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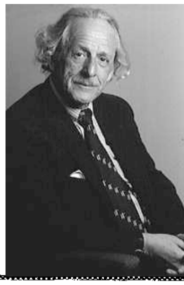

Current Comments®

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Science Literacy. Part 2. Major Research Areas and Recommendations for the Future

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This essay (the second of two parts) continues our examination of science literacy and education in the US. ISI® research fronts pertaining to current scientific curricula, popular science, and the sociology of scientific knowledge are discussed. Recommendations for improving science education and literacy are reviewed.

In Part 1 we discussed the current crisis in science literacy in the US—especially in the work force and in the schools.[1] We defined a scientifically literate person as someone who possesses an understanding of the nature and limits of science, a mastery of basic conceptual knowledge in the major disciplines, and a sense of the social, cultural, and ethical implications of science and technology. In this second part, we will review the limited research currently reported on science literacy and consider some of the recommendations that have been proposed for improving the science literacy of the American public.

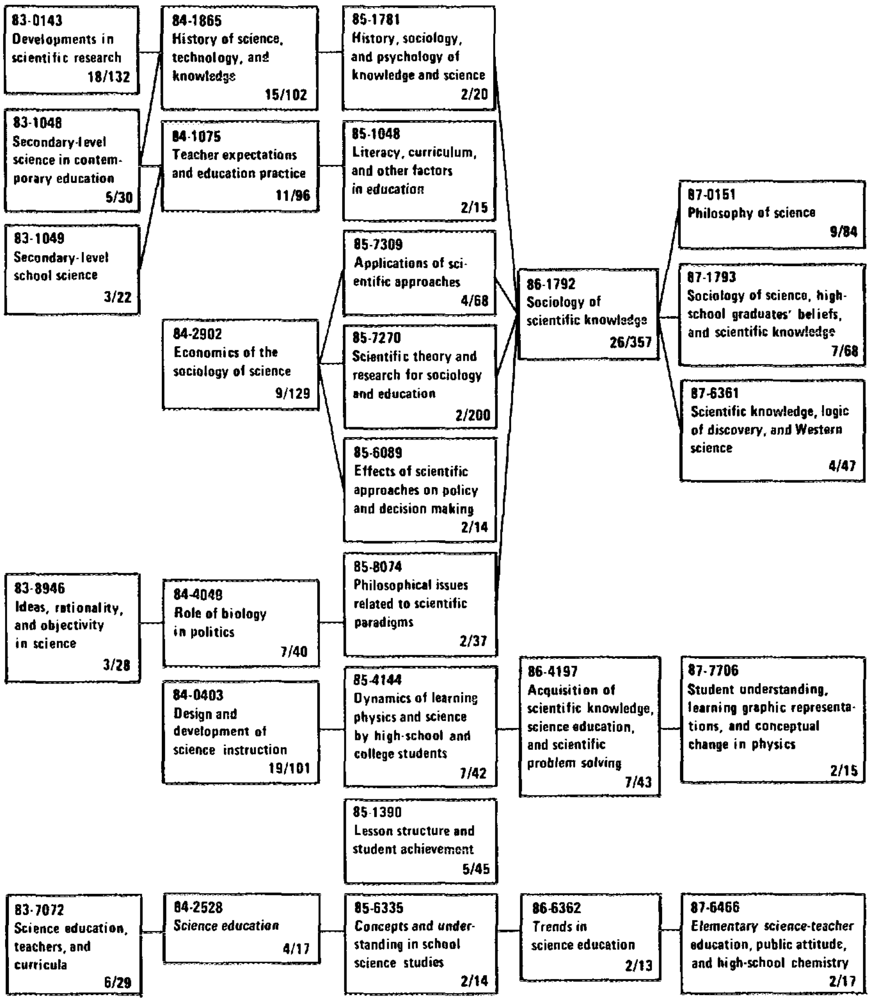
Research Fronts

The historiograph in Figure 1 shows the major issues raised over the past few years concerning the role of science in society. Four C1-level 1985 research fronts consolidated in 1986 into one front, "Sociology of scientific knowledge" (#86-1792). With 26 core documents and 357 citing papers, it represents the largest front identified by co-citation clustering for this topic in 1986. In 1987 it diverged again into three smaller areas.

Not surprisingly, among the core works identifying this front are those by Thomas S. Kuhn,[2,3] Department of Philosophy, Massachusetts Institute of Technology, Cambridge, and Karl R. Popper,[4] professor emeritus, University of London, UK. Kuhn's *Structure of Scientific Revolutions*[2] and Popper's *Objective Knowledge*[4] are among the most widely cited books of the century and were identified as being among the most-cited works in the *Arts & Humanities Citation Index*™.[5] Kuhn, through an examination of the history of science, proposes that a true scientific breakthrough occurs only when an accepted scientific theory is overthrown and the theory that replaces it requires that previous scientific beliefs be reevaluated. This idea contradicts the notion of "progress" in science and challenges the view of scientific knowledge as objective truth. Popper, who discusses the nature of scientific thought, claims that scientific knowledge is not, as is often thought, cumulative.

Since an understanding of the nature and limits of science is considered to be an important component of science literacy, it is not surprising that papers published on these questions would cite such classic works. Among the more recent papers published, many of them in the major science-education journals listed in Table 1, are several on the nature of scientific thought. For example, David Gooding, University of Bath, UK, asks, "How do scientists reach agreement

Figure 1: Historiograph of science literacy related research.



about novel observations?''[6] Joseph D. Robinson,[7] Department of Pharmacology, State University of New York, Syracuse, and Harvey Siegel,[8] Department of Philosophy, University of Miami, Florida, explore the rationality of science. And George Levine, Rutgers University, New Brunswick, New Jersey, masterfully discusses ''Literary science—scientific literature,''[9] the relationship between literature and science.

Research front #86-1792 connects with three 1987 fronts, ''Philosophy of science'' (#87-0151), ''Scientific knowledge, logic of discovery, and Western science'' (#87-6361), and ''Sociology of science, high-school graduates' beliefs, and scientific knowledge'' (#87-1793). The latter relates most directly to the problem of science literacy. This front has seven core publications, the most highly cited (with nearly 30 citations) being *Knowledge and Social Im-*

Table 1: Science education/literacy journals.
The first year of publication is included in parentheses.

American Biology Teacher (1938)
R. Moore, ed.
National Association of Biology Teachers
Reston, VA

Bulletin of Science, Technology & Society (1981)
R. Roy, ed.
STS Press
University Park, PA

Daedalus (1958)
S.R. Graubard, ed.
American Academy of Arts and Sciences
Cambridge, MA

IEEE Transactions on Education (1958)
F.S. Barnes, ed.
Institute of Electrical and Electronics Engineers
New York, NY

Impact of Science on Society (1950)
J.G. Richardson, ed.
United Nations Educational, Scientific, and Cultural Organization
Paris, France

Instructional Science (1971)
A. diSessa & P. Lefere, eds.
Kluwer Academic Publishers
Dordrecht, The Netherlands

International Journal of Science Education (1987)
R. Kempa, ed.
Taylor & Francis
London, United Kingdom

Issues in Science and Technology (1984)
S.J. Marcus, ed.
National Academy of Sciences
Washington, DC

Journal of Biological Education (1967)
J.A. Barker, ed.
Institute of Biology
London, United Kingdom

Journal of Chemical Education (1924)
J.J. Lagowski, ed.
American Chemical Society
Washington, DC

Journal of Educational Psychology (1910)
R.C. Calfee, ed.
American Psychological Association
Arlington, VA

Journal of Research in Science Teaching (1963)
R.H. Yeany, ed.
John Wiley & Sons
New York, NY

Knowledge—Creation, Diffusion, Utilization (1977)
W.D. Dunn, ed.
Sage Publications
Newbury Park, CA

Review of Educational Research (1931)
P.L. Peterson, ed.
American Educational Research Association
Washington, DC

Science Education (1916)
L.E. Klopfer, ed.
John Wiley & Sons
New York, NY

agery, a 1976 book by David Bloor,[10] Science Study Unit, University of Edinburgh, UK. This work examines the influence of belief, preconception, and experience on interpretation of observations in science. Most relevant among the citing papers is one by Reg W. Fleming, University of Saskatchewan, Saskatoon, Canada, who studied Canadian high-school graduates' beliefs about science, technology, and society.[11]

A second 1986 research front (see Figure 1) is entitled "Acquisition of scientific knowledge, science education, and scientific problem solving" (#86-4197). Among the most frequently cited core works are several on student understanding—and misunderstanding—of scientific concepts. For example, a paper by psychologists Michael McCloskey and colleagues, Johns Hopkins University, Baltimore, Maryland, reports that most undergraduates have little comprehension of basic laws of motion.[12] Over half of 50 students tested, including some who had studied physics, predicted that objects in motion would move in a curved path in the absence of any external forces. In another core paper, Lillian C. McDermott, Department of Physics, University of Washington, Seattle, reviews similar studies of student understanding of mechanics.[13] She observes that even students who can do textbook problems successfully have trouble interpreting classroom demonstrations based on the same concepts.

Other recently published papers that cite into this front focus on theories and proposals to improve the transmission of scientific knowledge in the schools. For instance, Frederick Reif, Departments of Physics and Education, University of California, Berkeley, in his paper "Scientific approaches to science education," stresses the importance of analyzing the thought process involved in problem solving to design successful teaching methods.[14] Later in this essay, we will discuss proposals for improving science education.

In 1987 a new front emerged entitled "Student understanding, learning graphic representations, and conceptual change in physics" (#87-7706). McDermott's paper, discussed earlier, is one of two core papers;[13] the second was coauthored by McDermott and David E. Trowbridge, University of Washington.[15] As with front #86-4197, mentioned earlier, the current papers retrieved are concerned with promoting an understanding of science in the schools. Reif is again a citing author, with the recent article "Instructional design, cognition, and technology: applications to the teaching of scientific concepts,"[16] in which he suggests that computers can be useful for designing science-teaching methods based on an understanding of cognitive processes.

Figure 1 shows that a 1986 research front, "Trends in science education" (#86-6362), was followed in 1987 by a "new" front, "Elementary science-teacher education, public attitude, and high-school chemistry" (#87-6466). There are two core works essential to this evolving topic: *What Research Says to the Science Teacher* edited by Norris C. Harms, University of Colorado, Boulder, and Robert E. Yager, University of Iowa, Iowa City;[17] and *Case Studies in Science Education* by Robert E. Stake and Jack A. Easley, University of Illinois, Urbana-Champaign.[18] The 1978 work by Stake and Easley is a comprehensive profile of current science teaching in kindergarten through 12th grade based on observations in 11 US schools.

The current papers on this area focus on students' perceptions of and attitudes toward science. Yager, former president, National Science Teachers Association, coauthored several of them. In "Perceptions of four age groups toward science classes, teachers, and the value of science," he and John E. Penick, University of Iowa, report that attitudes toward science become more negative as children grow older. While 90 percent of elementary-school students believed science would be valuable to them in the future, only 75 percent of seventh graders and only 20 percent of young adults felt this way.[19] On the other hand, the last few years have seen an incredible increase in the popularity of science museums, which would seem to indicate that children do maintain a sense of curiosity and excitement about science, or at least about some scientific topics. There seems to be some element in the teaching or presentation of science in school that turns young people off.

The literature in 1987 (#87-6466) focuses on teacher education and public attitudes. As in the previous year, Yager and Penick authored a number of papers, including one on "Resolving the crisis in science education—understanding before resolution."[20]

Recommendations for Improving Science Literacy

Part 1 of this essay suggested that, as a nation, we have allowed a serious gap to form in our competence in science and that this gap is already undermining the vitality of our economy, our scientific institutions, and our democratic form of government.[1] It is clear that systematic changes must be made in order to reverse this trend.

The vast majority of adult Americans constitute what Jon D. Miller, Public Opinion Laboratory, Northern Illinois University, De Kalb, quoted in Part 1, calls the "inattentive public"—the portion of the population that is not interested in understanding science or science-related issues.[21] This sector of the population, by virtue of its majority status, could exert veto power over science policy (and funding) at the local, state, and federal levels. Yet, it is virtually impossible to reach the inattentive majority with an adult science-literacy program. Miller suggests that the most effective use of our limited manpower and financial resources is to improve science education in the schools. Adult-education efforts, he suggests, can be effective if directed to the smaller portions of the adult population that comprise the "attentive public," the policy leaders, and the decision makers.[21]

Improving the Schools

Concern over science literacy has brought a flood of recommendations—some of them contradictory—for improving the way we teach science. Major studies, such as the National Commission on Excellence in Education's *A Nation at Risk*,[22] the Carnegie Foundation's *High School*[23] and *College*[24] reports, and Sigma Xi's *A New Agenda for Science*,[25] have provoked mixed responses from educators, teachers, policymakers, scientists, and others. More recently, the US Office of Technology Assessment has laid out a number of policy options designed to increase the number of students who complete degree work in science and engineering and to improve elementary and secondary education in science and math.[26]

Many of the recommendations being proposed today are the same ones that were proposed (but, clearly, never effectively implemented) in response to Sputnik in the 1950s and 1960s.[27] Among the measures most frequently recommended are these:

1. Increase class time spent on math and science.[28-30]
2. Take advantage of a child's natural curiosity about the world by beginning the teaching of math and science in kindergarten.[31,32]
3. Increase hands-on participation by students at every level (kindergarten through college)[31] and provide early opportunities for independent student research.[33]
4. Address issues in class that have a scientific basis and broad societal implications.[34,35] This approach is often referred to as a science-technology-society approach.
5. Improve teacher preparation in science and provide for continuing education for science teachers.[36,37]
6. Create opportunities for teacher advancement or professional development in the private sector.[37]
7. Increase teacher compensation and raise the status of teaching as a profession.[32,38]
8. Focus on understanding of basic science concepts, rather than on memorization of formulas or "facts," and include new ideas about the nature of scientific thought and the limits of science.[39]
9. Provide more effective teaching by hiring an in-school science resource specialist,[37] possibly drawing from an experienced pool of retired industrial and academic scientists.[40,41]
10. Use computers, not as substitutes for personal interaction with the teacher, but as tools for better understanding math and science.[42,43]
11. Involve local industry, professional organizations, labor unions, taxpayers, museums, libraries, public radio and television, and so on, in supporting science education in the schools.[36,38,44]

Stephen R. Graubard, Department of History, Brown University, Providence, Rhode Island, and editor of *Daedalus* (which devoted an entire issue to science literacy), who was quoted in Part 1, takes the following view:

> If scientific illiteracy is common today, it is because America's schools and universities permit the condition to exist, indeed perpetuate it.... The disgrace of America's schools is not that the educational effort has been made and failed—that students have proved themselves incompetent—but that it has been rarely tried. Modern science is thought to be beyond the intelligence of ordinary children....[38]

Graubard suggests that, if we wish to achieve a literate society, we must first regain faith in our children and in our public schools. Miller echoes this thought, pointing out that the plight of science education must be considered as part of the "general malaise" of American education as a whole. Noting that the basic problem is financial, Miller argues for new forms of funding, from income-tax revenue at the state level, to replace the outmoded system of property taxation and local referenda currently in place. Scientists, he concludes, must be willing to become part of the political and legislative effort if they are truly interested in reform and improvement.[45]

Improving Worker Literacy

In Part 1 we discussed the dismay of the business community over the high rate of illiteracy in the US population, not only in science and math, but in reading and writing as well.[1] One consequence of the crisis is the proliferation of corporate training programs that teach everything from basic literacy skills to time management to highly specialized technical material.[46]

One project that is designed not only to sharpen the worker's job skills, but to boost overall level of education, is an employee-development project sponsored by the Ford Motor Company and the United Auto Workers in collaboration with the University of Michigan, Ann Arbor. The advantages in increasing the competence of the workers are recognized by labor and management. As one participant in the program commented, "When a person starts thinking and learning in a classroom, it doesn't stop there. It becomes a habit, and you carry it not only to the job but everywhere else."[47]

Improving Adult Literacy

The role of science journalism, including written and broadcast media, in raising public awareness of science cannot be overestimated. As William D. Carey, consultant, Carnegie Corporation of New York, and retired executive officer of the American Association for the Advancement of Science (AAAS), said in a recent article, "The durability of the public's consensus support for science hangs most centrally and critically on journalists and their role as science watchers."[48] Benjamin S.P. Shen, Department of Astronomy and Astrophysics, University of Pennsylvania, Philadelphia, stresses the vital role of television programs such as "Nova" in promoting what he calls "cultural" science literacy—the interest in science as a major human achievement. Cautioning scientists not to dismiss popular science media too quickly, Shen points out that the small portion of the nonscientist population reached by such media probably includes "current and future opinion leaders and decision makers."[49] Their support of basic scientific research and improved science education for our children is essential. Bernard Dixon, European editor of ISI®'s newspaper, *THE SCIENTIST®*, has commented on the often underrated power of books and films in popularizing science.[50]

Keeping scientists and policymakers informed about developments in science and the policy issues that affect them was essential to the launching of *THE SCIENTIST*. In a recent editorial I discussed the importance of the image of science and of scientists that is presented to the public through television.[51] The myth of the "mad scientist" merely reinforces the fear that some people have of science, and this fear can readily translate into votes against appropriations for legitimate scientific research.

Efforts to promote responsible science journalism include a number of awards for excellent science writing offered by US corporations, professional associations, private endowments, and other institutions. We discussed many such awards in an essay last year.[52] Similar measures are being taken in the UK—where, for example, the Committee on the Public Understanding of Science and the Science Museum, London, have established the Science Book Awards, designed to recognize books that raise public awareness of science.[53] However, not even the best journalism can replace science education in the schools at the earliest ages.

The Role of Scientists

In January I addressed a special forum of the American Medical Association (AMA) on "Medicine for the Twenty-first Century." My talk covered the problem of science illiteracy and the need to improve science education in the classroom, in the media, and in the halls of government. I also discussed the special role that scientists, including physicians, must play in any effort to improve science education.[54] The specific recommendations that came out of this conference include:

1. Research scientists should work with teachers to convey enthusiasm for science in elementary schools and to influence policy decisions for science teaching in our schools.
2. Physicians, engineers, research scientists, and teachers need to cooperate to support science education.
3. Strategies for monitoring portrayals of scientists in the media and for promoting positive images should be established.
4. The AMA and other professional organizations of scientists should join forces to provide leadership for changes in science education. (As this article went to press, I learned that the AMA has announced a National Initiative on Science Education in America, a coordinated effort by scientists, educators, and legislators to identify and effect the necessary changes in science education. The initiative will begin with an organizational meeting set for the spring of 1989.)

Brian Pippard, writing in the *Times Literary Supplement*, makes a forceful case for the participation of scientists:

> If, as many scientists agree, it is highly desirable that scientific literacy should be a central pivot of education, it is the responsibility of some of us to put aside for a while our fascinating research (much of which could be postponed without loss to society) and devote our minds to a more challenging problem. This would involve, for example, reorganizing school and university education so that many more students learnt something of science without the implicit assumption that a full-dress professional treatment is the only way to impart understanding.[55]

A National Science Policy

From a national perspective, the call for improvements in science education dovetails with the call for the establishment of a coherent national science policy.[25,44,52] F. James Rutherford, chief education officer, AAAS, suggests that, in formulating a national policy, "science education should be viewed as an integral part of science."[56]

The Carnegie Corporation of New York recently announced the establishment of a commission that will study the interaction of science, technology, and government. The purpose of the commission, to be cochaired by Joshua Lederberg, president, The Rockefeller University, New York, and William T. Golden, president, New York Academy of Sciences, is to discover ways in which the interaction between government and the scientific community can be improved, for the benefit of society. One of the questions the commission plans to examine is, "How can the nation achieve a technically literate citizenry able to participate both in a modern democratic society and in a technological economy?"[57]

Conclusion

The increasing interdependence of science, technology, and society is forcing scientists, legislators, policymakers, and citizens to make decisions that affect what research will be done. The electorate and their representatives control these decisions by withholding or appropriating public funds and by direct regulation of scientific research. Improving science literacy and the public understanding of science has never been more important than it is today, and it will be even more important in the future. It is, in fact, tantamount to restating the almost universal acceptance of a belief in the need for compulsory education and literacy. In the final analysis, the two cultures merge.[9] In the years to come, given public and governmental support, the distinctions between the literary/professional education and science education will gradually disappear. As Levine points out:

> Any study of the works of the human imagination can no more omit science than it can omit art. Science is one of the great achievements of the human mind, and it matters powerfully, for better or worse, in the way people live, think, and imagine. There is no literature more important.[9]

* * * * *

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REFERENCES

1. **Garfield E.** Science literacy. Part 1. What is science literacy and why is it important? *Current Contents* (31):3-9, 1 August 1988.
2. **Kuhn T S.** *The structure of scientific revolutions.* Chicago, IL: University of Chicago Press, 1970. 210 p.
3. ——————. *The essential tension.* Chicago, IL: University of Chicago Press, 1977. 366 p.
4. **Popper K R.** *Objective knowledge: an evolutionary approach.* Oxford, UK: Clarendon Press, 1972. 380 p.
5. **Garfield E.** A different sort of great-books list: the 50 twentieth-century works most cited in the *Arts & Humanities Citation Index,* 1976-1983. *Current Contents* (16):3-7, 20 April 1987.
6. **Gooding D.** How do scientists reach agreement about novel observations? *Stud. Hist. Phil. Sci.* 17:205-30, 1986.
7. **Robinson J D.** Appreciating key experiments. *Brit. J. Hist. Sci.* 19(61):51-6, 1986.
8. **Siegel H.** What is the question concerning the rationality of science? *Phil. Sci.* 52:517-37, 1985.
9. **Levine G.** Literary science—scientific literature. *Raritan* 6(3):24-41, Winter 1987.
10. **Bloor D.** *Knowledge and social imagery.* London: Routledge & Kegan Paul, 1976. 156 p.
11. **Fleming R W.** High-school graduates' beliefs about science-technology-society. II. The interaction among science, technology and society. *Sci. Educ.* 71:163-86, 1987.
12. **McCloskey M, Caramazza A & Green B.** Curvilinear motion in the absence of external forces: naïve beliefs about the motion of objects. *Science* 210:1139-41, 1980.
13. **McDermott L C.** Research on conceptual understanding in mechanics. *Phys. Today* 37(7):24-32, July 1984.
14. **Reif F.** Scientific approaches to science education. *Phys. Today* 39(11):48-54, November 1986.
15. **Trowbridge D E & McDermott L C.** Investigation of student understanding of the concept of velocity in one dimension. *Amer. J. Phys.* 48:1020-8, 1980.
16. **Reif F.** Instructional design, cognition, and technology: applications to the teaching of scientific concepts. *J. Res. Sci. Teach.* 24:309-24, 1987.
17. **Harms N C & Yager R E,** eds. *What research says to the science teacher.* Washington, DC: National Science Teachers Association, 1981. 130 p.
18. **Stake R E & Easley J A.** *Case studies in science education. Vol. II. Design, overview and general findings.* Urbana-Champaign, IL: University of Illinois, 1978. 22 Chpts.
19. **Yager R E & Penick J E.** Perceptions of four age groups toward science classes, teachers, and the value of science. *Sci. Educ.* 70:355-63, 1986.
20. ——————. Resolving the crisis in science education—understanding before resolution. *Sci. Educ.* 71:49-55, 1987.
21. **Miller J D.** Scientific literacy: a conceptual and empirical review. *Daedalus* 112(2):29-48, Spring 1983.
22. **National Commission on Excellence in Education.** *A nation at risk.* Washington, DC: US Government Printing Office, 1986. 65 p.
23. **Boyer E L.** *High school: a report on secondary education in America.* New York: Harper & Row, 1983. 363 p.
24. ——————. *College: the undergraduate experience in America.* New York: Harper & Row, 1987. 328 p.

25. **Sigma Xi.** *A new agenda for science.* New Haven, CT: Sigma Xi, 1987. 47 p.
26. **US Congress. Office of Technology Assessment.** *Educating scientists and engineers: grade school to grad school.* Washington, DC: OTA, 1988. 128 p.
27. **Marcuccio P.** Responding to the economic Sputnik. *Phi Delta Kappan* 64:618-20, 1983.
28. **Sigda R B.** The crisis in science education and the realities of science teaching in the classroom. *Phi Delta Kappan* 64:624-7, 1983.
29. **National Science Board.** *Science indicators: the 1985 report.* Washington, DC: National Science Foundation, 1985. p. 124-39.
30. **Westheimer F H.** Are our universities rotten at the "core"? *Science* 236:1165-6, 1987.
31. **Hawkins D.** Nature closely observed. *Daedalus* 112(2):65-89, Spring 1983.
32. **Simpson R D.** National attentiveness to science: an educational imperative for the eighties and beyond. *Education* 104(1):7-11, 1983.
33. **Garfield E.** Research and dedicated mentors nourish science careers at undergraduate institutions. *Current Contents* (33):3-9, 17 August 1987.
34. **Thier H D.** Societal issues and concerns: a new emphasis for science education. *Sci. Educ.* 69:155-62, 1985.
35. **Prewitt K.** Scientific illiteracy and democratic theory. *Daedalus* 112(2):49-64, Spring 1983.
36. **Rowe M B.** Science education: a framework for decision-makers. *Daedalus* 112(2):123-42, Spring 1983.
37. **Jackson P W.** The reform of science education: a cautionary tale. *Daedalus* 112(2):143-66, Spring 1983.
38. **Graubard S R.** Nothing to fear, much to do. *Daedalus* 112(2):231-48, Spring 1983.
39. **Arons A B.** Achieving wider scientific literacy. *Daedalus* 112(2):91-122, Spring 1983.
40. **Lyons K, Phillips J & Wilson B.** Industrial scientists help science education in local schools. *Phys. Today* 37(12):9; 87-9, December 1984.
41. **Hechinger F M.** Teaching as a second career: tapping the scientists. *Appl. Opt.* 26:2212-65, 1987.
42. **Kemeny J G.** The case for computer literacy. *Daedalus* 112(2):211-30, Spring 1983.
43. **Garfield E.** *MicroWorks*: ISI's new educational program prepares your child for the information society. *Current Contents* (42):3-9, 19 October 1987.
44. **Shapley D & Roy R.** *Lost at the frontier.* Philadelphia: ISI Press, 1985. p. 153.
45. **Miller J D.** Personal communication. 2 July 1988.
46. **Eurich N P.** Corporate classrooms and America's schools. *Educ. Digest* 51(5):32-3, January 1986.
47. **Abelson P H.** Continuing education for blue-collar workers. *Science* 238:875, 1987.
48. **Carey W D.** Scientists and sandboxes: regions of the mind. *Amer. Sci.* 76(2):143-5, March-April 1988.
49. **Shen B S P.** Science literacy. *Amer. Sci.* 63:265-8, 1975.
50. **Dixon B.** Books and films: powerful media for science popularization. *Impact Sci. Soc.* 36:379-85, 1986.
51. **Garfield E.** The image of scientists matters. *THE SCIENTIST* 1(17):9, 13 July 1987.
52. ———. Science-writing awards: recognition and reward for promoting public understanding and awareness of science. *Current Contents* (12):3-9, 23 March 1987.
53. **Science Museum/COPUS.** *Winners of science book prizes 1988 announced at award ceremony in launch pad.* 7 June 1988. 5 p. (Press release.)
54. **Garfield E.** *Science education: a campaign on three fronts.* Speech presented to the American Medical Association, Plenary Session on Public Issues, 21 January 1988. Rancho Mirage, CA. 17 p.
55. **Pippard B.** Review of "The advancement of science, and its burdens: the Jefferson Lecture and other essays" by G. Holton. *Times Literary Supplement* 17 July 1987. p. 74.
56. **Rutherford F J.** Response from F. James Rutherford. (Shapley D & Roy R) *Lost at the frontier.* Philadelphia: ISI Press, 1985. p. 201-5.
57. **Carnegie Corporation of New York.** *Carnegie Corporation of New York establishes new Commission on Science, Technology, and Government.* 15 April 1988. 8 p. (Press release.)