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Author(s): Jon D. Miller
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Jon D. Miller

Scientific Literacy: A Conceptual and Empirical Review

In a democratic society, the level of scientific literacy in the population has important implications for science policy decisions. As this essay will show, the level of scientific literacy in the United States is deplorably low; thus any measures we can take to raise this level, to foster informed and intelligent participation in science policy issues, will improve the quality of both our science and technology and our political life.

In order to provide a framework for a discussion of scientific literacy in the United States, it is necessary first to examine how the meaning of the term itself has changed, to look at some of the attempts to measure it, and to ascertain which groups are scientifically literate and what levels of literacy have been attained.

EVOLUTION OF MEANING

"Scientific literacy" is one of those terms that is often used but seldom defined. To be literate has two quite different meanings: to be learned, and—perhaps what most people today mean when they speak of literacy or of being literate—to be able to read and write. Unfortunately, a good deal of the current debate about scientific literacy fails to distinguish between the two, and much of the confusion surrounding the issue can be traced to this omission.

Can a person with a thorough grounding in the traditional study of letters, but lacking at least some knowledge of science—and vice versa—be considered learned? This question has been the subject of a healthy (though sporadic) debate over the last century. Thomas Huxley began it, in 1880, with his lecture "Science and Culture," and

Matthew Arnold responded in 1882 with "Literature and Science." C.P. Snow took up the argument again in 1959 in *The Two Cultures,* to be answered by F.R. Leavis in 1962 in *Two Cultures? The Significance of C.P. Snow*. The debate was joined by Lionel Trilling, Martin Green, Richard Wollheim, and others.[1] Yet, all of these contributions had as their focus the definition of being learned, not the issue of communicating science to broader populations, although Harry Levin in 1965 characterized Snow's lecture as an "earnest plea for intercommunication across the high table, as between exponents of the scientific and humanistic disciplines."[2]

Although the issues raised by Huxley, Arnold, and Snow have lost none of their importance, they are generally beyond the scope of this essay. In one significant sense, however, Huxley and Snow, who called for the incorporation of formal science training into the collegiate programs of Cambridge, won a de facto victory. Graduate education generally remains specialized, but the inclusion of both the humanities and the sciences into the undergraduate curriculum of arts and sciences colleges is now almost universal in the United States and Western Europe. On the other hand, numerous technical institutes and engineering colleges have largely excluded the study of both the humanities and the social sciences from the undergraduate core curriculum.

The second meaning of literate—to be able to read and write at a functional level—can be extended to suggest that scientific literacy refers to the ability of the individual to read about, comprehend, and express an opinion on scientific matters.

The development of scientific literacy by a broader public did not become the subject of systematic study until the 1930s, when John Dewey, in a paper entitled "The Supreme Intellectual Obligation," declared that

> the responsibility of science cannot be fulfilled by methods that are chiefly concerned with self-perpetuation of specialized science to the neglect of influencing the much larger number to adopt into the very make-up of their minds those attitudes of openmindedness, intellectual integrity, observation, and interest in testing their opinions and beliefs, that are characteristic of the scientific attitude.[3]

Following Dewey's charge, a number of science educators began to think about the formal definition and measurement of the scientific attitude. Ira C. Davis, for one, believed that the individual who possesses this attitude will "show a willingness to change his opinion on the basis of new evidence; . . . search for the whole truth without prejudice; . . . have a concept of cause and effect relationships; . . . make a habit of basing judgment on fact; and . . . have the ability to distinguish between fact and theory."[4] Victor H. Noll and A.G. Hoff came up with similar definitions, and they began the task of developing items for use in testing.[5] Virtually all of the empirical work done before the Second World War had as its focus the development of a scientific attitude.

With the postwar growth of standardized testing, a number of science educators and test developers began to focus on the level of comprehension of basic scientific constructs and terms. A growing number of studies, epitomized by the standardized tests of the Educational Testing Service (ETS) and the College Board, attempted to chart the level of cognitive scientific knowledge among various groups in the population.

Beginning in the mid-sixties, the National Assessment of Educational Progress (NAEP) started to collect data from national random samples of precollegiate students concerning, among other categories, their level of scientific knowledge. These studies were the first to measure systematically both the understanding of the norms, or processes, of science and the cognitive content of the major disciplines. These two dimensions together—an understanding of the norms of science and knowledge of major scientific constructs—constitute the traditional meaning of scientific literacy as applied to broader populations. But if scientific literacy is to become truly relevant to our contemporary situation, one additional dimension must be added: awareness of the impact of science and technology on society and the policy choices that must inevitably emerge.

About fifteen years ago, concern about the public's knowledge of various scientific or technological public policy issues began to surface. Environmental groups, for example, found that some minimal level of scientific knowledge was necessary if individuals were to understand debates about pollution of the environment. In addition, the increasing number of state referenda on issues such as nuclear power and laetrile were generating apprehension in the scientific community about the public's ability to understand the issues and to make an informed judgment. These concerns echo those of the fifties, when groups opposed to fluoridation of water were able to win referenda on this issue, primarily because the majority of those voting were not scientifically literate. Not able to comprehend the arguments about fluoridation, many voters appeared to prefer not to drink something whose potential effects they did not understand.

In summarizing the case for a broader public understanding of public policy issues—what Benjamin Shen has recently characterized as "civic science literacy"[6]—Robert Morison wrote:

> Science can no longer be content to present itself as an activity independent of the rest of society, governed by its own rules and directed by the inner dynamics of its own processes. Too many of these processes have effects which, though beneficial in many respects, often strike the average man as a threat to his autonomy. Too often science seems to be thrusting society as a whole in directions in which it does not fully understand and which it certainly has not chosen.
>
> The scientific community must redouble its efforts to present science—in the classroom, in the public press, and through education-extension activities of various kinds—as a fully understandable process, "justifiable to man," and controllable by him.[7]

SOME PREVIOUS EMPIRICAL MEASURES

Despite the lively discourse that surrounded the issue of scientific literacy, few efforts were made to measure it for the population broadly, or even for major segments of it. Until the last decade, nearly all the important efforts that were made focused on school populations, most often on small selected sets of schools or classrooms. For a nation generally disposed to social measurement, this was a somewhat disappointing database.

Before analyzing its current levels and distribution, it might be useful to review briefly the previous efforts made to measure scientific literacy from the perspective of its three constitutive dimensions.

The Norms and Methods of Science

Most of the early empirical work in this area had as its focus the definition and measurement of the scientific attitude as described by Dewey. Davis, using examples from the everyday experience of the student, sought to develop sets of items that would create situations to force a judgment. By providing a set of rational, intuitive, or superstitious alternatives, Davis attempted to measure the student's utilization of the scientific attitude. For example, students were presented with statements such as "Red hair means that a person has a fiery temperament," "A disease is a punishment for some particular moral wrong," or "Air is composed of molecules." Davis collected data from approximately one thousand Wisconsin high-school students and teachers, and reached the following conclusions:

1. High-school pupils in Wisconsin are not superstitious.

2. High-school pupils make almost as good records as the teachers.

3. Many of the theories in science are being taught as facts by many of our best teachers.

4. Pupils seem to have a fairly clear concept of the cause and effect relationship, but they do not seem to be able to recognize the adequacy of a supposed cause to produce the given result.

5. Many teachers tend to propagandize their material when there is no scientific evidence for the statements they make.

6. Teachers do not consciously attempt to develop the characteristics of a scientific attitude. If pupils have acquired these characteristics, it has come about by some process of thinking or experiences outside of the science classroom.[8]

Tests similar to those used by Davis, stressing the use of everyday examples to measure the use of scientific thinking, were developed by Noll and Hoff.[9]

In its science testing program, NAEP included a number of items concerning knowledge of scientific norms and the ability to reason to conclusions from relatively simple data. These studies provide the only national estimates of the knowledge levels of scientific norms or the ability of young people to think in logical and ordered terms.

In its 1972-73 assessment of science achievement, students of nine, thirteen, and seventeen years of age were asked to perform a set of simple tests and experiments and to explain the results. Each student, for example, was shown unlabeled pieces of sandstone, quartz, and granite, and asked to select the stone that would "most likely [be] formed under water." The sandstone was selected by 60 percent of the nine-year-olds, 71 percent of the thirteen-year-olds, and 78 percent of the seventeen-year-olds. When asked to explain why they had selected the sandstone, however, only 7 percent of the first group, 15 percent of the second, and 26 percent of the third were able to describe the process of sedimentation, even vaguely, or to provide other acceptable explanations.[10] That similar patterns were found in several other experiments, such as color mixing, temperature mixing, relative volume, rotation and revolution, and simple circuit boards, suggests that much of what may appear to be scientific knowledge in multiple-choice testing is not supported by an *understanding* of the underlying scientific principles and processes.

Unfortunately, the National Assessment did not use multi-item scales extensively, which would have provided more reliable summary measures, preferring instead to collect and report sets of individual test items from year to year. Most of these data are available for secondary analysis, and there is much work to be done in converting this very important archive into analyses to provide a portrait of the level and distribution of precollegiate and young adult understanding of the norms and methods of science.[11]

Cognitive Science Knowledge

As the use of standardized testing expanded during the fifties and sixties, a number of tests were developed to measure a student's knowledge of basic scientific constructs.[12] A majority were used by teachers and school systems to evaluate individual students, to determine admission or placement, or for related academic counseling purposes. While some test score summaries have been published by the ETS and other national testing services, these reports reflect the scores of only those students who plan to attend college or who for some other reason have elected to take the test; and it is this self-selected nature of the student populations involved that continues to raise substantial problems for interpretation and analysis. (The NAEP studies cited previously are noteworthy in that they are the only national data collection program in which the bias of self-selection inherent in voluntary testing programs has been eliminated.)

The only national data set that provides scores of cognitive science knowledge for broad and randomly selected populations is the National Assessment, which for over a decade has periodically collected cognitive science knowledge data from national samples of nine-, thirteen-, and seventeen-year-olds. In some years, a national sample of young adults twenty-six through thirty-five was also used to assess the continuing impact of formal study.

On the basis of three assessments between 1969 and 1977, NAEP found declining science achievement scores for all age groups and almost all socioeconomic subgroups. Female students, black students, students whose parents did not complete high school, and students who live in large central cities were all substantially below the national average in science achievement.[13]

Attitudes toward Organized Science

The third dimension of the scientific literacy typology is an individual's knowledge about what may be generally called organized science—that is, basic science, applied science, and development—and includes both general information about the impact of science on the individual and society and more concrete policy information on specific scientific or technological issues.

The first national study that included a meaningful set of measures of attitudes toward organized science and knowledge about it was a 1957 science news survey conducted by the Survey Research Center at the University of Michigan for the National Association of Science Writers. Although the purpose of the survey was to study the public's interest in science news and its information consumption patterns, the interview schedule also included measures of general attitudes toward organized science and knowledge of it, as well as some issues that were then current.[14]

The survey found that only a minority of the public was strongly interested in scientific issues and that the level of public knowledge about science was relatively low. It found, too, that the public tended to hold high expectations for the future achievements of science and technology, but were aware of the two-edged nature of the scientific enterprise. Stephen Withey summarized the public mood: "On the surface the natives are quiet, supportive, and appreciative but there is some questioning, some alert watching, and considerable mistrust. The public will wait and see; they have no reason to do anything else, and many have no other place to turn."[15]

Beginning in 1972, the National Science Board initiated a biennial survey of public attitudes toward science and technology,[16] which found that the public retained a high level of appreciation and expectation amid signs of an increasing wariness. Yet, there was no evidence to indicate the development of a strong antiscience sentiment.

In subsequent surveys in 1979 and 1981, the focus changed to a more structured approach, in an attempt to identify the segment of the population interested in, and knowledgeable about, science policy matters, and to examine the attitudes of this "attentive public."[17] The results showed that about 20 percent of American adults followed scientific matters regularly and that their attitude toward organized science was more favorable as a rule than that of the general population groups previously measured.

The attitudes of young adults toward organized science was even more positive. In a 1978 national survey of high-school and college students, researchers identified the developmental roots of adult attentiveness to science matters, and determined that the attitudes of these young adults were generally positive and supportive of science.[18] Like older Americans surveyed, however, substantial segments of these young adults were not very interested in, and had little information about, scientific and technological matters. Approximately 90 percent of the high-school students who did not plan to attend college failed to meet minimal criteria for interest in scientific issues or for cognitive knowledge of basic scientific constructs. There is no reason to believe that the next generation will be antiscientific; more likely, it will continue to hold the same attitudes—corrected for the rising levels of educational achievement of the new generation—as do adults today.

That there has been little consensus on a comprehensive definition of scientific literacy seems obvious from the relatively uncoordinated efforts to measure its dimensions. And although a number of partial measures have been developed, we are still without one that will help delineate that segment of the American population that we can call scientifically literate. It is to the task of constructing and analyzing a single measure of scientific literacy that we now turn.

LEVELS AND DISTRIBUTION OF SCIENTIFIC LITERACY

The 1979 National Science Foundation survey of adult attitudes toward science and technology, on which the following examination of the current level of scientific literacy and its distribution in the population is based, included all of the items necessary to measure each of the three dimensions of scientific literacy, and utilized a national probability sample from which valid generalizations can be made.[19] We will look first at the public's ability to understand the process of scientific study, then at their comprehension of selected disciplinary constructs, and finally, examine the public's understanding of some contemporary political issues that involve science and technology. Once each of the dimensions has been measured appropriately, the three facets will be combined into a single measure of scientific literacy.

Understanding the Scientific Approach

The first national survey to measure adult comprehension (as opposed to that of schoolchildren and young adults) of the process of scientific study—what Dewey termed the scientific attitude—was the University of Michigan science news study of 1957. Each respondent was asked to define the meaning of "scientific study," and the open-ended response was coded into a set of categories that reflected various perceptions of scientific study. In reviewing the data, Withey concluded that only about 12 percent could be said to have a reasonable understanding of the term.[20]

The NSF survey included the same question: it asked each respondent to assess whether he or she had a clear understanding of the meaning of scientific study, a general sense of its meaning, or little understanding of its meaning. Those who said they had a clear understanding of the term were asked to explain its meaning in their own words, and the response was recorded verbatim.[21] (The responses were later coded by two coders independently, and those cases that involved disagreements in coding were judged by the coding supervisor.)

Approximately 14 percent of those surveyed were able to provide a minimally acceptable definition[22] of the meaning of scientific study (Table 1), a level of understanding that is not statistically different from the 12 percent previously recorded. There has apparently been little improvement over the last twenty-two years in the proportion of American adults who correctly understand the meaning of scientific study.

Following the multiple measurement principle,[23] the 1979 survey also included a short battery of items about astrology. Each respondent was asked, first, how often he or she read astrology reports, and then to characterize astrology as very, "sort of," or not at all scientific. Eight percent thought astrology was very scientific; 34 said it

TABLE 1. Adults Who Understand the Scientific Approach

	%	N
All adults	9	1,635
Age		
17-34	14	670
35-54	8	492
55 and over	4	473
Gender		
Female	8	862
Male	11	773
Education		
Less than high school	1	465
High-school degree	5	550
Some college	16	382
Baccalaureate degree	24	146
Graduate degree	32	92

was sort of scientific; and half recognized that it is not scientific at all. In general, these responses allowed correction of the results obtained from the question about the meaning of scientific study, because any person who correctly understood the scientific process would have rejected the notion of astrology as scientific. Following this logic, a final measure of understanding of scientific study was constructed: to qualify as understanding the process of scientific investigation, a respondent would have to be able to provide a reasonable definition of scientific study *and* to recognize that astrology is not scientific. Using this yardstick, only 9 percent of those sampled could meet this rather minimal test.

The 1979 data pointed to a strong association between formal education and an understanding of the scientific approach, yet only a third of those with graduate degrees qualified as understanding the process of scientific inquiry. A separate multivariate logit analysis indicated that most of the differences observed by age and gender could be attributed to the level of formal education.

From these data, only one in ten American adults, it appears, understands the meaning of the scientific approach, but other data from the same survey suggest that the majority of the public *can* differentiate between science and pseudoscience in more concrete terms. When asked if the results of animal studies on the safety and efficacy of chemical food additives had induced them to change their eating or food buying habits, 74 percent of the respondents answered in the affirmative, compared to 5 percent who said that astrology reports had prompted them at one time or another to change their plans. As Table 2 shows, although the influence of astrology reports on behavior was significantly associated with low levels of formal education, there was a uniformly high acceptance of the results of animal studies regardless of the level of educational attainment.

In 1979, then, only one in ten American adults understood the meaning of the scientific approach, but a substantially larger proportion of the population did have a high level of confidence—or faith—in what they perceived to be scientific studies.

Understanding Basic Scientific Constructs

The argument here is clear and simple. The individual who does not comprehend basic terms like atom, molecule, cell, gravity, or radiation will find it nearly impossible to follow the public discussion of scientific results or public policy issues pertaining to science and

TABLE 2. Influence of Scientific Studies and Pseudoscientific Reports on Decision-Making (percentage reporting a change in personal behavior)

	Animal Studies	Astrology Reports	N
All adults	74	5	1,635
Age			
17-34	73%	7%	670
35-54	77	4	492
55 and over	74	6	473
Gender			
Female	79	7	862
Male	69	3	773
Education			
Less than high school	71	9	465
High-school degree	75	7	550
Some college	76	3	382
Baccalaureate degree	75	0	146
Graduate degree	78	1	92

technology. In short, a minimal scientific vocabulary is necessary to be scientifically literate.

The 1979 NSF survey included three items—radiation, GNP, and DNA—that may be said to represent basic science and social science terminology. Again, respondents were asked whether they held a clear understanding of each term, a general sense of its meaning, or little understanding of its meaning. Although the accuracy of these self-assessments was not verified, as it was for the understanding of the meaning of scientific study, there is little reason to believe that such checks would not have shown the same discrepancy.[24]

According to the data, about half the respondents thought they had a clear understanding of radiation, about a third thought they understood GNP, and only one in five claimed knowledge of the meaning of DNA (Table 3). Again, there was a strong correlation between knowledge of these terms and the level of formal education.

To provide a single measure of this dimension, a summary index was constructed: a respondent would have to report a clear understanding of at least one of the three constructs and not less than a general sense of a second to be classified as knowledgeable about basic scientific constructs. Exactly half met this requirement. Formal education was once again the key determinant: 96 percent of those

TABLE 3. Adults Reporting a Clear Understanding of Basic Scientific Concepts

	Radiation	GNP	DNA	High on Index	N
All adults	49	31	22	50	1,635
Age					
17–34	44%	43%	21%	64%	670
35–54	49	30	17	47	492
55 and over	39	23	10	34	473
Gender					
Female	41	21	20	43	862
Male	58	43	26	59	773
Education					
Less than high school	30	7	3	18	465
High-school degree	47	23	15	45	550
Some college	60	47	37	72	382
Baccalaureate degree	70	67	52	88	146
Graduate degree	78	80	57	96	92

holding graduate degrees met the criterion in contrast to only 18 percent of those without a high-school diploma.

Understanding of Science Policy Issues

As science becomes increasingly dependent upon public support, and as public regulation reaches deeper into the conduct of organized science, the frequency and importance of science policy issues on the national agenda will undoubtedly increase. Slightly over half the bills introduced in Congress involve science or technology in some degree,[25] and the establishment of the standing Committee on Science and Technology in the House of Representatives attests to the importance of scientific and technological issues in the national political system.

The 1979 NSF survey provides a useful measure of the third dimension of scientific literacy—the understanding of some of the major public policy issues that involve or directly affect the conduct of science and technology. The survey includes separate batteries of items about three controversies—the use of chemical additives in food, nuclear power, and space exploration. For each, respondents were asked to cite two potential benefits and two potential harms. Approximately two thirds cited at least two benefits or dangers (or one of each) for food additives and nuclear power, but only a third were similarly knowledgeable about the potential benefits and harms

TABLE 4. Adults with High Score on Selected Science-Related Public Policy Issues

	Nuclear Power	Food Additives	Space Program	High on Index	N
All adults	68	61	32	41	1,635
Age					
17–34	71%	68%	42%	51%	670
35–54	70	63	30	38	492
55 and over	62	52	20	30	473
Gender					
Female	62	60	26	34	862
Male	73	63	38	48	773
Education					
Less than high school	50	37	16	16	465
High-school degree	66	62	28	37	550
Some college	80	75	43	55	382
Baccalaureate degree	87	84	47	68	146
Graduate degree	89	91	58	81	92

of space exploration (Table 4). As with the other two dimensions of scientific literacy, the level of formal education related positively to how well informed the respondent was.

To be counted among those knowledgeable about scientific and technological public policy issues, a respondent had to name a minimum of six potential benefits or harms out of a possible twelve—the single criterion devised to measure this dimension of scientific literacy. Approximately 41 percent qualified.

Using the three dimensions described in the preceding section, a single measure of scientific literacy was constructed that required a minimally acceptable score in all three areas for an individual to be considered scientifically literate. On the basis of this measure, only 7 percent of the respondents—primarily males, individuals over thirty-five, and college graduates—qualified (Table 5). But even among holders of graduate degrees, only a quarter could be called scientifically literate.

IMPLICATIONS FOR A DEMOCRATIC SOCIETY

Assuming that this estimate is correct, that the overwhelming majority of the American adult population is scientifically *il*literate,

TABLE 5. The Percentage of the Public Classified as Scientifically Literate

	Scientifically Literate	
All adults	7	
Age		
17–34	11%	
35–54	7	
55 and over	3	473
Gender		
Female	6	867
Male	9	773
Education		
Less than high school	0	465
High-school degree	2	550
Some college	14	382
Baccalaureate degree	22	146
Graduate degree	26	92

what are the implications for our political system? How is science policy to be made? Can the basic tenets of a participatory political system be maintained? These issues can only be addressed, I believe, by placing them in the context of the general process of political specialization that has become the hallmark of American politics in recent decades.

Political Specialization

No individual today, no matter how good his or her intentions, can hope to acquire and maintain a mastery of more than a few political issues at one time. Thus the modern citizen who chooses to follow political affairs opts for political specialization—that is, selects out of the myriad issues those few in which he or she is willing to invest the time and other resources necessary to become and remain informed.

The need for specialization springs from a combination of two basic forces. First, participation in the political process is but one of the many demands on the time of contemporary men and women. That many adults choose to devote a smaller share of their time to political affairs, in favor of more attractive, perhaps more personally satisfying alternatives, can be seen in the steady decline of public participation in the political system over the last four decades. Even presidential elections, which command the highest levels of public concern and participation, attract barely half the eligible adults in the United States.

Second, the specialized information required to be knowledgeable about almost any given political issue is increasing rapidly. Issues involving science fall into this category, as do most of the issues on the national political agenda. For example, an area like economic policy—often referred to as the pocketbook issue—has become increasingly complex and is beyond the ken of a substantial majority of American adults. If only 31 percent of the adult population professed to have a clear understanding of a term like GNP,[26] how many citizens, then, might be expected to comprehend the current debate over "supply-side economics" or the fate of the dollar in international monetary markets?

Both forces have worked to narrow the political horizon of most American adults. Unlike "single-issue" politics, where the interest of the participant revolves totally around one strongly felt political position, political specialization is a rational and gradual narrowing of the number of topics on which an individual can hope to remain adequately informed. Even then, they are not nearly as well informed about an issue as their interest would imply.

How does this specialization process affect the more general political system? Three decades ago, Gabriel Almond described the process as it applied to public attitudes toward foreign policy and public participation in its formulation. In his original work, he illustrated, in stratified pyramidal form, the types of public participation in the political process that were likely to occur under conditions of issue specialization (Figure 1).[27] At the pinnacle are those who have the power to make binding policy decisions, a group that would include a mix of executive, legislative, and judicial officers. In the case of science policy, the officers would be primarily at the federal level.

Nongovernmental policy leaders, often referred to as elites in political science, comprise the second level. This group interacts regularly with the decision-makers, and from time to time, as noted by James Rosenau and others, there is some flow of elites into decision-making posts, and of decision-makers into the leadership group.[28] When there is a high level of concurrence between the decision-makers and the leadership group, policy is made, and normally there is no wider public participation in the policy process. The policy leadership group may itself divide on some issues. In this case, appeals may be

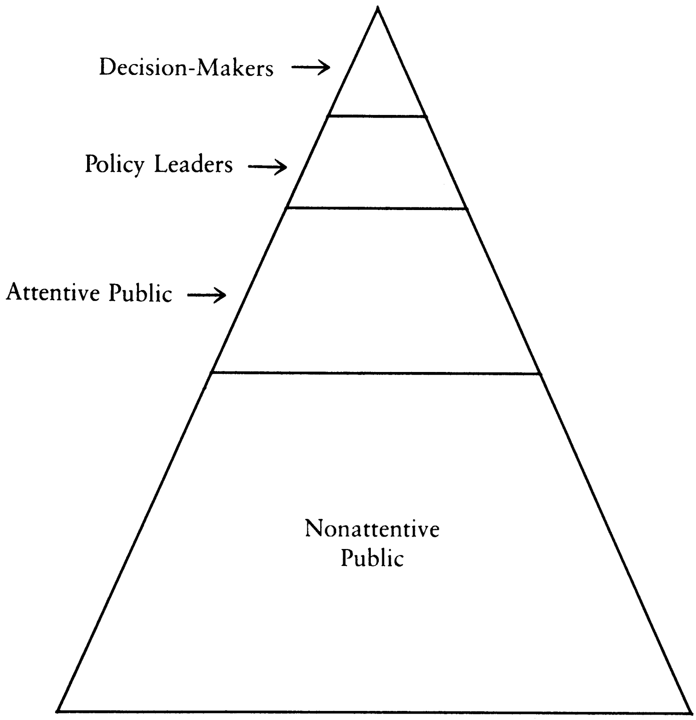

Figure 1. A Stratified Model of Science and Technology Policy Formulation

made to the attentive public—the third level—to join in the policy process and to try to influence decision-makers by contacting them directly and by persuasion. The attentive public is composed of individuals interested in a particular policy area and willing to become and remain knowledgeable about the issue. In 1979 the attentive public for science policy included about 27 million adults, or about 18 percent of the adult population.[29]

Although the processes for mobilizing the attentive public for science policy are only now being studied, the flow of appeals from leaders to the attentive public apparently takes place through professional organizations, specialized journals and magazines, and employment-related institutions. The flow of concerns from the attentive public to the decision-makers, on the other hand, undoubtedly goes through the traditional avenues of letter writing and telephone and personal contacts.

The attentive public also becomes involved when there is a high degree of consensus among the leadership group but a lack of concurrence by some or all of the decision-makers. In this case, the leadership groups work to mobilize the attentive public to contact the decision-makers and to argue directly for the preferred policy. The recent discussions of federal funding for science illustrate this case.

At the bottom of the pyramid is the general, or nonattentive, public. For the most part, these individuals have little interest in science policy and a low level of knowledge about organized science. Two very important points must be understood about this group, however. First, should the general population become sufficiently unhappy about the policies that the decision-makers, leaders, and the attentive public have fostered in any area, it can exercise a political veto. The public's role in ending the wars in Korea and Vietnam illustrate how powerful this option can be. It is this very ability of the general population to intervene and veto that sustains the democratic nature of the policy formulation process.

Second, it is important not to equate nonattentiveness to science policy with ignorance or lack of intellectual activity. We are all nonattentive to a vast number of issues. Many of the nonattentive public may be well educated, interested in other issues and knowledgeable about them, and politically active. According to the data from the 1979 NSF survey, about half of the adult population in the United States at the time of the survey were attentive to one or more political issues.[30]

Scientific Literacy and the Formulation of Science Policy

Given this stratified decision-making process, the low level of scientific literacy raises two important problems. First, among the 80 percent of the population not attentive to science policy, the level of scientific literacy is extraordinarily low—in the 2 to 3 percent range. In the context of the political specialization process, we would not expect a very high rate of scientific literacy in the nonattentive public, and few voters would be expected to make their choices primarily on the basis of scientific or technological issues. Yet in recent years, an increasing number of referenda have concerned issues related to science or technology—nuclear power, laetrile, recombinant DNA facilities, fluoridation—and it is apparent that a substantial majority of the general electorate will not be able to make informed judgments on these issues.

Second, approximately 70 percent of the attentive public for science policy did *not* meet the minimal criteria for scientific literacy. This is a surprising result, but not an inexplicable one. Almost half of the adult population had a minimal facility with basic scientific terms

(Table 3), and 40 percent had at least a minimal level of issue information (Table 4). Many of these individuals may have had a high level of interest in one or more science-related issues and may have followed them through popular magazines such as *Science 83, Smithsonian, National Geographic, Discover,* or *Omni,* without understanding the scientific processes involved. They would perhaps have more difficulty comprehending articles in *Science, Scientific American,* or in professional or disciplinary journals, but can undoubtedly write very clear letters to their congressmen and senators. They would appear to be dependent upon science journalists to "interpret" the scientific debate on most issues.

As more appeals are made to the attentive public to pressure directly for public policy outcomes, the importance of this group will grow. Yet, the situation is a fragile one. Given the large numbers in this group who are dependent on "translators," the personality or philosophical perspective of the translator may become as important—if not more so—than the substance of the scientific arguments.

There are compelling cultural, economic, and political arguments for a major effort to expand scientific literacy in both the general and attentive publics. In my opinion, the most effective place to start is in the elementary and secondary schools—a point on which other contributors to this issue will elaborate. Beyond improved science education at this level, I would urge that high priority be placed on the expansion of scientific literacy among the attentive public for science policy, both in terms of increasing their overall numbers and in augmenting their basic level of literacy. What makes political specialization possible is just this basic level of literacy in any given issue area. There is an interested audience searching for more sophisticated information than is normally available in the news media. The extraordinary growth of semisophisticated science magazines like *Discover, Omni,* and *Science 83,* for example, represents in large part the desire for more and better information among the attentive public for science policy.

From Dewey to Morison, the scientific community has been urged to communicate more effectively and openly with the public, especially the informed public—and scientists and engineers are responding by showing a new level of willingness to explain their problems and aspirations to interested lay audiences. But if this communication is to continue and expand so that the science policy process can function effectively, there must be an audience capable of understanding both the substance of the arguments and the basic processes of science. We can accomplish this by addressing, without delay, the educational needs of the attentive public for science policy.

ENDNOTES

[1]Martin Green, "A Literary Defense of 'The Two Cultures,' " *The Kenyon Review* (1962): 731-39; Thomas H. Huxley, "Science and Culture," in *Collected Essays* (New York: Appleton, 1898); F.R. Leavis, *Two Cultures? The Significance of C.P. Snow* (New York: Pantheon Books, 1963); C.P. Snow, *The Two Cultures and the Scientific Revolution* (New York: Cambridge University Press, 1959); Lionel Trilling, "Science, Literature and Culture: A Comment on the Leavis-Snow Controversy," *Commentary* 1962, pp. 461-77; Richard Wollheim, "Grounds for Approval," *The Spectator* 1959, pp. 168-69.

[2]Harry Levin, "Semantics of Culture," in *Science and Culture,* edited by Gerald Holton (Boston: Beacon Press, 1965), p. 2.

[3]John Dewey, "The Supreme Intellectual Obligation," *Science Education.* 18 (1934): 1-4.

[4]Ira C. Davis, "The Measurement of Scientific Attitudes," *Science Education* 19 (1935): 117-22.

[5]A.G. Hoff, "A Test for Scientific Attitude," *School Science and Mathematics* 36 (1936): 763-70; Victor H. Noll, "Measuring the Scientific Attitude," *Journal of Abnormal and Social Psychology* 30 (1935): 145-54.

[6]Benjamin Shen, "Scientific Literacy and the Public Understanding of Science," in *Communication of Scientific Information,* edited by S. Day (Basel: Karger, 1975).

[7]Robert S. Morison, "Science and Social Attitudes," *Science* 165 (1969): 150-56.

[8]Davis, "The Measurement of Scientific Attitudes."

[9]Hoff, "A Test for Scientific Attitude," and Noll, "Measuring the Scientific Attitude."

[10]National Assessment of Educational Progress, *Selected Results for the National Assessments of Science: Scientific Principles and Procedures,* Science Report No. 04-S-02 (Denver: Educational Commission of the States, 1975).

[11]Jon D. Miller, "Secondary Analysis and Science Education," *Journal of Research in Science Teaching* 19 (1982): 719-25.

[12]Oscar K. Buros, *The Sixth Mental Measurements Yearbook.* (Highland Park, New Jersey: Gryphon Press, 1965).

[13]National Assessment of Educational Progress, *Three National Assessments of Science: 1969-1977,* Science Report No. 08-S-00 (Denver: Educational Commission of the States, 1978a); and *Science Achievement in the Schools,* No. 08-S-01 (Denver: Educational Commission of the States, 1978b).

[14]Robert C. Davis, *The Public Impact of Science in the Mass Media,* Survey Research Center, Monograph No. 25, University of Michigan, Ann Arbor, 1958; and Stephen B. Withey, "Public Opinion about Science and the Scientists," *Public Opinion Quarterly* 23 (1959): 382-88.

[15]Withey, Ibid.

[16]National Science Board, *Science Indicators 1972*; *Science Indicators 1974*; *Science Indicators 1976*; and *Science Indicators 1980* (Washington, D.C.: Government Printing office, 1973, 1975, 1977, 1981).

[17]Jon D. Miller, *The American People and Science Policy* (New York: Pergamon, 1983); Jon D. Miller, Kenneth Prewitt, and Robert Pearson, *The Attitudes of the U.S. Public toward Science and Technology,* a final report to the National Science Foundation, 1980.

[18]Jon D. Miller, Robert W. Suchner, and Alan V. Voelker, *Citizenship in an Age of Science* (New York: Pergamon, 1980).

[19]The 1979 survey collected personal interviews from a national stratified cluster sample of 1,635 adults. The field work was performed by the Institute for Survey Research at Temple University, and the interviews averaged fifty-five minutes in length. For a full description of the sample selection methods and the interview instrument, see Miller et al., *The Attitudes of the U.S. Public toward Science and Technology.*

[20]Withey, "Public Opinion about Science."

[21]The questions concerning the understanding of scientific study are illustrative of the limitations and utility of survey measurements. Asking an individual if he or she has a clear understanding of the meaning of scientific study is inherently subjective. Undoubtedly some individuals overestimated their level of understanding, while others underestimated it. Yet, the subjective nature of the response is also its strength, since a person who does not think that he or she understands the term would be unlikely to utilize it in communicating with others. The pairing of this subjective query with the more objective and substantive follow-up definition and astrology questions allowed for a correction for overestimates of understanding in the subjective query. The resulting estimate of the proportion of adults with an understanding of the meaning of scientific study should be taken as an upper limit on the occurrence of this understanding under more rigorous measurement methods.

[22]To be classified as understanding the process of scientific study, a respondent had to report that scientific study involved (1) the advancement and potential falsification of generalizations and hypotheses, leading to the creation of theory, (2) the investigation of a subject with an open mind and a willingness to consider all evidence in determining results, or (3) the use of experimental or similar methods of controlled comparison or systematic observation. Responses that characterized scientific study as the accumulation of facts, the use of specific instruments (i.e., looking at things through a microscope), or as simply careful study, were coded as incorrect.

[23]Donald T. Campbell and Donald W. Fiske, "Convergent and Discriminant Validation by the Multitrait-Multimethod Matrix," *Psychology Bulletin* 56 (1959): 81-105.

[24]As I pointed out in note 21, it is important to note the limitations inherent in these measures. If probes had been employed for this second question, some of the respondents who rated their understanding of these terms to be high would have been reclassified downward. These estimates should be taken as upper limits of the true value in the population.

[25]Shen, "Scientific Literacy and the Public Understanding of Science."

[26]Miller et al., *The Attitudes of the U.S. Public toward Science and Technology.*

[27]Gabriel Almond, *The American People and Foreign Policy* (New York: Harcourt Brace, 1950).

[28]James Rosenau, *Citizenship Between Elections* (New York: Free Press, 1974).

[29]Miller, *The American People and Science Policy;* Miller et al., *The Attitudes of the U.S. Public toward Science and Technology.*

[30]Miller et al., *The Attitudes of the U.S. Public toward Science and Technology.*