The General Population's Ignorance of Science-Related Societal Issues: A Challenge for the University * ‡ ◊

Richard R. Hake; Physics Dept., Indiana University;
<rrhake@earthlink.net>, <http://www.physics.indiana.edu/~hake>

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*Partially supported by NSF Grant DUE/MDR-9253965.

‡ The reference is: R.R. Hake, "The General Population's Ignorance of Science Related Societal Issues: A Challenge for the University," *AAPT Announcer* **30**(2), 105 (2000); on the web at **< http://www.physics.indiana.edu/~hake/ >**. (Note that hot linked URL's are in **< bold blue >).**

◊ Based on R.R. Hake, *The Science Illiteracy Crisis: A Challenge for The University*, a libretto for a Wagnerian musical drama to be presented under the stars in the open-air Santa Fe Opera Theater, **< http://www.santafeopera.org/ >**: an annotated interweaving of classic themes and original work, unpublished, 1989. The leitmotiv: "The road to U.S. science literacy begins with effective university science courses for pre-college teachers."

OUTLINE

I. Introduction: The Cosmic Connection

A. Extraterrestrials: Fermi asked "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

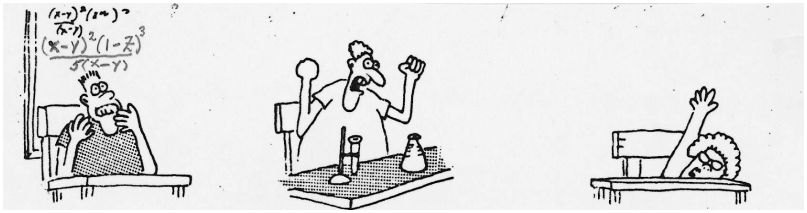
*See e.g., D. Goldsmith & T. Owen, *The Search for Life in the Universe* (Addison Wesley, 1992).

B. I Shall Argue in the Affirmative:

Be It Resolved That: There's no evidence for extraterrestrial intelligent life because:

UNIVERSITIES *THROUGHOUT THE UNIVERSE* HAVE FAILED TO PROVIDE EFFECTIVE INTRODUCTORY SCIENCE/MATH COURSES

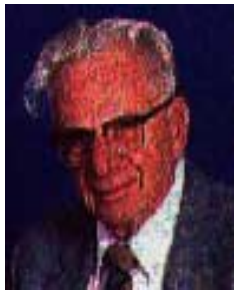
Throughout the Universe there exits:



From Gary Larsen

Math Anxiety *Chemistry Conniptions* *Physics Floundering*

II. What is Science Literacy?: Arons's Twelve Hallmarks [Quoting A.B. Arons, *A Guide To Introductory Physics Teaching* (Wiley, 1990), Chapter 12, "Achieving Wider Scientific Literacy."]



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 term require careful ***operational*** definition, 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*. (My ***bold italics***.)
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."* (My *italics*.)

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. (My *italics*.)

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. (My *italics*.)

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. ***Science and Engineering Indicators*** (NSF, 1998), Chap. 7, "Science and Technology"; on the web at **< http://www.nsf.gov/sbe/srs/seind98/start.htm >**:

"..... it appears that only 11 percent of Americans can define the term 'molecule.' …. A large proportion of the population knows that a molecule is a small piece of matter, but is unable to relate it to an atom or a cell, which are also small pieces of matter. And, despite substantial media attention to deep space probes and pictures from the Hubble Space Telescope, only 48 percent of Americans know that the earth goes around the sun once each year….. ***Only 27 percent of Americans understand the nature of scientific inquiry well enough to be able to make informed judgments about the scientific basis of results reported in the media***. Public understanding of the nature of scientific inquiry was measured through questions about the meaning of scientific study and the reasons for the use of control groups in experiments." (My *italics*.)

B. Eugenie C. Scott, "Not (Just) in Kansas Anymore," *Science* **228**, 813-815 (2000); on the web at **< http://www.sciencemag.org/cgi/content/full/288/5467/813 >**:

"In August of 1999, after months of wrangling, the Kansas State Board of Education passed its state science education standards. Against the recommendations of a committee of 27 scientists and teachers, the board voted to strip from the standards all mention of the Big Bang, the age of the Earth, and any reference to organisms having descended from the same ancestors: in other words evolutionary astronomy, geology, and biology. Teachers were informed that evolution would not be included in the state high-school assessment exams, greatly decreasing the likelihood that the subject would be taught…….. As the media probed for more stories, the National Center for Science Education (where I work…… **< http://www.natcenscied.org/ >** ……..) informed the sometimes incredulous press that, yes, indeed, *antievolutionism is a widespread problem in American kindergarten through high school or 'K-12' education.*" (My *italics*.)

C. Jerome Epstein, "Cognitive Development in an Integrated Mathematics and Science Program," *J. of College Science Teaching*, 12/97 & 1/98, pp. 194-201:

"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****…..****(even Wellesley****!* - see J. Epstein, "What is the Real Level of Our Students," 1999, unpublished). (My *italics*.)

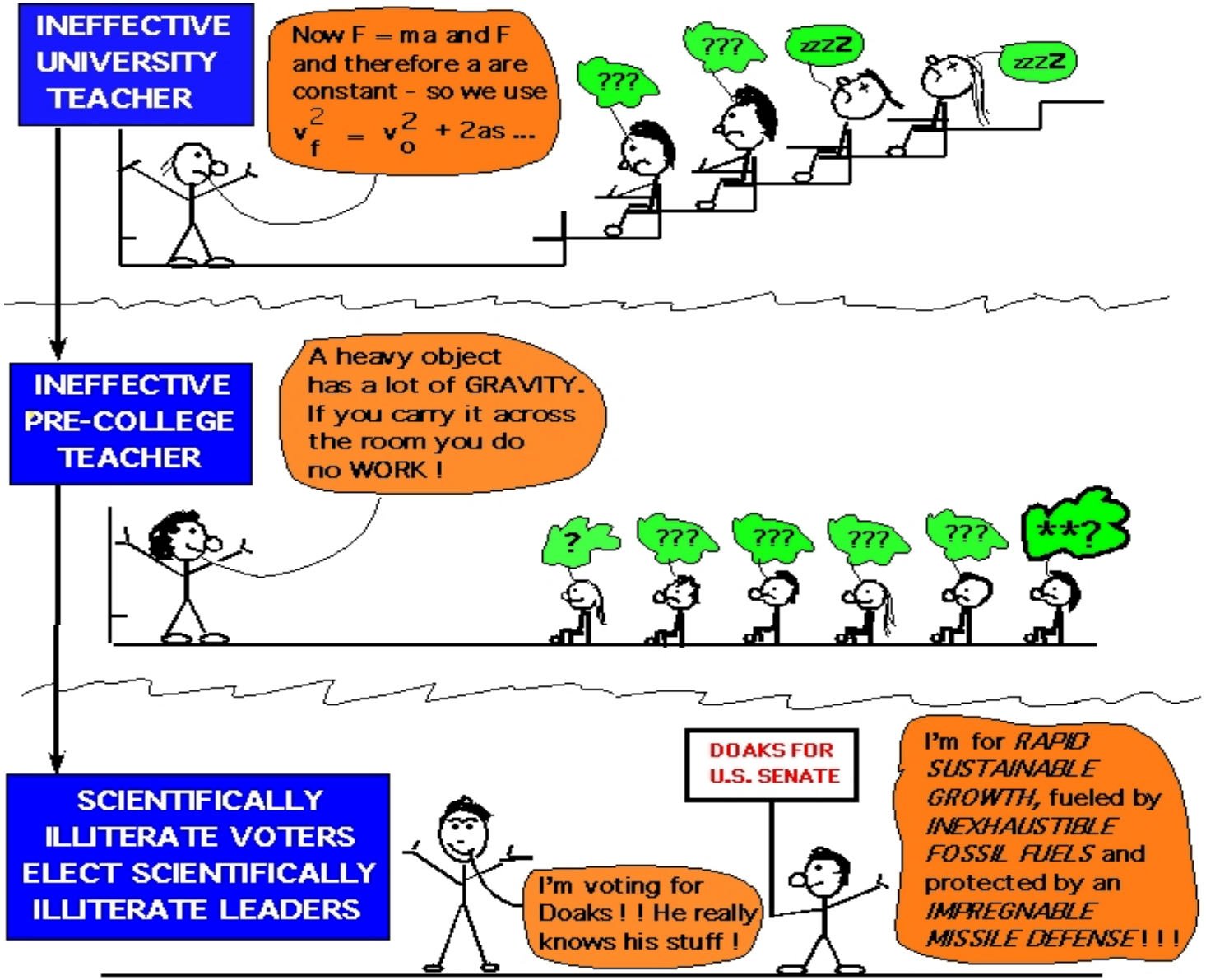
D. Woodie Flowers "Why change, Been doin' it this way for 4000 years!" ASME Mechanical Engineering Education Conference: *Drivers and Strategies of Major Program Change*, Fort Lauderdale, Florida, March 26-29, 2000; on the web as PowerPoint plus video at < **http://hitchcock.dlt.asu.edu/media2/cresmet/flowers/** >. (Download the free *RealPlayer*.):

Slide 42, 43: BBC videotape *Simple Minds* showing MIT graduates having trouble getting a flashlight bulb to light, given one bulb, one battery, and one piece of wire. This is the MIT counterpart of Harvard's *A Private Universe*, a videotape showing Harvard graduating seniors confidently explaining that the seasons are caused by yearly variation in the distance of the Earth from the Sun! And if such occurs at MIT and Harvard, how about Podunk State?

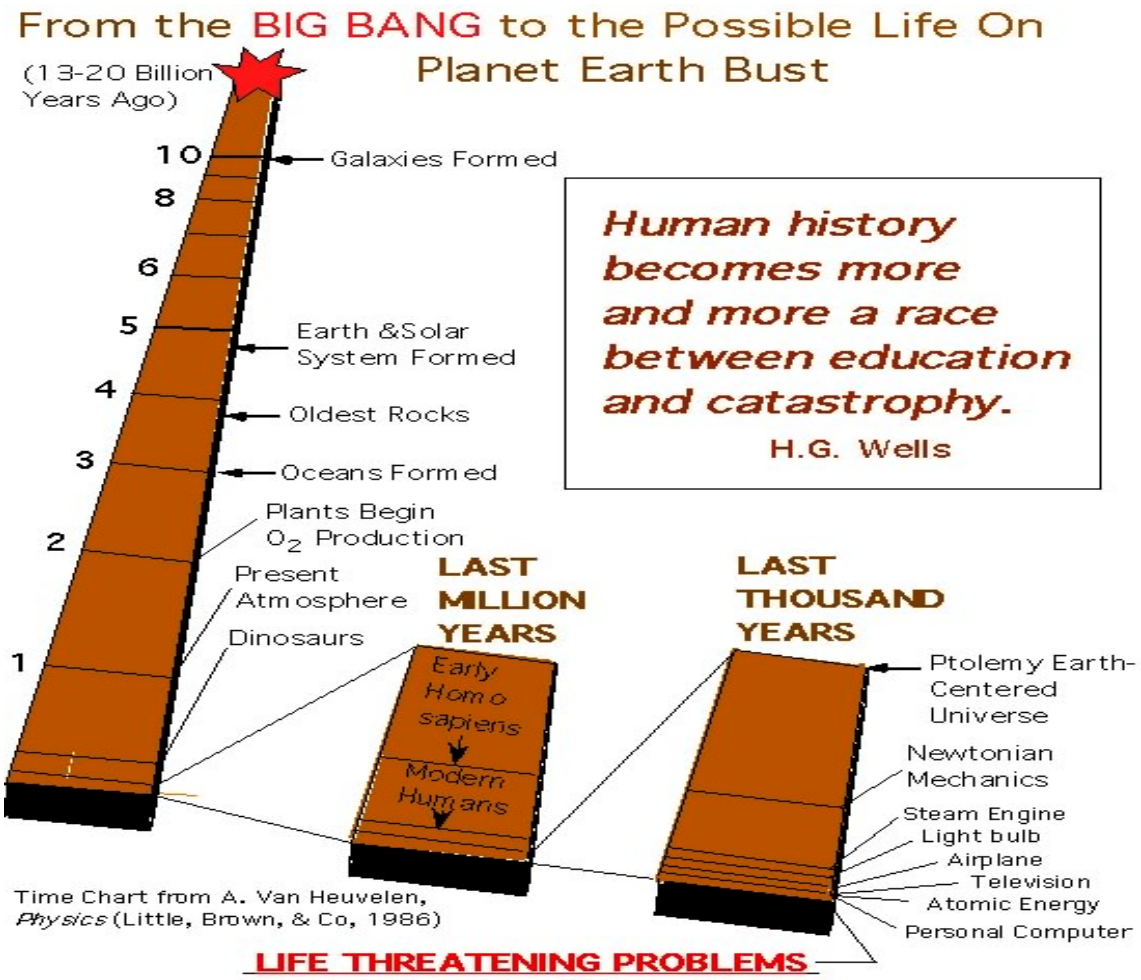
For *A Private Universe* consult **< http://www.learner.org/catalog/science/pup/ >.** For an equivalent of the *Simple Minds* videotape go to *Minds of Our Own* at **< http://www.learner.org/catalog/science/mooo/ >** and the "Program Descriptions" at **< http://www.learner.org/catalog/science/mooo/mooodes.html >.** The latter gives a description of three *Minds of Our Own* videotapes available, including the MIT footage:

"***Why is it that students can graduate from MIT and Harvard, yet not know how to solve a simple third-grade problem in science: lighting a light bulb with a battery and wire?*** Through the example of an experienced teacher, the program takes a hard look at why teaching fails, even when he uses all of the traditional tricks of the trade. The program shows how new research, used by teachers committed to finding solutions to problems, is reshaping what goes on in the nation's schools." (My *italics*.)

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



V. **Time Chart** (based on that in Van Heuvelen's text)



VI. Some Life-Threatening Science-Related Societal Problems

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

1. Overpopulation (doubles about every 35 years)
2. Threat of weapons of mass destruction
3. Human welfare (starvation, homelessness, unemployment, drugs, epidemics, AIDS, etc.)
4. Environment (pollution of air, water, land, food; global warming; 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
7. Third world crises
8. Superstition
9. 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

C. Are a Few Words From the Wise Sufficient?

1. **Edward O. Wilson** in *Consilience: The Unity of Knowledge* (Knopf, 1998), esp. Chap. 12 "To What End":

E.O. Wilson

"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.***" (My *italics*.)

2. Albert Baez* in "Education's 4 C's vs Society's 4 P's," *Hispanic Engineer*, Winter, 1990:

Albert Baez

"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 once said, "El respeto al derecho ajeno es 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."

*Physicist Baez, pioneer in X-ray optics and former Director of the Division of Science Teaching at UNESCO, is President of Vivamos Mejor/USA < **http://www.igc.org/vivamosmejor/index.html** >.

VII. University Reform - Needed But Unlikely

A. **Kati Haycock,*** Director of the Education Trust ‡

Kati Haycock

"Higher education….(unlike Governors and CEO's) ….. has been left out of the loop and off the hook….(in the effort to improve America's public schools since release of *A Nation at Risk* in 1983) …. Present neither at the policy tables where improvement strategies are formulated nor on the ground where they are being put into place, *most college and university leaders remain blithely ignorant of the roles their institutions play in helping K-12 schools get better - and the roles they currently play in maintaining the status quo*…. How are we going to get our students to meet high standards if ***higher education continues to produce teachers who don't even meet those same standards***? How are we going to get our high school students to work hard to meet new, higher standards if most colleges and universities will continue to admit them regardless of whether or not they even crack a book in high school?" (My *italics*.)

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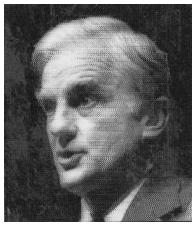
* "The Role of Higher Education in the Standards Movement" in *1999 National Education Summit Briefing Book* < **http://www.summit99.org/briefing/briefing.html** >.

‡ The Education Trust is on the web at < **http://www.edtrust.org** >.

B. **Derek Bok**,* president emeritus of Harvard

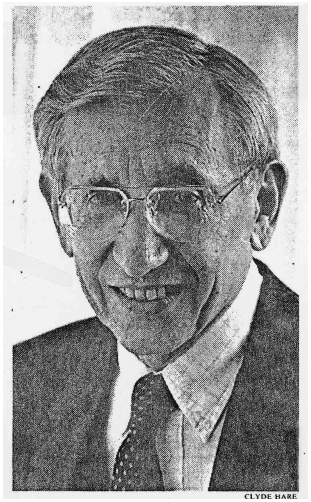


Derek Bok

"Armed with the security of tenure and the time to study the world with care, professors, would appear to have a unique opportunity to at as society's scouts to signal impending problems long before they are visible to others. *Yet rarely have members of the academy succeeded in discovering emerging issues and bringing them vividly to the attention of the public.* What Rachel Carson did for the risks to the environment, Ralph Nader for consumer protection, Michael Harrington for problems of poverty, Betty Friedan for women's rights, they did as independent critics, not as members of a faculty. Even the seminal work on the plight of blacks in America was written by a Swedish social scientist, not by a member of an American university. After a major problem has been recognized, universities will usually continue to respond weakly unless outside support is available and the subjects involved command prestige in academic circles. *These limitations have hampered efforts to address many of the critical challenges to the nation.* If universities were fully responsive to society's needs……(they)….. *would strive to maintain schools of education and public service of a quality and strength commensurate with the importance of these fields of activity……* ***Despite universal concern over the plight of the public schools, there is no indication that faculties of education are rising in importance or quality***." (My *italics*.)

**Universities and the Future of America* (Duke University Press, 1990), esp., Chapter 2, "Universities and the Search for a Better Society."

C. **Richard M. Cyert**, president emeritus of Carnegie Mellon



Richard M. Cyert

"***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 ignore the educational function in which they are engaging and from which a large fraction of their revenues are earned***." (My *italics*.)

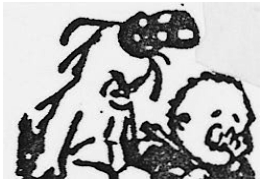
VIII. Why Do We Find No Evidence for Extraterrestrial Intelligent Life?

On Earth, human understanding fails to keep pace with the exponential-in-time advances in science and technology (see Time Chart on p. 13). **Serious problems threaten life on planet Earth.**

I submit that similar problems arose in other societies throughout the universe at our stage of development. ***Universities in those societies, as in our own, were unconcerned with introductory science education for non-research-oriented students.***

The resultant dearth of competent pre-college science/math teachers led to science illiteracy similar to ours, the election of scientifically illiterate leaders, consequent failure to solve life-threatening problems, and subsequent destruction of those societies. I conjecture that this accounts for the failure to detect any evidence of extraterrestrial intelligent life (Drake Eq.: N ≈ L*) …….. QED

Walt Kelley's Pogo



We have met the enemy and he is us (university faculty)!

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* D. Goldsmith & T. Owen, *The Search for Life in the Universe* (Addison Wesley, 1992), p. 412. Here N is the number of currently active civilizations in our galaxy with the desire and ability to communicate, and L is the lifetime in years of an average such civilization. The authors caution that the right hand side of the equation could be between 300L and (1/100 billion)L = (10exp-11)L! The number of stars in our milky way galaxy is estimated to be 300 billion.

References and Footnotes

A. THE COSMIC CONNECTION

1. SETI Institute < **http://www.seti.org/** >.

2. The Astrobiology Curriculum < **http://astrobio.terc.edu/** >: "TERC and NASA are developing an interdisciplinary year-long course for middle and high-school students using astrobiology as its unifying, underlying structure. Through a series of *inquiry-based activities centered on the search for life on other planets*, students will explore diverse concepts in chemistry, biology, physics, Earth and space science, and engineering. Astrobiology provides students opportunities to master fundamental science concepts in a relevant context and apply their skill and understanding directly in a variety of investigative modes. Projected publication date is January 2002." (My *italics*.)

3. D. Goldsmith & T. Owen, *The Search for Life in the Universe* (Addison Wesley, 1992).

4. T.B.H. Kuiper and G.D. Brin, "Resource Letter ETC-1: Extraterrestrial Civilization," *Am. J. Phys.* **57**, 12 (1989).

5. F. Dyson, *Origins of Life* (Cambridge Univ. Press, 1985).

6. A. Hobson, "Revitalize Your Introductory Courses with Modern Topics such as SETI," GIREP Newsletter (Groupe international de Recherché sur l'Enseignement de la Physique < **http://www.pef.uni-lj.si/girep/** >), in press.

B. SCIENCE LITERACY

1. Science and Engineering Indicators (NSF, 1998), Chap. 7, "Science and Technology"; on the web at **< http://www.nsf.gov/sbe/srs/seind98/start.htm >**.

2. E.C. Scott, "Not (Just) in Kansas Anymore," *Science* **228**, 813-815 (2000); on the web at **< http://www.sciencemag.org/cgi/content/full/288/5467/813 >**.

3. J. Epstein, "Cognitive Development in an Integrated Mathematics and Science Program," *J. of College Science Teaching*, 12/97 & 1/98, 1998, pp. 194 - 201.

4. W. Flowers, "Why change, Been doin' it this way for 4000 years!" ASME Mechanical Engineering Education Conference: *Drivers and Strategies of Major Program Change*, Fort Lauderdale, Florida, March 26-29, 2000; on the web as PowerPoint plus video at **< http://hitchcock.dlt.asu.edu/media2/cresmet/flowers/ >**. (Download the free *RealPlayer*.)

5. *Benchmarks for Science Literacy - Project 2061*, AAAS (Oxford Univ. Press, 1993); see at **< http://project2061.aaas.org/tools/benchol/bolframe.html >**.

6. G. Holton, "The Anti-Science Phenomenon," (and citations therein) in *Science and Anti-Science* (Harvard University Press, 1993); *Einstein, History, and Other Passions: The Rebellion Against Science at the End of the Twentieth Century* (Addison Wesley, 1996).

7. N. Koertge, ed., *A House Built on Sand: Exposing Postmodernist Myths about Science* (Oxford, 1998).

8. R. Newton, *The Truth of Science: Physical Theories and Reality* (Harvard Univ. Press, 1997).

9. *The Nation's Report Card*, National Assessment of Educational Progress (NAEP); on the web at < **http://nces.ed.gov/nationsreportcard/site/home.asp** >. C. Y. O'Sullivan, C. M. Reese, and J. Mazzeo *NAEP 1996 Science: Report Card for the Nation and the States*, on the web at < **http://nces.ed.gov/nationsreportcard/96report/97497.shtml** >: "Three percent of the nation's students reached the *Advanced* level at all three grade levels. Twenty-six percent of fourth- and eighth-grade students and 18 percent of the twelfth-grade students performed within the *Proficient* level, while 38 percent, 32 percent, and 36 percent performed within the *Basic* level for grades 4, 8, and 12, respectively." Paul Gross, ref. B-16, states that "in the Massachusetts assessment system, the category matching NAEP's 'Basic' is called 'Needs Improvement.' That is much more honest.")

10. NRC, *Global Perspectives for Local Action: Using TIMSS to Improve U.S. Mathematics and Science Education* (National Academy Press, 1999): "U.S. students; worst showing was in population 3……..(final year of secondary School……corresponding to U.S. high school seniors)…….*In the assessment of general mathematics and science knowledge, U.S. high school seniors scored near the bottom of the participating nations.* In the assessments of advanced mathematics and physics given to a subset of students who had studied those topics, no nations had significantly lower mean scores than the United States. *The TIMSS results indicate that a considerably smaller percentage of U.S. students meet high performance standards than do students in other countries.*" (My *italics*.)

11. R.M. Hazen and J. Trefil, *Science Matters: Achieving Scientific Literacy* (Doubleday, 1991).

12. A.B. Arons, *A Guide To Introductory Physics Teaching* (Wiley, 1990); reprinted with minor updates in *Teaching Introductory Physics* (Wiley, 1997). The latter book also contains *Homework and Test Questions for Introductory Physics Teaching* (Wiley, 1994) along with a new monograph *Introduction to Classical Conservation Laws*. See esp. Chap. 12 "Achieving Wider Scientific Literacy."

13. A. Hobson, "Teaching Relevant Science for Scientific Literacy," *J. College Science Teaching*, in press.

14. A. Melott, "What Happened to Science Education: Kansas and Beyond," *APS Forum on Physics and Society Newsletter* **29**(2), 6-9 (2000); on the web at **< http://www.aps.org/units/fps/aapr00.html#a3 >.**

15. K.M. Ashman, "The Tactics and Agenda of the New Creationists," *APS Forum on Physics and Society Newsletter* **29**(3), 2-5 (2000); on the web at **< http://www.aps.org/units/fps/ashman.html >**.

16. P.R. Gross, "Politicizing Science Education" on the web at **< http://www.edexcellence.net/library/gross.html >.** In my opinion, Gross's discussions of the anti-evolution movement and the need for improvement of science education are on target, but his blanket condemnation of "constructivism" is inconsistent with the results of physics-education research of the past two decades, which demonstrates the relative effectiveness of constructivist-oriented educational strategies such as "interactive engagement" and "collaborative learning" (see, e.g., refs. D - 24, 25).

17. In my opinion, the science literacy of the general population would be increased if the "Benezet Method" were to be widely implemented in K-12. See S. Mahajan & R.R. Hake, Is It Finally Time for a Physics Counterpart of the Benezet/Berman Math Experiment of the 1930's?" *Physics Education Research Conference 2000: Teacher Education*, Univ. of Guelph, August 2-3, 2000; see also the "Benezet Centre" at **< http://wol.ra.phy.cam.ac.uk/sanjoy/benezet >**: "Students in Manchester, New Hampshire were not subjected to arithmetic algorithms until grade 6. In earlier grades they read, invented, and discussed stories and problems; estimated lengths, heights, and areas; and enjoyed finding and interpreting numbers relevant to their lives. In grade 6, with 4 months of formal training, they caught up to the regular students in algorithmic ability, and were far ahead in general numeracy and in the verbal, semantic, and problem-solving skills they had practiced for the five years before." We conjecture that implementation of the "Benezet Method" in early grades would drastically improve the effectiveness of high-school and university physics, science, and math instruction.

C. SCIENCE-RELATED SOCIETAL PROBLEMS

1. E.O. Wilson, *Consilience: The Unity of Knowledge* (Knopf, 1998), esp. Chap. 12 "To What End."

2. A.V. Baez, "Teaching Youth about the Environmental Impact of Science and Technology **< http://library.fortlewis.edu/~instruct/glosas/takbook/chapters/baez.htm >.** See also Baez's biography at **< http://library.fortlewis.edu/~instruct/glosas/takbook/bios/baez.htm >.**

3. Union of Concerned Scientists (UCS), *World Scientists' Warning to Humanity* **< http://www.ucsusa.org/about/warning.html >**. *Some 1700 of the world's leading scientists, including the majority of Nobel laureates in the sciences, issued this appeal in November 1992.* The appeal was written and spearheaded by the late Henry Kendall, former chair of UCS's board of directors.

4. UCS, *The Science of Population, Development, and the Environment* **< http://www.ucsusa.org/resources/pop.science.html >.**

5. UCS, *The Science of Global Warming* **< http://www.ucsusa.org/warming/gw.science.html >**.

6. UCS, *The Science of Biodiversity* **< http://www.ucsusa.org/resources/biodiv.science.html >**.

7. A.A. Bartlett, “Forgotten fundamentals of the energy crisis,” *Am. J. Phys.* **46**(9), 876-888 (1978): “The greatest shortcoming of the human race is our inability to understand the exponential.”

8. A.A. Bartlett, "Reflections on Sustainability, Population Growth, and the Environment," *Population and Environment* **16**(1), 5-34 (1994); revised version, *Renewable Resources Journal* **15**(4), 6-23 (1997-98); on the web at **< http://lahr.org/john-jan/growth/bartlett.html >**.

9. H.E. Daly, *Beyond Growth: The Economics of Sustainable Development* (Beacon Press, 1996).

10. A. Hobson, *Physics: Concepts and Connections* (Prentice Hall, 1999). Good treatment of societal topics, see esp. the chapters "Are We Alone? : The Search for Extraterrestrial Intelligence" and "The Energy Future.”

11. M. Gell-Mann, *The Quark and the Jaguar: Adventures in the Simple and the Complex* (W.H. Freeman, 1994), esp. Part IV, “Diversity and Sustainability.”

12. G. Holton, “Scientists Organizing to Fulfill their Civic Responsibility,” *Physics and Society* **28**(4), 11-13 (1999); on the web at **< http://www.aps.org/units/fps/aoct99.html#a6 >**: “My research associate, Dr. Gerhard Sonnert, and I have begun to put together a Michelin Guide to all such voluntary scientists’ organizations, past and present…….(to counter widespread ignorance of associations)…….. founded by scientists, including very distinguished ones, who felt called upon to take time from their work to pursue their social and ethical duty to society, as they perceived it, to help guide the uses of science and technology towards the public good.”

D. UNIVERSITY REFORM

1. F.M. Cornford, *Microcosmographia Academica Being A Guide for the Young Academic Politician* (Bowes & Bowes, Cambridge, 4th ed., 1949 - first published in 1908): "I shall take it that you are in the first flush of ambition and just beginning to make yourself disagreeable. You think (do you not?) that you have only to state a reasonable case, and people must listen to reason and act upon it at once. It is just this conviction that makes you so unpleasant. There is little hope of dissuading you; but *has it occurred to you that nothing is ever done until every one is convinced that it ought to be done, and has been convinced for so long that it is now time to do something else?* And are you not aware that conviction has never been produced by an appeal to reason which only makes people uncomfortable? If you want to move them, you must address your arguments to prejudice and the political motive, which I will presently describe." (My *italics*.)

2. F. Reif, "Educational Challenges for the University," *Science* **184**, 537-542 (1974): "…..the University, unlike any progressive industry, is not in the habit of improving its own performance by systematic investment in innovative research and development. Indeed, the resources allocated by the university to educational innovation are usually miniscule or non-existent."

3. Kati Haycock, "The Role of Higher Education in the Standards Movement" in *1999 National Education Summit Briefing Book*
< **http://www.summit99.org/briefing/briefing.html** >.

4. D. Bok, *Universities and the Future of America* (Duke University Press, 1990).

5. P. Smith, *Killing the Spirit: Higher Education in America* (Viking, 1990): "Ortega y Gasset reminds us that a generation *in form* can accomplish more genuine reform than centuries of lackluster effort……. But so strong is the hold on our minds and imaginations of what *is* that to make any substantial change in the way we think about the whole process of education will require, in David Bohm's words, 'an energy, a passion, a seriousness, beyond even that needed to make creative and original discoveries in science, art, or in other fields.' "

6. J.J. Duderstadt (president emeritus and Professor of Science and Engineering, Univ. of Michigan - Ann Arbor), "New Roles for the 21st-Century University: Changing times demand a new social contract between society and the institutions of higher education," *Issues* **16**(2), 37-51 (1999-2000) **< http://bob.nap.edu/issues/16.2/duderstadt.htm >:** "….a 21st-century analog to the land-grant university might be a termed a 'learn-grant' university, *designed to develop human resources as it top priority along with the infrastructure necessary to sustain a knowledge-driven society.*"(My *italic*s.)

7. J.J. Duderstadt, *A University for the 21st Century* (Univ. of Michigan Press, 2000) for a synopsis see **< http://www.press.uchicago.edu/cgi-bin/hfs.cgi/500/11091.ctl** >: "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*." (My *italic*s.)

8. *Daedalus* **127**(4), 1998 issue "Education yesterday, education tomorrow." For a description see < **http://daedalus.amacad.org/inprint.html** >. Contains essays by researchers in education and by historians of more rapidly developing institutions such as power systems, communications, health care, and agriculture. Sets out to answer a challenge posed by Kenneth Wilson: "If other major American 'systems' have so effectively demonstrated the ability to change, why has the education 'system' been so singularly resistant to change? What might the lessons learned from other systems' efforts to adapt and evolve have to teach us about bringing about change - successful change - in America's schools?" For a partial answer see ref. 9.

9. K.G. Wilson and C.K. Barsky, "Applied Research and Development: Support for Continuing Improvement in Education," *Daedalus* **127**(4), 233- 258 (1998): "We see the need for a launch of a research and development initiative in education, paralleling existing national research initiatives related to AIDS or global climate change ..... Today we have to think of education as demanding in multiple dimensions: as a science, as a design challenge, and as a performing art while still being an imperative for life in a democracy. Handed down traditions are no longer enough." See also < **http://www.physics.ohio-state.edu/~redesign/** >.

10. J.I. Goodlad, *Teachers For Our Nation's Schools* (Jossey-Bass, 1990) : "Few matters are more important than the quality of the teachers in our nation's schools. Few matters are as neglected.… A central thesis of this book is that there is a natural connection between good teachers and good schools and that this connection has been largely ignored …. *It is folly to assume that schools can be exemplary when their stewards are ill-prepared*." (My *italics*.)

11. Karl Pister (former Chancellor of UC - Santa Cruz), "Renewing the Research University," *University of California at Santa Cruz Review* (Winter 1996): "Three cultural shifts must occur if.... (public universities).....are to succeed...(in meeting the needs of the country).… First, *we need to encourage innovative ways of looking at problems, moving away from the increasing specialization of academia to develop new interdisciplinary fields that can address complex real-world problems from new perspectives*. Second, the orientation of faculty effort and the faculty reward system in our universities must support the full range of institutional missions in a more balanced manner. Third, *our society must be willing to make quality education, especially in science and technology, accessible at all levels for all students*. Education must be seen more as an investment in society's well-being and less as a cost." (My *italics*.) < **http://www.ucsc.edu/news_events/review/text_only/Winter-96/Win_96-Pister-Renewing_.html** >.

12. D. Kennedy, *Academic Duty* (Harvard University Press, 1997): "Members of Congress, foundation executives, the most experienced journalists, and other thoughtful observers of the American scene are all asking the same question - *'Can the universities really make a difference with respect to the Big Problems facing us?'* The question stems from real concern about the seriousness of the problems, and equally from a mistrust of the ability of the academic sector to mobilize in a way likely to produce solutions…….*The skepticism is about the universities' ability to reorganize, to marshall the diverse talents to approach complex problems of large scale.* Whether the academy can overcome the resistance of departmental structure and long tradition to 're-engineer' itself in the face of these challenges is an open question." (My *italics*.)

Kennedy fails to mention the skepticism regarding the ability of universities to even ***recognize*** the "Big Problems" indicated in refs. 1-11 above, let alone *reorganize* to face them.

13. *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (Advisory Committee to the NSF Directorate for Education and Human Services chaired by Melvin George, 1996), on the web at **< http://www.nsf.gov/cgi-bin/getpub?nsf96139 >**: "Many faculty in SME&T at the post-secondary level continue to blame the schools for sending underprepared students to them. But, increasingly, ***the higher education community has come to recognize the fact that teachers and principals in the K-12 system are all people who have been educated at the undergraduate level, mostly in situations in which SME&T programs have not taken seriously enough their vital part of the responsibility for the quality of America's teachers***." (My *italics*.)

14. *Unlocking Our Future: Toward a New National Science Policy*, A Report to Congress by The House Committee on Science chaired by Vernon Ehlers, 9/24/98 at **< http://www.house.gov/science/science_policy_study.htm >**: "Currently, the U.S. spends approximately $300 billion a year on education and less than 30 million, 0.01% of the overall education budget, on education research. At a time when technology promises to revolutionize both teaching and learning, this miniscule investment suggests a feeble long-term commitment to improving our educational system." (cf., ref. 9)

15. *Preparing for the 21st Century: The Education Imperative* (National Research Council, 1997), on the web at **< http://www2.nas.edu/21st >**. Also in this series at the same URL are: (a) *Science and Engineering Research in a Changing World*, (b) *Technology and the Nation's Future*, (c) *Challenges Facing a Changing Society*, (d) *The Environment and the Human Future*, (e) *Focussing on Quality in a Changing Health Care System*.

16. *Reinventing undergraduate education: A blueprint for America's Research Universities.* The Boyer Commission on Educating Undergraduates in the Research University (Carnegie Foundation for the Advancement of Teaching, 1998), also at < **http://notes.cc.sunysb.edu/Pres/boyer.nsf** >: "The university's essential and irreplaceable function has always been the exploration of knowledge. *This report insists that the exploration must go on through what has been considered the 'teaching' function as well as the traditional 'research' function.* The reward structures in the modern research university need to reflect the synergy of teaching and research - and the essential reality of university Life: that baccalaureate students are the university's economic life blood and are increasingly self-aware." (My *italics*.)

17. E.L. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate* (Carnegie Foundation, 1990): "Thus the most important obligation now confronting the nation's colleges and universities is to break out of the tired old teaching versus research debate and define, in more creative ways, what it means to be scholar. It's time to recognize the full range of faculty talent and the great diversity of functions higher education must perform."

18. C.E. Glassick, M.T. Huber, G.I. Maeroff, *Scholarship Assessed: Evaluation of the Professoriate* (Jossey-Bass, 1997).

19. R.C. Hilborn, "Physics at the Crossroads: Innovation and Revitalization in Undergraduate Physics – Plans for Action," report on a College Park AAPT conference of 9/96, < **http://www.aapt.org/events/events.html** >; "Guest Comment: Revitalizing undergraduate physics – Who needs it?" *Am. J. Phys.* **65**, 175-177 (1997).

20. D. Goodstein, (a) "Now Boarding: The Flight from Physics," *Am. J. Phys.* **67**(3), 183-186 (1999) , also on line at < **http://ojps.aip.org/** >: "The most important role of the college physics course today seems to be to weed out a few poor souls who might otherwise make it into medical school or some other kind of quasi-scientific training. *If the profession of teaching physics were a business, we would be filing for bankruptcy*." (b) "Scientific Elites and Scientific Illiterates," Sigma Xi, Proceedings of a Forum on Ethics, Values, and the Promise of Science (New Haven, CT: Sigma XI, February 25-26, 1993); (c) "The Big Crunch" under "David Goodstein" at < **http://www.caltech.edu/subpages/pmares.html** >. (My *italics*.)

21. R.R. Hake, "What Can We Learn from the Biologists About Research, Development, and Change in Undergraduate Education?" *AAPT Announcer* **29**(4), 99 (1999); available on the web at < **http://www.physics.indiana.edu/~hake** > as [WhatLearn.pdf, 1/31/2000, 204K]. *The potential of the WWW as a mechanism for promoting interdisciplinary synergy in education reform is emphasized.* The Appendix contains: (a) "Undergraduate Physics Education Needs Revitalization," discussing both pedagogical and political/institutional problems, (b) 81 references relevant to the presentation..

22. R.R. Hake, "What Can We Learn from the Physics Education Reform Effort?", ASME Mechanical Engineering Education Conference: *Drivers and Strategies of Major Program Change*, Fort Lauderdale, Florida, March 26-29, 2000; on the web at < **http://www.physics.indiana.edu/~hake** > as a pdf document (125 references) at [ASME.pdf, 3/27/00, 436K], and as PowerPoint plus video at < **http://hitchcock.dlt.asu.edu/media2/cresmet/hake/** >. (Download the free *RealPlayer*.)

23. R.R. Hake, "The Need for Improved Physics Education for Teachers: FCI Pretest Scores For Graduates of High School Physics Courses - Is It Finally Time to Implement Curriculum S?" *Physics Education Research Conference 2000: Teacher Education*; Guelph, Canada; 8/2000; on the web at as a pdf document (16 references) at < **http://www.physics.indiana.edu/~hake** > .

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

25. E.F. Redish, "Millikan Lecture 1998: Building a Science of Teaching Physics," *Am. J. Phys.* **67**(7), 562-573 (1999); on the web at < **http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html** >.

26. K. Ford, "Whatever Happened to Curriculum S?" *Phys. Teach.* **25**, 138-139 (1987): "Curriculum S (for synthesis) ……(proposed at the Second Ann Arbor Conference, November 1962)…….. was to serve students who wanted to study physics as background for something other than physics research: business, law, medicine, *teaching*, some other scientific study, or just informed citizenship….. It is time to look again at Curriculum S…….***we need a physics major program suitable for (and attractive to) some of the teachers of the next generation - not just high-school physics teachers, but elementary and middle school teachers as well.*** " (My *italics*.)

27. E.L. Jossem, "Undergraduate Curricula in Physics: A Report on the Princeton Conference on Curriculum S," *Am. J. Phys.* **32**(6), 491-497 (1964).