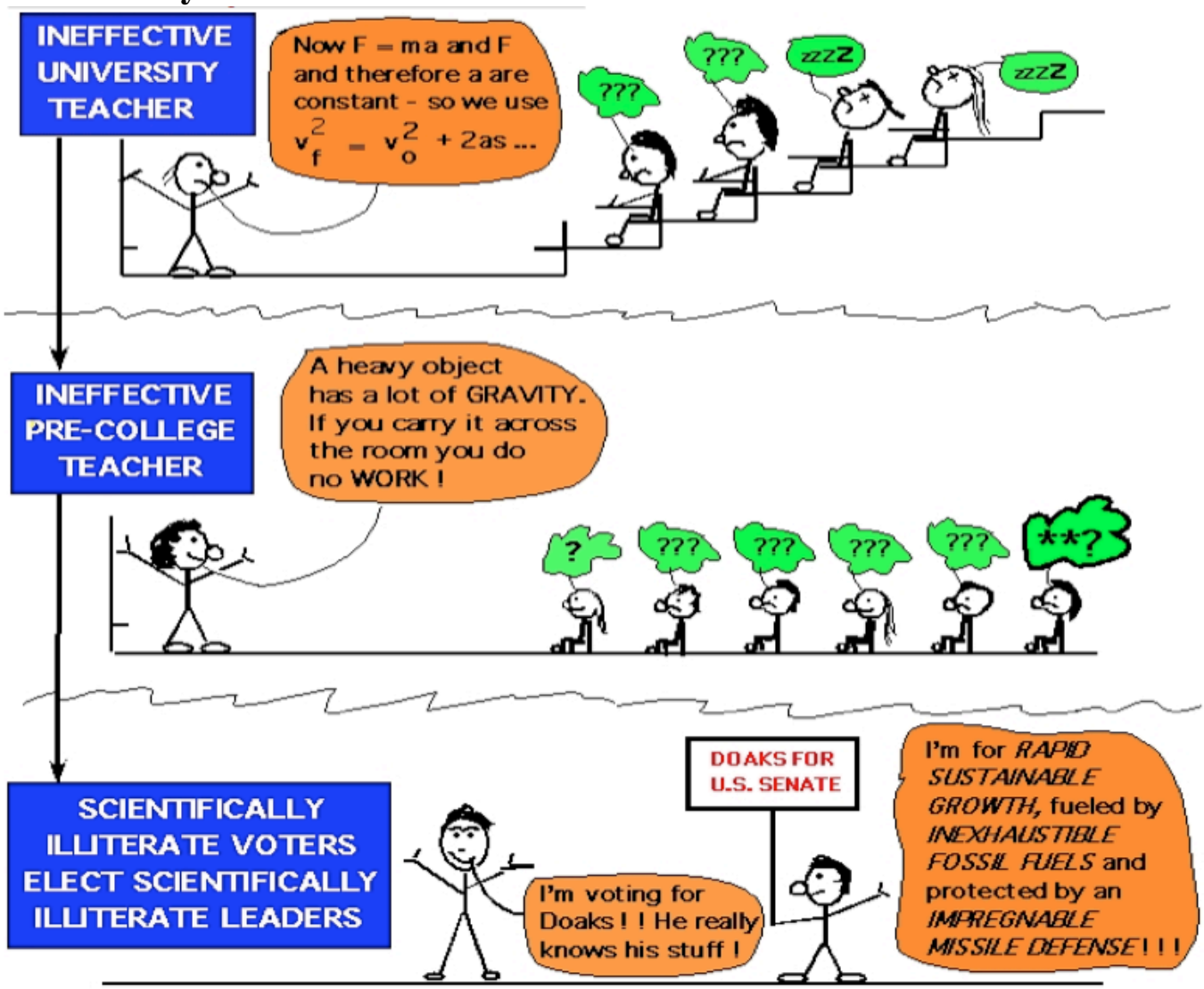
3. The United States ranks 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering [OECD (2009a).

4. The United States ranks 20th in high school completion rate among industrialized nations and 16th in college completion rate [OECD (2009b)].

5. The average American K-12 student spends four hours a day in front of a TV [McDonough (2009)].

6. Sixty-eight percent of U.S. state prison inmates are high school drop-outs or otherwise did not qualify for a diploma [Harlow (2003)].

IV. Ineffective Introductory Science Courses in the Universities Generate Scientifically Illiterate Leaders

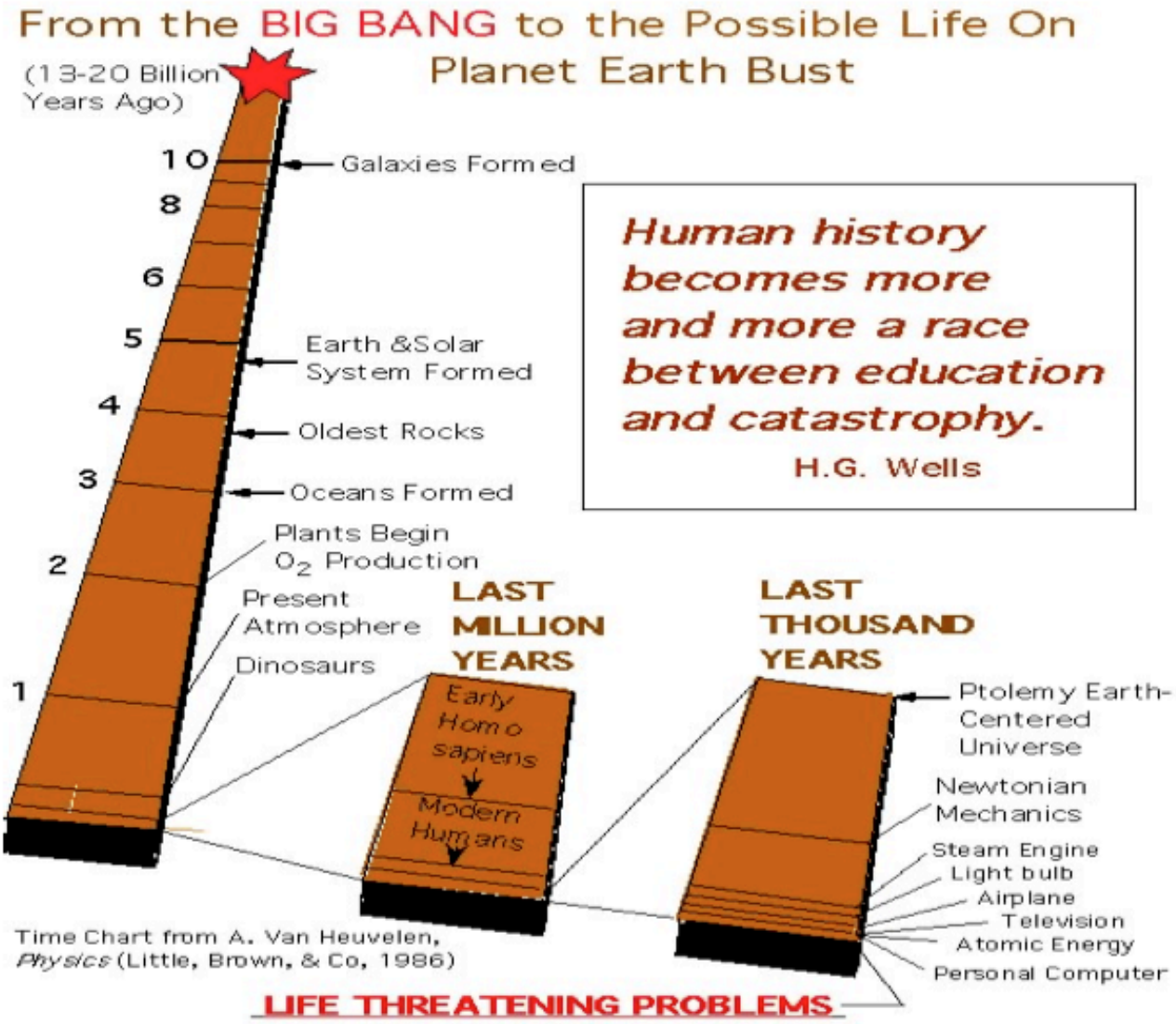


A. Larry Cuban's (2003) Take on Teachers:

"I know from both experience and research that the teacher is at the heart of student learning and school improvement by virtue of being the classroom authority and gatekeeper for change. Thus the preparation, induction, and career development of teachers remain the Archimedian lever for both short- and long-term improvement of public schools."

But the Archimedian lever requires an above-poverty-level fulcrum – see e.g., "Our Impoverished View of Educational Reform" [Berliner (2005)]; "Poverty and Potential: Out-of-School Factors and School Success [Berliner (2009)]; "Is the 'Teacher Effect' the Dominant Factor in Students' Academic Gain?" Hake (2011i,j); "Flow and diffusion of high-stakes test scores" [Marder & Bansal (2009); & "Failure of U.S. Public Secondary Schools in Mathematics: Poverty is a More Important Cause than Teacher Quality" Marder (2011)]]. . . . . .

V. Time Chart [based on a chart in *Physics: A General Introduction* [Van Heuvelen (1986)]



VI. Some Life-Threatening Science-Related Societal Problems

A. Political-Scientific (a few of many examples)

1. Overpopulation*
2. Threat of weapons of mass destruction
3. Human welfare (starvation, homelessness, unemployment, drugs, epidemics, AIDS, etc.)
4. Environment (global warming; pollution of air, water, land, food; ozone depletion; deforestation; loss of biodiversity)
5. Long-term energy crisis: man-made waste heat approaches Sun's input heat to Earth; depletion of fossil fuels
6. Third world crises
7. Superstition
8. Terrorism

B. Economic-Scientific (a few of many examples)

1. Natural resource waste (fossil fuels, forests, grasslands, rivers, ecosystems)
2. Widening gap between the rich and the poor
3. Lowering of living standards in many countries
4. Human resource waste (minorities, lower castes, women)
5. Unemployment

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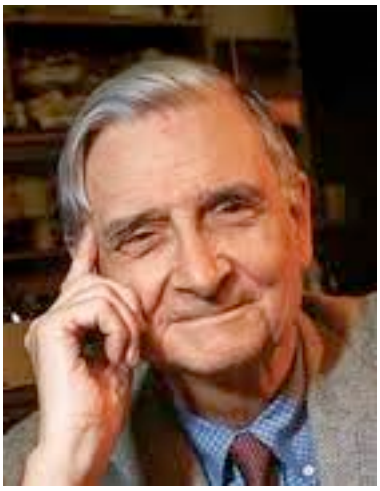
* James Duderstadt (2000) in *A University for the 21st Century* wrote: "With the world population now at 6 billion . . .[On 25 May 2011 13:48-0700 world population was 6,920,701,279 - see <http://1.usa.gov/j2u6Gw>]]. . . ., we are already consuming 40% of the world's photosynthetic energy production. Current estimates place a stable world population at about 8 to 10 billion by the late twenty-first century, assuming fertility rates continue to drop over the next several decades. Yet even at this reduced rate of population growth, we could eventually consume all of the planet's resources, unless we take action. Because of this overload of the world's resources, even today, over 1.2 billion of the world's population live below the subsistence level, and 500 million below the minimum caloric intake level necessary for life."

C. Are A Few Words From the Wise Sufficient?

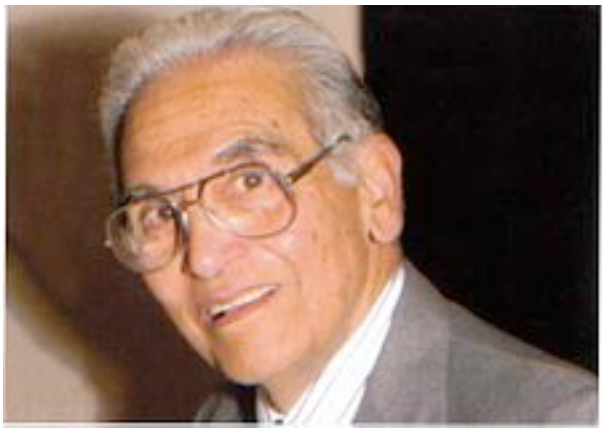
1. Edward O. Wilson <http://en.wikipedia.org/wiki/E._O._Wilson>



Wilson (1999) wrote in *Consilience: The Unity of Knowledge*:

> "The global population is precariously large, and will become much more so before peaking some time after 2050. Humanity overall is improving per capita production, health, and longevity. But it is doing so by eating up the planet's capital, including natural resources and biological diversity millions of years old.
>
> Homo sapiens is approaching the limit of its food and water supply. Unlike any species before, it is also changing the world's atmosphere and climate, lowering and polluting water tables, shrinking forests, and spreading deserts. **Most of the stress originates directly or indirectly from a handful of industrialized countries**.
>
> Their proven formulas for prosperity are being eagerly adopted by the rest of the world. The emulation cannot be sustained, not with the same levels of consumption and waste. **Even if the industrialization of the developing countries is only partially successful, the environmental aftershock will dwarf the population explosion that preceded it**."

2. Albert Baez <http://en.wikipedia.org/wiki/Albert_Baez>



Baez, pioneer in X-ray optics, father of Joan, and former Director of the Division of Science Teaching at UNESCO, wrote:

> "I believe that science and technology are extremely important because they have been the most powerful agents for social change in the history of mankind. In the process, science and technology have extended the length and improved the quality of our lives. But we must also concede that they have contributed to the deterioration of the human environment. This shows up in four of the most serious problems of our society, the **4 P's: population, pollution, poverty, and proliferation of weapons of mass destruction**.
>
> In spite of this, I claim we need more, not less, science and technology, but they must be utilized constructively. To this end I believe that **education will have to play an increasingly important role**. But it will have to be an education that generates the real basics, the **4 C's: curiosity, creativity, competence, and compassion**. There can be no science without curiosity, no technology without creativity, and no production without competence, but **without compassion they may all be used to destroy the Environment and life on Earth.**
>
> The world stands in need of an environmental ethic which, in my mind, should spring from respect and affection for all living things. Benito Juarez. . . . .[[<http://en.wikipedia.org/wiki/Benito_Juárez>]]. . . . . once said, 'El respeto al derecho ajenoes la paz,' which translates loosely into: 'Respect for the rights of others is the basis of peace.' Juarez had respect for the rights of people in mind, of course, but if we extend the concept to all living things - plants, animals, and the Earth itself - we have the basis of peace with the Earth and peace on Earth. **This, I believe, is the end toward which science and technology should be applied.**"

3. Dennis Meadows <http://en.wikipedia.org/wiki/Dennis_Meadows>

Meadows wrote (private communication of 17 November 2009 to R.R. Hake, quoted by permission):

> "The global society, and particularly the US, is like a small boatload of people about to enter a long stretch of white water and rapids.
>
> For the foreseeable future we will be totally preoccupied with immediate problems and far too distracted to develop and implement a rational long-term plan. Eventually, after climate change, fossil fuel depletion, and several other manifestations of the growth limits have produced some new sort of semi stable state, with a MUCH lower population and material standard of living, our species will hopefully be able to start identifying, choosing, and pursuing its longer term options.
>
> I do not expect to be alive when that time comes."

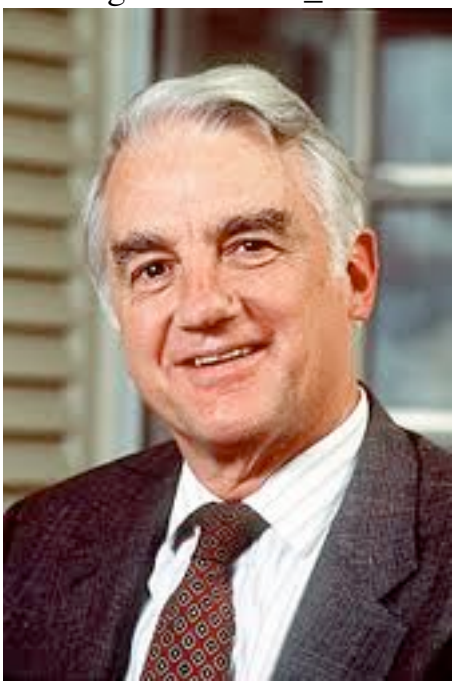
4. Rodger W. Bybee <http://www.bscs.org/about/roster/rodgerbybee.html>

In "Planet Earth in Crisis: How Should Science Educators Respond?" Bybee (1991) concludes):

> In the last half of the 20th century, environmental problems expanded from local to global prominence. Distant, early warnings such as Carson's. . .[[(1962, 2002)]]. . . *Silent Spring* have become clear and present alarms in the form of McKibben's. . .[[(2006)]]. . . book, *The End of Nature*. Problems such as global warming, ozone depletion, and acid precipitation have conspired to form a planetary crisis. The implications for change are obvious, and **the imperative for educators to respond is powerful**.
>
> The thesis of this essay is that **the lack of crucial vision of sustainability is a serious omission in contemporary science education**. Educators have responded to contemporary problems. . . .[[see e.g., "Physics educators need to become more knowledgeable about and involved in renewable energy" (Ehrlich, 2010)]]. . . . .and have perceived the need to change; they have not, however, had a clear direction for change. **Sustainable development is the proposed direction**. . . Concurrent with the clear direction, there must be policies with understandable ideas and acceptable values. Policies for curriculum and instruction that will enhance sustainable growth. . . . . .[[But see "Sustainable Growth: An Impossibility Theorem" in Daly & Townsend (1992).]]. . . . . are based on the ideas of fulfilling basic human needs, improving the environment, conserving resources, and developing a sense of community. The values suggested for a sustainable society are justice and beneficence in the distribution of goods and services for basics needs; stewardship and prudence in the human use of the environment and resources; and cooperation and mutual regard in the development of a greater sense of community among people. . . . . .
>
> If a new vision is to be developed, we must construct it through educational policies and translate an obligation to respond; the situation is urgent, **the problems are clear, the means are available, and the role of education is clear**.

VII. University Reform - Needed But Unlikely*: University Leaders Bemoan the Inertia of Higher Education: Why Is It So Slow To Recognize the Value of *Interactive Engagement* Methods in Promoting Higher-Level Learning?"

A. Derek Bok <http://en.wikipedia.org/wiki/Derek_Bok>



Bok (2005a), former president of Harvard University, wrote in "Are colleges failing?":

> ". . . studies indicate that problem-based discussion, group study, and other forms of active learning produce greater gains in critical thinking than lectures, yet the lecture format is still the standard in most college classes, especially in large universities."

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* Section VII borrows from the previous unpublished "Can Scientific Research Enhance the Art of Teaching?" [Hake (2007)].

B. James Duderstadt

<http://en.wikipedia.org/wiki/James_Johnson_Duderstadt>

Duderstadt (2000), President Emeritus and University Professor of Science and Engineering at the University of Michigan, made much the same point, writing in *A University for the 21st Century*:

> "Few faculty members have any awareness of the expanding knowledge about learning from psychology and cognitive science. Almost no one in the academy has mastered or used this knowledge base. One of my colleagues observed that if doctors used science the way college teachers do, they would still be trying to heal with leeches."

C. Richard M. Cyert <http://en.wikipedia.org/wiki/Richard_Cyert>

Cyert, former president of Carnegie Mellon University, wrote in Tuma & Reif (1980):

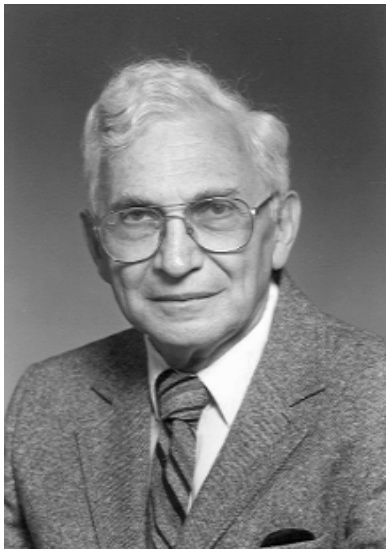
> "The academic area is one of the most difficult areas to change in our society. We continue to use the same methods of instruction, particularly lectures, that have been used for hundreds of years. Little scientific research is done to test new approaches, and little systematic attention is given to the development of new methods. Universities that study many aspects of the world ignore the educational function in which they are engaging and from which a large part of their revenues are earned."

D. Donald Kennedy <http://en.wikipedia.org/wiki/Donald_Kennedy>

Kennedy (1990), former president of Stanford University, in his "Stanford President's Address: Stanford in Its Second Century" wrote:

> "We have not been very systematic about our quest to improve teaching, even though we value it highly and frequently do well at it. I am struck, for example, by the lack of conversation about what pedagogy means, and what makes it successful. It is our profession, yet it is mysteriously absent from our professional discourse. Here we are, engaged in an activity that is vital to ourselves, our students, and our public - yet we speak of how to do it, if at all, as though it had no data base, lacked a history, and offered no innovative challenges."

E. Fred Reif



Reif (1974), a physics-education-research pioneer, in a commentary "Educational Challenges for the University" in *Science,* as relevant today as it was 37 years ago, wrote:

> "The university does not systematically encourage faculty members to turn their talents to educational endeavors; in fact such endeavors are usually regarded as being of dubious legitimacy compared to more prestigious activities. . . . educational innovations are few in number and often marginal in their impact. Nor is this situation surprising, since the university, unlike any progressive industry, is not in the habit of improving its own performance by systematic investment in innovative research and development."

VIII. Why Do We Find No Evidence for Extraterrestrial Intelligent Life? Resolution of Fermi's Paradox: "Where is Everybody?" *

A. On Earth, human understanding fails to keep pace with the exponential-in-time advances in science and technology (see Time Chart on p. 14).

B. Serious problems threaten life on planet Earth – see Sect. VI, pp. 15 -19: "Some Life-Threatening Science-Related Societal Problems."

C. I submit that similar problems arose in other societies throughout the universe at our stage of development. *University faculty in those societies, as in our own, were unconcerned with introductory science education for non-research-oriented students* and failed to take seriously the admonitions of their more astute leaders – see Sect. VII, pp. 20-24 "University Reform - Needed But Unlikely."

D. The resultant dearth of competent pre-college science/math teachers led to science illiteracy similar to ours, the election or acceptance of scientifically illiterate leaders – see Sect. IV, p. 13: "Ineffective Introductory Science Courses in the Universities Generate Scientifically Illiterate Leaders" - **consequent failure to solve life-threatening problems, and subsequent destruction of those societie**s.

E. I conjecture that the above accounts for our failure to detect any evidence of extraterrestrial intelligent life (Drake Eq.: N ≈ L/40*) . . . . . QED

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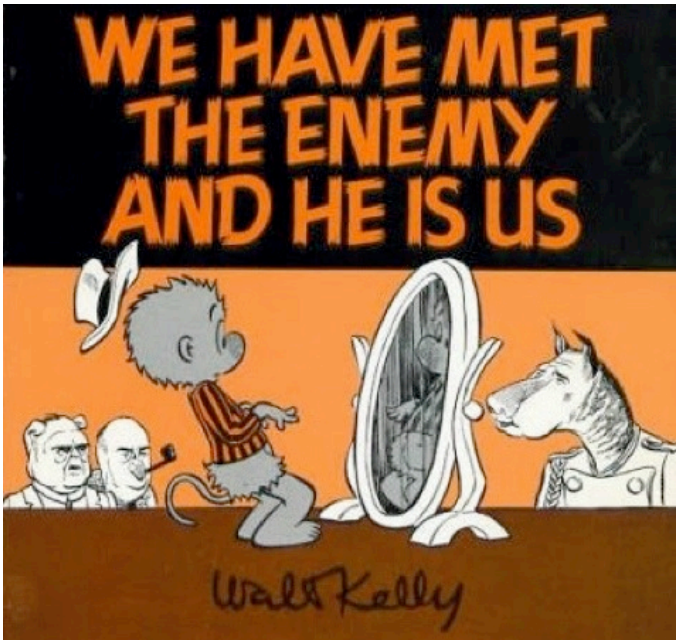
* For previous similar resolutions of "Fermi's Paradox" see Sect. 5.1.2 "It is the nature of intelligent life to destroy itself" at <http://en.wikipedia.org/wiki/Fermi_paradox>.

**Goldsmith & Owen (2001, p. 450): "When we multiply all the factors . . . .[[in the Drake Equation]]. . . .together, we find that the result for the number N of intelligent civilizations in our galaxy now with communication ability and desire equals L/40, where L is the lifetime, measured in years of a civilization once it has developed the ability and desire to communicate with others."



"US" = University Faculty !!

Q. Should the Culture of University Science Education Be Changed?

References [All URL's accessed on 20-25 May 2011; some shortened by <http://bit.ly/>.]

Anderson, W.A., U. Banerjee, C.L. Drennan, S.C.R. Elgin, I.R. Epstein, J. Handelsman, G.F. Hatfull, R. Losick, D.K. O'Dowd, B.M. Olivera, S.A. Strobel, G.C. Walker, I.M. Warner. 2011. "Changing the Culture of Science Education at Research Universities: Universities must better recognize, reward, and support the efforts of researchers who are also excellent and dedicated teachers," *Science*, 14 January, **331**(6014): 152-153: (a) online to subscribers at <http://bit.ly/kmngAx>; (b) an abstract is free to all at <http://bit.ly/jcOuNh>; (c) as of 18 May 2011, the entire article was free to all as a 172 kB pdf at <http://bit.ly/eSLoCl>; (d) supporting online references suggested by R.R. Hake on 11 January 2011 are at <http://bit.ly/g24Iqm> [over 75 references and 90 hot links relevant to (1) Undergraduate Education Reform, and (2) Biology Education Reform]. See also *Harvard Magazine* (2011) and *Science Daily* (2011).

Arons, A.B. 1997. *Teaching Introductory Physics*. Wiley, publisher's information at <http://bit.ly/jBcyBU>. Amazon.com information at <http://amzn.to/bBPfop>. Note the searchable "Look Inside" feature. For an appreciation of the late Aronold Arons see "The Arons Advocated Method" [Hake (2004)].

Baez, A. 1990. "Education's 4 C's vs Society's 4 P's," *Hispanic Engineer*, Winter.

Bok, D. 2005a. "Are colleges failing? Higher ed needs new lesson plans," *Boston Globe*, 18 December, online at <http://bo.st/ffRQFa>. Copied into the APPENDIX of Hake (2005). See also Bok (2005b).

Berliner, D.C. 2005. "Our Impoverished View of Educational Reform," Teachers College Record, August 02, online as an 872 kB pdf at <http://bit.ly/ff8BVj>.

Berliner, D.C. 2009. "Poverty and Potential: Out-of-School Factors and School Success," online as a 729 kB pdf at <http://bit.ly/fqiCUA>

Bok, D. 2005b. *Our Underachieving Colleges: A Candid Look at How Much Students Learn and Why They Should Be Learning More*. Princeton University Press - information including the preface and Chapter 1 is online at <http://press.princeton.edu/titles/8125.html>. Amazon.com information is at <http://amzn.to/kXOKbF>, note the searchable "Look Inside" feature. See especially pages 115-116 on the research of Halloun & Hestenes (1985a,b) and pages 132-134 on the work of Eric Mazur (1997, 2009). Bok is one of the few administrators in higher education who is aware of the pioneering education research and development that's been going on in physics.

Bybee, R.W. 1991. "Planet Earth in Crisis: How Should Science Educators Respond?" *The American Biology Teacher* **53**(3): 146-153; the first page is online at <http://bit.ly/l9iQTw>.

Carson, R. 2002. *Silent Spring* - with an introduction by Linda Lear and an afterword by Edward O. Wilson. Mariner Books. Amazon.com information at <http://amzn.to/kdCeAV>, note the searchable "Look Inside" feature. According to <http://en.wikipedia.org/wiki/Rachel_Carson> this book was first published in 1962.

Crouch, C.H. & E. Mazur. 2001. "Peer Instruction: Ten years of experience and results," *Am. J. Phys.* **69**(9): 970-977; online at <http://bit.ly/ac5Gcn>.

Cuban, L. 2003. "Why Is It So Hard To Get Good Schools?" Teachers College Press, publisher's information at <http://bit.ly/gSn3P2>. Amazon.com information at <http://amzn.to/j0eIiz>, note the searchable "Look Inside" feature.

Daly, H.E. 1997. *Beyond Growth: The Economics of Sustainable Development*. Beacon Press; publisher's information at <http://bit.ly/jaOyy0>. Amazon.com information at <http://amzn.to/mLv8v4 >. A searchable Google book preview is online at <http://bit.ly/kbzXvg>. For a good review see Hobson (1999). See also Daly (2008).

Daly, H.E. 2008. "A Steady-State Economy: A failed growth economy and a steady-state economy are not the same thing; they are the very different alternatives we face," Sustainable Development Commission, UK, April 24; online as a 136 kB pdf at <http://bit.ly/kGFpKw>.

Daly, H.E. & K.N. Townsend, eds. 1992. *Valuing The Earth: Economics, Ecology, Ethics*. MIT Press, publisher's information at <http://bit.ly/jmoZGN>. Amazon.com information at <http://amzn.to/kVZVTM >. Note the searchable "Look Inside" feature. Pages 267-274 "Sustainable Growth: An Impossibility Theorem" are online at <http://dieoff.org/page37.htm>; therein it is stated: "In its physical dimensions the economy is an open subsystem of the earth ecosystem, which is finite, nongrowing, and materially closed. As the economic subsystem grows it incorporates an ever greater proportion of the total ecosystem into itself and must reach a limit at 100 percent, if not before. Therefore its growth is not sustainable. The term 'sustainable growth' when applied to the economy is a bad oxymoron—self-contradictory as prose, and unevocative as poetry." See also Daly (1997, 2008).

Dancy, M. & C. Henderson. 2010. "Pedagogical practices and instructional change of physics faculty." *Am. J. Phys*. **78**(10): 1056-1063; online as a 426 kB pdf at <http://bit.ly/9b4rX1>. The authors wrote: ". . . . self-reports of actual classroom practices indicate that the availability of . . .[physics education research curricula and pedagogies]. . . has not led to fundamental changes in instruction. . . [suggesting]. . . a need for research-based dissemination that accounts for the complexity of instructional change." In this regard see Fairweather (2008).

Duderstadt, J.J. 2000. *A University for the 21st Century*. Univ. of Michigan Press; for a description see <http://bit.ly/cvJ1yI>. Amazon.com information at <http://amzn.to/lxT8YU>, note the searchable "Look Inside" feature. See also Duderstadt (2001, 2005); & Duderstadt et al. (2005).

Duderstadt, J. J. 2001. "Science policy for the next 50 years: from guns to pills to brains," in *Proceedings of the AAAS Annual Meeting*, San Francisco, February; online as a 365 kB pdf at <http://bit.ly/kuo1gZ>.

Duderstadt, J. J. 2005. "The Future of the University: A Perspective from the Oort Cloud," Emory University Futures Forum, Atlanta, GA, 8 March; online as a 262 kB pdf at <http://bit.ly/jard4H>. For "Oort Cloud" see <http://en.wikipedia.org/wiki/Oort_cloud>.

Duderstadt, J., W.A. Wulf, & R. Zemsky. 2005. "Envisioning a Transformed University," *Issues in Science and Technology* **22**(1): 35-41. National Academy Press; online at <http://bit.ly/kwh1Eb>.

Elton, L. 2004. "Could undergraduate physics teaching be better?" The Pantaneto Forum, Issue 16, October, online at <http://bit.ly/lIpgTc>.

ERIC. 2011. Education Resources Information Center; online at <http://www.eric.ed.gov/>.

Ehrlich, R. 2010. "Physics educators need to become more knowledgeable about and involved in renewable energy," *Phys. Teach.* **48**(2): 86-87; online to subscribers at <http://bit.ly/ltztkS>. According to Ehrlich (2010) and information at <http://mason.gmu.edu/~rehrlich/>, Ehrlich's current interest is in "promoting renewable energy education in the U.S. . . [and he has]. . . recently created a web site <http://rev-up.org> for this purpose."

Fairweather, J. 2008. "Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education: A Status Report for The National Academies National Research Council Board of Science Education," online at <http://bit.ly/ePTL0W>. According to Labov et al. (2009) Fairweather "was asked to review and synthesize all of the additional articles submitted for the October workshop. . . .[[see National Academies (2008)]]. . . . . Fairweather wrote: "NSF- and association-funded reforms at the classroom level, however well intentioned, have not led to the hoped for magnitude of change in student learning, retention in the major, and the like *in spite of empirical evidence of effectiveness*. . . . . .[[*italics* in the original]]. . . Among the most important elements of a successful change strategy to promote the improvement of undergraduate STEM education. . . [[is recognizing]]. . . that more effort needs to be expended on strategies to promote the adoption and implementation of STEM reforms rather than on assessing the outcomes of these reforms. Additional research can be useful but the problem in STEM education lies less in not knowing what works and more in getting people to use proven techniques." The difficulty of "getting people to use proven techniques" has been emphasized by Dancy & Henderson (2010).

Goldsmith, D. & T. Owen. 2001. *The Search for Life in the Universe*. Addison Wesley, 3rd edition. Amazon.com information at <http://amzn.to/ij9jKj>, note the searchable "Look Inside" feature.

Hake, R.R. 1998a. "Interactive-engagement vs traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.* **66**(1): 64-74; online as an 84 kB pdf at <http://bit.ly/d16ne6>.

Hake, R.R. 1998b. "Interactive-engagement methods in introductory mechanics courses," online as a 108 kB pdf at <http://bit.ly/aH2JQN>. A crucial companion paper to Hake (1998a). Rejected **:-(** by a confused AJP editor who thought the very transparent, crystal clear, and well-organized Physical-Review-type data tables were "impenetrable" !!

Hake, R.R. 2000. "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University," *AAPT Announcer* **30**(2): 105; online as a 2.1 MB pdf at <http://bit.ly/9LxKOL>.

Hake, R.R. 2004. "The Arons Advocated Method," submitted to the *American Journal of Physics* on 24 April 2004, but rejected by an editor who evidently believed a referee who erroneously claimed that *Arons did no physics education research* ! (did ethnographer Margaret Mead <http://bit.ly/eSQat5> do no anthropological research?); online as a 144 kB pdf at <http://bit.ly/boeQQt>.

Hake, R.R. 2005. "Are colleges failing?" AERA-L post of 19 Dec 2005 17:54:37-0800; online at <http://bit.ly/erBRGN>.

Hake, R.R. 2009. " 'The Threat to Life on Planet Earth' Is a More Important Issue Than David Brooks' 'Skills Slowdown', " online on my blog "Hake'sEdStuff at <http://bit.ly/cj2zUS> with a provision for comments.

Hake, R.R. 2010a. "Re: Confessions of a Converted Lecturer," online on the OPEN! AERA-L archives at <http://bit.ly/juDixO>. Post of 16 March 2010 to various discussion lists. This post was transmitted to various discussion lists and is and is also on my blog "Hake'sEdStuff" at <http://bit.ly/gXmkaT> with a provision for comments. I give: (a) 8 references to commentary critical of the passive-student lecture - staple of U.S. higher education, and 2 references to commentary which seems to be lecture-friendly.

Hake, R.R. 2010b. "Re: Confessions of a Converted Lecturer #5,"online on the OPEN! AERA-L archives at <http://bit.ly/e6hH2w>. Post of 21 Mar 2010 11:35:39-0700 to to AERA-L, Net-Gold, and PBL. The abstract and link to the complete post were transmitted to various discussion lists and are also on my blog "Hake'sEdStuff" at <http://bit.ly/cCOEJ8>. Here I attempt to remedy the perceived neglect of UK physicist Lewis Elton's contributions by quoting extensively from his article "Could undergraduate physics teaching be better?" [Elton (2004)].

Hake, R.R. 2010d. "Education Research Employing Operational Definitions Can Enhance the Teaching Art," online as a 3.8 MB pdf at <http://bit.ly/aGlkjm>, invited talk, AAPT Portland Meeting, 19 July.

Hake, R.R. 2011a. "Changing the Culture of Science Education at Research Universities," online on the OPEN! AERA-L archives at <http://bit.ly/eqw6ow>. Post of 4 Mar 2011 08:04:14-0800 to AERA-L, Net-Gold, and PhysLrnR. The abstract and link to the complete post were transmitted to various discussion lists and are also online on my blog "Hake'sEdStuff" at <http://bit.ly/hnkAuJ> with a provision for comments. See also Hake (2011b,c).

Hake, R.R. 2011b. "Changing the Culture of Science Education at Research Universities #2" AERA-L post of 6 Mar 2011 15:16:50 -0800; online at <http://bit.ly/ji9Pod>. Response to Math-Teach's Robert Hansen wrote: "If you want to fix education you don't start at the end . . . . .You start at the beginning."

Hake, R.R. 2011c. "Changing the Culture of Science Education at Research Universities #3," online on the OPEN! AERA-L archives at <http://bit.ly/gSNTGi> Post of 12 Mar 2011 16:53:33-0800 to AERA-L & Net-Gold. The abstract and link to the complete post were transmitted to various discussion lists and are also online on my blog "Hake'sEdStuff" at <http://bit.ly/hmX5GL> with a provision for comments. Response to PhysLrnR's Bill Goffe who wrote (paraphrasing): "I agree that teaching should be more valued, but economists Martin & Gillen (M&G) (2011). . . .[[in " 'Holy Grail' of Reform"]]. . . . do a nice job in explaining why this seems unlikely in the near future."

Hake, R.R. 2011d. "Culture of Science Education - Response to Woods," online on the OPEN! AERA-L archives at <http://bit.ly/fetCy6>. Post of 14 Mar 2011 15:30:33-0700 to AERA-L & Net-Gold. The abstract and link to the complete post were transmitted to various discussion lists and are also online on my blog "Hake'sEdStuff" at <http://bit.ly/eTbDlk> with a provision for comments. Don Woods wrote (paraphrasing): ". . . . . by my latest count there are at least 20 valid forms of evidence that can be used for measuring teaching 'productivity.' These include Concept Inventories . . . . . as well as a well-designed **course evaluations**, ... exams and assignments,. . . . . More details are given in my forthcoming book *Motivating and Rewarding University Teachers to Improve Student Learning: A Guide for Faculty and Administrators*"[Woods (2011)]. For another post stimulated by Woods' comments see "SET's Are Not Valid Gauges of Students' Higher-Level Learning #2" [Hake (2011g)].

Hake, R.R. 2011f. "Should the Culture of University Science Education Be Changed?" Invited talk, Southern California Section of the AAPT, 14 May 2011, Pierce College, soon to be online at <http://bit.ly/b2UsK6>.

Hake, R.R. 2011g. "SET's Are Not Valid Gauges of Students' Higher-Level Learning #2," online on the OPEN! AERA-L archives at <http://bit.ly/jLZaz5>. Post of 17 May 2011 09:47:36-0700 to AERA-L and Net-Gold. The abstract and link to the complete post were distributed to various discussion lists and are also on my blog "Hake'sEdStuff? at <http://bit.ly/ixcQxs>. Stimulated by Woods' statement that SET's could be used for measuring teaching "productivity."

Hake, R.R. 2011h. "Helping Students to Think Like Scientists in Socratic Dialogue Inducing Labs," summarily rejected **:-(** by the editors of the 2010 Physics Education Research Conference, but accepted for publication in *The Physics Teacher* - scheduled to appear in a Fall 2011 issue; online as a 446 kB pdf at <http://bit.ly/99yb7p>.

Hake, R.R. 2011i. "Is the 'Teacher Effect' the Dominant Factor in Students' Academic Gain?" online on the OPEN! AERA-L archives at <http://bit.ly/g6UWUZ>. Post of 7 Apr 2011 17:51:59-0700 to AERA-L and Net-Gold. The abstract and link to the complete post were transmitted to various discussion lists and are also on my blog "Hake'sEdStuff" at <http://bit.ly/ifvkSz>.

Hake, R.R. 2011j. "Is the 'Teacher Effect' the Dominant Factor in Students' Academic Gain? #3" online on the OPEN! AERA-L archives at <http://bit.ly/jy61UB>. Post of 3 May 2011 13:02:37 -0700. The abstract and link to the complete post were transmitted to various discussion lists and are also on my blog "Hake'sEdStuff" at <http://bit.ly/k1HsRH> with a provision for comments.

Halloun, I. & D. Hestenes. 1985a. "The initial knowledge state of college physics students," *Am. J. Phys.* **53**(11): 1043-1055 (1985); online at <http://bit.ly/b1488v>. Scroll down to "Evaluation Instruments."

Halloun, I. & D. Hestenes. 1985b. "Common sense concepts about motion." *Am. J. Phys.* **53**(11): 1056-1065; online at <http://bit.ly/b1488v>.

Handelsman, J., S. Miller, & C. Pfund, 2007. *Scientific Teaching*, Freeman, publisher's information at <http://bit.ly/kXayhF>. Amazon.com information at <http://amzn.to/aKssNI>. For some physics-oriented counterparts to this biology-oriented book see, e.g., (a) *Teaching Introductory Physics* [Arons (1997)]; (b) *Peer Instruction: A User's Manual* [Mazur (1997]; (c) *Teaching Physics With the Physics Suite* [Redish (2003)]; and (d) *Applying Cognitive Science to Education* [Reif (2008)].

Harlow, C. 2003. "Educational and Correctional Populations, Bureau of Justice Statistics Special Report," January; online as a 299 kB pdf at <http://bit.ly/kpu5u6>.

Harvard Magazine. 2011. "Tackling Teaching and Learning," May/June; online at <http://bit.ly/frK2Ot>. Scroll down about half way to read a section beginning ". . . there are individual champions of innovative teaching. Cabot professor of biology Richard M. Losick, who is also head tutor in molecular and cellular biology, has been funded by the Howard Hughes Medical Institute (HHMI) to enhance science education."

HHMI News. 2010a. "HHMI Professors," 20 May; online at <http://bit.ly/alXrgy> - contains photos and thumb-nail bios of the authors of Anderson et al. (2011).

HHMI News. 2010b. "Awards $79 Million for Science Education to Research Universities, Top Scientists," online at <http://bit.ly/cJcs9t>.

Hobson, A. 1999. Review of Daly (1997), *APS Forum on Physics and Society Newsletter* **28**(2), 2 April; online at <http://bit.ly/l9NilX>.

Kennedy, D. 1999. *Academic Duty*. Harvard University Press, publisher's information at <http://bit.ly/edBogg>. Amazon.com information at <http://amzn.to/hbeAsp>, note the "Look Inside" feature. An expurgated Google book preview is online at <http://bit.ly/hmuC5R>.

Labov, J.B., S.R. Singer, M.D. George, H.A. Schweingruber, & M.L. Hilton. 2009. "Effective Practices in Undergraduate STEM Education Part 1: Examining the Evidence," *CBE Life Sci Educ* **8**(3): 157-161; online at <http://bit.ly/cRc0JC>. This is a discussion of the "Workshop on Linking Evidence and Promising Practices in STEM Undergraduate Education" [National Academies (2008)].

Lasry, N., E. Mazur, & J. Watkins. 2008. "Peer instruction: From Harvard to the two-year college," *Am. J. Phys*. **76**(11): 1066-1069; online at <http://bit.ly/ac5Gcn>.

Marder, M. & D. Bansal. 2009. "Flow and diffusion of high-stakes test scores," Proceedings of the National Academy of Sciences 106 (41): 17267-17270, 13 October; online at <http://bit.ly/hYbbLe>.

Marder, M. 2011. "Failure of U.S. Public Secondary Schools in Mathematics: Poverty is a More Important Cause than Teacher Quality," to be submitted, online as a 3.3 MB pdf at <http://bit.ly/fjUquC>. See also Marder & Bansal (2009) and Marder (2010).

Martin, R. & A. Gillen. 2011. " 'Holy Grail' of Reform" *Inside Higher Ed*, 28 January; online at <http://bit.ly/h1NTd6>. Economists Martin & Gillen write: "The 'holy grail' of higher education reform should be the creation of a market for exceptional college teachers. The vigorous market for scholars provides the keys to this project. . . . . The key requirement is a mechanism for excellent teachers to establish their reputations independently of those who have a vested interest in the outcome."

Mazur, E. 1997. *Peer Instruction: A User's Manual*, Prentice Hall, publisher's information at <http://bit.ly/iVnt9n>. Amazon.com information at <http://amzn.to/mDisqM>. Compadre information at <http://bit.ly/bygvAd>. See also the last entry at <http://bit.ly/ac5Gcn>.

Mazur, E. 2009. "Confessions of a Converted Lecturer" talk at the University of Maryland on 11 November 2009. That talk is now on UTube at <http://bit.ly/dBYsXh>, and the abstract, slides, and references - sometimes obscured in the UTube talk - are at <http://bit.ly/9qzDIq> as a 4 MB pdf. As of 20 May 2011 09:25-0700 Eric's talk had been viewed 37,642 times. In contrast, serious articles in the education literature (and even essays such as this one) are often read only by the author and a few cloistered specialists, creating tsunamis in educational practice equivalent to those produced by a pebble dropped into the Pacific Ocean. See also Hake (2010a,b).

McDonough, P. 2009. "TV Viewing Among Kids at an Eight-Year High, Nielsen Wire, October; online at <http://bit.ly/mrS7s0>

McKibben, B. 2006. *The End of Nature*. Random House. Amazon.com information at <http://amzn.to/ixXLRI>. A more recent book is McKibben (2011).

McKibben, B. 2011. "*Eaarth: Making a Life on a Tough New Planet*. St. Martin's Griffin. Amazon.com information at <http://amzn.to/lOK2MV>. McKibben website information at <http://bit.ly/kOOL3l>

Merlot. 2011. Multimedia Educational Resource for Learning and Online Teaching; online at <http://www.merlot.org/merlot/index.htm>.

National Academies. 2007. Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future*, National Academies Press; online at <http://books.nap.edu/catalog/11463.html>. See also the update, National Academies (2010).

National Academies. 2008. "Evidence on Promising Practices in Undergraduate Science, Technology, Engineering, and Mathematics (STEM) Education: Workshop on Linking Evidence and Promising Practices in STEM Undergraduate Education," online at <http://bit.ly/fAhNpA>: Meeting 1 of 30 June, online at <http://bit.ly/ciNwjQ>; Meeting 2 of 13-14 October containing commissioned papers online at <http://bit.ly/ceg1Bx>. See also the commentary on these workshops by Labov et al. (2009).

National Academies. 2010. Committee on Science, Engineering, and Public Policy, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, National Academies Press; online at <http://www.nap.edu/catalog.php?record_id=12999>. The description reads [My **emphasis**]:

> "In the face of so many daunting near-term challenges, U.S. government and industry are letting the **crucial strategic issues of U.S. competitiveness** slip below the surface. Five years ago, the National Academies prepared *Rising Above the Gathering Storm*, a book that cautioned: "Without a renewed effort to bolster the foundations of our competitiveness, we can expect to lose our privileged position."
>
> Since that time we find ourselves in a country where much has changed--and a great deal has not changed. So where *does* America stand relative to its position of five years ago when the *Gathering Storm* book was prepared? The unanimous view of the authors is that our nation's outlook has worsened. The present volume, *Rising Above the Gathering Storm, Revisited*, explores the tipping point America now faces. **Addressing America's competitiveness challenge will require many years if not decades**; however, the requisite federal funding of much of that effort is about to terminate.

Rising Above the Gathering Storm, Revisited provides a snapshot of the work of the government and the private sector in the past five years, analyzing how the original recommendations have or have not been acted upon, what consequences this may have on future competitiveness, and priorities going forward. In addition, readers will find a series of thought- and discussion-provoking factoids. . . .[[see e.g., Section IIID of this essay]]]. . . . - many of them alarming--about the state of science and innovation in America.

Rising Above the Gathering Storm, Revisited is a wake-up call. To reverse the foreboding outlook will require a sustained commitment by both individual citizens and government officials--at all levels. This book, together with the original *Gathering Storm* volume, provides the roadmap to meet that goal. While this book is essential for policy makers, **anyone concerned with the future of innovation, competitiveness, and the standard of living in the United States will find this book an ideal tool** for engaging their government representatives, peers, and community about this momentous issue."

In (a) the present talk, (b) "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University" [Hake (2000)], and (c) " 'The Threat to Life on Planet Earth' Is a More Important Issue Than David Brooks' 'Skills Slowdown' " [Hake (2009)], **I suggest that there may be even more crucial strategic reasons than "U.S. competitiveness" for addressing the deficiencies of U.S. education.**

NCES. 2003. National Center for Education Statistics, "Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-1988 and 1999-2000"; online as a 586 KB pdf at <http://1.usa.gov/mSJhwR>.

NSB. 2010. National Science Board, *Science and Engineering Indicators 2010,* online as a 12.4 MB pdf at <http://1.usa.gov/kOGlcG>.

OECD. 2009a. Organization for Economic Cooperation and Development, "Education at a Glance 2009: OECD Indicators"; online as a 4.6 MB pdf at <http://bit.ly/isMkuP>, Table A-3.5.

OECD. 2009b. Organization for Economic Cooperation and Development, "Education at a Glance 2009: OECD Indicators"; online as a 4.6 MB pdf at <http://bit.ly/isMkuP>. Rankings include OECD members and partners, and college graduation ranking is based on Tertiary-A institutions. See: Tables A2.1 and A3.1.

Redish, E.F. 2003. *Teaching Physics With the Physics Suite* (TPWPS), John Wiley, publisher's information at <http://bit.ly/jxFJsz>. Amazon.com information at <http://amzn.to/klXd38>. TPWPS is online at <http://www2.physics.umd.edu/~redish/Book/>. Note the crucial correction of Fig. 5.2 and its caption on page 100.

Reif, F. 1974. "Educational Challenges for the University: Significant educational progress and innovation require superior talent and a changed university role, *Science* **184**(4136): 537-542; the first page is online at <http://bit.ly/mzceXA>. See also Reif (2008).

Reif, F. 2008. *Applying Cognitive Science to Education: Thinking and Learning in Scientific and Other Complex Domains*. The MIT Press, publisher's information at <http://bit.ly/mnYkbY>. Amazon.com information on the 2010 paperback edition is at <http://amzn.to/lL1hqQ>, note the searchable "Look Inside" feature. The preface is online as a 70 kB pdf at <http://bit.ly/mdPCaD>.

Science Daily. 2011. “Academics Urge Universities to Change Culture to Value Teaching as Highly as Research,” online at <http://bit.ly/eJYce5>.

Scott, E.C. & N.J. Matzke. 2007. “Biological design in science classrooms,” National Academy of Sciences of the USA; an abstract is online at <http://bit.ly/izNMEc>. A 1.0 MB pdf is online at <http://bit.ly/jz6XDN>.

Tuma, D.T. & F. Reif, eds. 1980. *Problem Solving and Education: Issues in Teaching and Research*, Lawrence Erlbaum. Amazon.com information at <http://amzn.to/jcAK2d>.

Van Heuvelen, A. 1986. *Physics: A General Introduction*, Scott Foresman. Amazon.com information at <http://amzn.to/jzpPKi>.

Wieman, C. 2007. “Why Not Try a Scientific Approach to Science Education?” *Change Magazine*, September/October; online as a 804 kB pdf at <http://bit.ly/anTMfF>. See also Wieman & Perkins (2005).

Wieman, C. & K. Perkins. 2005. "Transforming Physics Education," *Phys. Today* **58**(11): 36-41; online as a 292 kB pdf at <http://bit.ly/9DRJ6l>.

Wilson, E.O. 1999. *Consilience: The Unity of Knowledge*. Vintage Press. Amazon.com information at <http://amzn.to/eUcec3>. Note the searchable “Look Inside” feature. See also Wilson (2003).

Wilson, E.O. 2003. *The Future of Life*. Vintage Press. Amazon.com information at <http://amzn.to/h7jzRb>. Note the searchable “Look Inside” feature.

Wood, W.B. 2009. “Innovations in teaching undergraduate biology and why we need them.” *Annual. Rev. Cell Dev. Biol.* **25**: 93-112; online at <http://bit.ly/9IRDGp>.

Woods, D.R. 2011. *Motivating and Rewarding University Teachers to Improve Student Learning: A Guide for Faculty and Administrators*," City University of Hong Kong Press, ordering information at eurospanbookstore.com <http://bit.ly/geXRc5>, wherein the publication date is given as 15 Jun 2011.