Public Understanding of Science: Science Literacy and Its Implications for Effective Public Policy Formulation

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PUBLIC UNDERSTANDING OF SCIENCE: 
SCIENCE LITERACY AND ITS IMPLICATIONS FOR 
EFFECTIVE PUBLIC POLICY FORMULATION

BY
SARA C. HICKOX

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I. INTRODUCTION

During the past decade, the results of many published surveys, conducted both in the U.S. and abroad, have pointed to vast weaknesses in the public's understanding of science and technology, and the impact of this deficiency on public policy formulation. Alternatively, complementing studies have focused upon how scientists, educators, and the media are making an effort to ameliorate the problem of scientific illiteracy and how scientific and technological information can best be made accessible to the broad audiences that are seeking a better understanding of science and its implications.

Based on an examination of public policy, science policy, and science education literature pertaining to public understanding of science, it is apparent that the rapid rate of scientific and technological progress in recent decades is forcing the need for a better informed citizenry. It is also clear that science and technology are changing people's lives, for better or worse. As a result, the attendant ethical, moral, political, and educational dilemmas are more encompassing and more complex than ever. The level of the public's scientific literacy has demonstrable economic ramifications as well as an effect on whether citizens are willing and able to participate in the creation of public policy that incorporates scientific and technological underpinnings. The literature offers many examples of the role of education, both formal (private and public elementary, secondary, and undergraduate/graduate collegiate education) and informal/nonformal (newspapers and magazines; television and motion pictures; multimedia and information super highways; museums, science and nature centers, and aquaria; and other nonformal educational outlets), in influencing the degree to which the citizenry is, indeed, active and well informed.
The focus of this paper is to analyze contemporary literature dealing with public understanding of science, the role of the public in formulation of public policy related to science and technology issues, and the role of science education in combating scientific illiteracy. An attempt is made to synthesize information about the state of scientific literacy (sometimes called technological, ecological, or environmental literacy) and to assess the implications of an increase in the public's knowledge of science and technology in their becoming more involved in the public policy arena. Further, this paper addresses the increasingly important role of informal and nonformal education in enhancing and reinforcing the public's basic knowledge of science and technology and related issues that affect their everyday lives and well-being. The specific responsibilities of the media, professional educators, scientists, and universities in combating scientific illiteracy through education and communication are also discussed.
II. DEFINING SCIENTIFIC LITERACY

Scientific literacy is an outgrowth and expansion of general literacy and may often be cited in a more refined way as technological, ecological, or environmental literacy. Traditionally, basic literacy was defined as "...the minimum level of reading and writing skills that an individual must have to participate in written communication."¹ But in more recent decades, basic literacy skills have been redefined to encompass such skills as reading a map or medical instructions on a prescription as well as completing a job application or one's income tax forms. Placing this new "functional literacy" definition in the context of public understanding of science and technology, to be "scientifically literate," one should have "...the level of understanding of science and technology needed to function minimally as citizens and consumers in our society."²

In some cases, authors have taken the definition even one step further to focus not only on having a basic understanding the nature of science and technology, but also a understanding of the broad-reaching consequences of peoples' actions as citizens and consumers. One such definition includes that of David Orr in his newly published book of essays, Ecological Literacy: Education and the Transition to a Postmodern World: "Literacy is the ability to read. Numeracy is the ability to count. Ecological literacy, according the Garrett Hardin, is the ability to ask "What then?"³ Orr goes on to state that the ecologically literate person will "...appreciate something of how social structures, religion, sciences,

²Ibid., 4-5.
technology, patriarchy, culture, agriculture, and human cussedness combine as causes of our (environmental) predicament."4

DIFFERENTIATING BETWEEN SCIENCE AND TECHNOLOGY

While the words "science" and "technology" appear to sometimes be used interchangably, it is appropriate to offer a distinction between the two before going further:

Science can be defined as "a branch of knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws,"5 or "learning or study concerned with demonstrable truths or observable phenomena, and characterized by the systematic applications of the scientific method."6

Technology is "the branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and the environment, drawing upon such subjects as industrial arts, engineering, applied science, and pure science,"7 or "the application of science, especially to industrial or commercial objectives."8

The two terms are inevitably intertwined. In the preface of his book, In Defence of Science: Science, Technology and Politics in Modern Society, J.W. Grove offers his differentiation between science and technology and their connection to public policy:

4Ibid., 93.
7Random House, supra note 5, 1950.
8American Heritage, supra note 6, 1698.
Scientists study nature; but nature places constraints on what they can discover about it. Scientific knowledge is often useful and thus feeds technology; but technology, in turn, affects the practice of science, for example by making possible new techniques and instruments. Science impinges on politics when advances in knowledge pose questions for public policy; and politics impinges on science because governments today seek to sponsor and promote scientific work "in the national interest" and control its direction.9

In differentiating between scientists and technologists, Malcolm Goggin, in the introduction of his book *Governing Science and Technology in a Democracy*, offers his clarification:

Scientists are the source of new discoveries. Claiming to be objective and precise, scientists supposedly pursue knowledge without regard to ends. Technologists, on the other hand, apply the discoveries of scientists in the service of economic and political ends. They see knowledge as solving socially defined problems.10

While many authors have offered their definitions of scientific literacy, in almost every case, their definitions point to two very different, yet complementary needs that citizens have for becoming scientifically literate:

1. **Economic**: to prepare themselves for a future heavily dependent on science and technology affording individuals and nations the ability to compete in an increasingly technical and international workforce (including the need for future scientists and engineers).

2. **Public Policy**: to be a member of an informed electorate with the ability to participate the policy debates that make our country a democracy (including the capability to make wise consumer choices).11

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Another approach to this two-pronged, economic/public policy definition of scientific literacy is presented by Dorothy Howell in her 1992 book entitled, *Scientific Literacy and Environmental Policy: The Missing Prerequisite for Sound Decision Making*:

On the one hand, it [scientific literacy] assumes the abilities to read with comprehension news items on science and to apply scientific information to personal decisions on emerging policy based on science. On the other it instills the capacity for meaningful participation in policy formulation through recognition of relevant issues with an appreciation of the underlying science and technology, including a realistic view of their limitations.12

**SCIENTIFIC LITERACY FROM AN ECONOMIC POINT OF VIEW**

Concern over scientific illiteracy from an economic point of view is surely not a new concept. As early as 1897, Sir Kenneth Dunham, an industrial chemist and president of the British Association for the Advancement of Science, "...feared the economic consequences of the public's lack of understanding of science."13 He was concerned that the "...general public's ignorance of and indifference toward science, which often shaded into downright hostility toward technology, would disadvantage the U.K. in its efforts to compete in the international high-technology marketplace."14 Nearly a century later, Jon D. Miller, Vice President of the Chicago Academy of Sciences and author of numerous studies on public understanding of science, reiterates Dunham's concerns:

Today's children—the next generation—will undoubtedly live in a significantly more scientific and technological culture....In this kind of economy, a basic understanding of science and technology will be the starting point for the development of the additional

12Howell, *Scientific Literacy*, supra note 11, xv.
14Ibid., 575-6.
professional and technical skills needed to be competitive in an era of intense international economic competition."15

A 1987 National Science Foundation report, *Undergraduate Science, Mathematics and Engineering Education*, also highlights the shift toward a global economy and the increased need for understanding the impact of science on our lives and our economy. The report identifies a need for "...the best technically trained, most inventive and adaptable work force of any nation...."16 Richard Atkinson, in his 1990 presidential address to the American Association for the Advancement of Science (AAAS), describes the supply and demand for scientists and engineers and notes that the projected shortage of technical personnel, trained both at the baccalaureate and graduate level, "...will have a major impact on economic growth, international competitiveness, and national security."17 For Ph.D. level scientists alone, National Science Foundation studies predict that by the year 2000, there will be a shortage of a half-million scientists and engineers in the United States.

Noting the unique nature of scientific careers today, Daniel E. Koshland, *Science* editor, comments:

An interesting feature of modern careers is that they have become more reversible. The flow between industry and academia goes both ways in this era...The rapid pace of modern science means that few people today are doing exactly what they were trained to do when they completed their degrees. New instruments, new concepts, and new protocols make yesterday's training obsolete at an alarming rate.18

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15 Miller, "Public Understanding of Science and Technology in the United States," *supra* note 11.
16 Hanson, "Science Literacy," *supra* note 11, 105.
Nevertheless, even with this flexibility, policy makers are worried about the manpower shortages and the outfall of scientific illiteracy—"...the demographic time bomb that will worsen the skills shortage, especially in science, information technology, and engineering."19

Not only is the public having to adapt to a more scientific world in the workplace and on the homefront, but so is the political system. Gabriel Almond and G. Bingham Powell present their views on sources of change in the political system in their 1966 book, *Comparative Politics: A Developmental Approach*. In it they describe industrial, technological, and scientific revolutions as some of the strongest forces of socio-economic change:

Throughout the past few centuries people have witnessed remarkable changes in man's way of life and thought. These changes have been, in large part, associated with the economic advantages of the specialization of labor and the adoption of new technologies to master the environment. Among the consequences of these changes has been an increasingly widespread belief that the conditions of life are not inevitably fixed, that they can be altered through human action. Associated secondarily with these changes have been the processes of urbanization and education, a radical growth in communication and in interdependence of thought and economic activity, and in most cases a real improvement in the physical conditions of life.20

**Scientific Literacy from a Public Policy Point of View**

For the public to play an informed and contributing role in governing, it must be up to the challenges brought about by fast-paced socio-economic change. In Miller's most

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recent study on public understanding of science published in 1990, he peers ahead into the 1990s and the early decades of the 21st century and concludes:

It is clear that national, state, and local political agendas will include an increasing number of important scientific and technological controversies in the years ahead...the number of public policy controversies that require some scientific or technological knowledge for effective participation has been increasing...it is important to note now that the public plays the role of final arbiter in disputes, especially when the scientific community and the political leadership are divided on a particular issue....The preservation of the democratic process demands that there will be a sufficient number of citizens able to understand the issues, deliberate the alternatives, and adopt public policy."21

As stated in the introduction to Howell's book on scientific literacy and environmental policy, "...scientific illiteracy has disenfranchised society in the United States in decisions ranging from personal health...to environmental quality....there is little hope for sound policy formulation in these programs until nationwide scientific literacy is actively practiced...." Howell goes on to state:

Basic to our democratic republic is the active participation of the electorate in governing. Public policy is the responsibility of the people it is intended to serve. Participation is expected (if not invited or actually demanded) in all areas of formal policymaking, from legislation through adjudication of its provisions in court. But no one can deny the recent emergence of novel problems inhibiting meaningful involvement by the public at large. These fundamental problems are exacerbated whenever a national policy is evolving at the intersection where law and politics meet science and technology.22

For people to play an effective role in public policy debates, scientists and technologists must also be willing and able to interpret and share the information they

21 Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 2.
22 Howell, Scientific Literacy, supra note 11, 3.
generate. Accordingly, the public must have the capability to understand the implications of this scientific and technological information made available to them if they are to make informed choices regarding the public policy issues put before them. There is, however, a growing concern for ineffective communication and transfer of knowledge as one of the major shortcomings in our educational system relating to scientific and technological literacy. As Howell contends:

With astonishing acceleration, scientific advances are entering the marketplace without much opportunity for public reflection. Perceived hazards may subsequently come before our institutions of policy formulation, only to be resolved in the absence of informed participation by society at large. In the marketplace and throughout the politico-legal system, policy evolves through a balancing among vested interests. Underlying realities of science and technology are propounded with little regard for their effective communication across disciplinary lines or to the lay public. The result is frequently beneficial to one particularly articulate sector at the expense of others, including the larger society. In the process, science and technology themselves become garbled, if not lost entirely.23

23Ibid., xiv.
III. FORMULATING SCIENCE AND TECHNOLOGY PUBLIC POLICY

To further discuss the role of scientific literacy in the public policy arena, it is first necessary to identify the public policy formulation players in that arena. "Who actually governs?" is a question asked by many, including Robert Dahl, in his classic Who Governs?: Democracy and Power in an American City. He notes, "In a political system where nearly every adult may vote but where knowledge, wealth, social position, and access to officials and other resources are unequally distributed, who actually governs?"24

THE PUBLIC POLICY FORMULATION PLAYERS

Subsets of the citizenry can become involved in policy formulation process at different times and for many different reasons. In a landmark 1950 study of public participation in the formulation of foreign policy,25 Professor Gabriel A. Almond used the phrase "attentive public" to refer to an "informed and interested stratum—before whom elite discussion and controversy take place."26 He defines a structure of "elites" that is subdivided into "political, administrative-bureaucratic, interest, and communications elites"—the players that participate in foreign policy "initiation and formulation."27 The political elite are elected, high appointives and leaders of parties; the administrative-bureaucratic elite include professionals who have special powers because of their "...interest in and familiarity and immediate contact with particular policy problems; " the interest elites represent "...private, policy-oriented associations...which in their variety

26Ibid., 139.
27Ibid., 139-40.
reflect the economic, ethnic, religious, and ideological complexity of the American population," and the communications elites are the "...owners, controllers, and active participants of the mass media—radio, press, and movies."\textsuperscript{28}

To better relate Almond's structure to the science and technology public policy agenda, Miller further refines and expands upon Almond's model. He devises a broader, pyramidal structure which includes five categories of players—decision makers, policy leaders, attentive public, interested public, and non-attentive public.\textsuperscript{29} This pyramidal structure (see Figure 1) identifies the relative status and illustrates the role of the various players in the policy formulation process for specialized issues, such as those represented by science and technology issues today.

**DECISION MAKERS**

Voters generally are responsible for selecting this central set of players in the policy making system, with ballots often cast based not on the issues themselves, but on the basis of "...broader considerations of a sense of competence and shared values or concerns"\textsuperscript{30} expressed by the candidate. Decision makers are congressional members and leaders who "...sit on or chair committees with jurisdictions over science and technology issues as well as executive branch officers with decision authority relevant to these issues."\textsuperscript{31} In all, at the federal level, there are about 100 individuals in the congressional and executive branches that represent this group. Their level of scientific literacy may vary. There is a relatively high level of stability in this group, as witnessed by the high rate of incumbent reelection.\textsuperscript{32}

\textsuperscript{28}\textit{Ibid.}, 139-40.
\textsuperscript{29}Miller, "Public Understanding of Science and Technology in the United States," \textit{supra} note 1, 29.
\textsuperscript{30}\textit{Ibid.}, 113.
\textsuperscript{31}\textit{Ibid.}, 109-10.
\textsuperscript{32}\textit{Ibid.}, 110.
FIGURE 1

PLAYERS IN THE POLICY FORMULATION PROCESS

Decision Makers
Policy Leaders
Attentive Public
Interested Public
Non-Attentive Public

33Ibid., 29.
POLICY LEADERS

Policy leaders are generally selected by democratic procedures within the scientific organizations or disciplines they represent, or given this role because of the office or position they hold in a corporation, organization, or educational institution. There are approximately 5,000 individuals who can be considered science and technology policy leaders. They represent groups including:

- Officers of major scientific and technical societies and associations
- Members of the National Academy of Science, National Academy of Engineering, and the Institute of Medical Sciences
- Directors and principal officers of major scientific and engineering companies
- Presidents and deans of major universities engaged in scientific and engineering research and education
- Scientists, engineers, and others who testify before congressional committees on science and technology issues
- Scientists, engineers, and others who serve on departmental level science and technology policy advisory committees in the executive branch
- Scientists, engineers, and others who publish important books and articles on science and technology policy
- Science journalists who work for national media

ATTENTIVE PUBLIC

From Miller and Almond's perspective, the "attentive" public are individuals who are "...interested in a given policy area, knowledgeable about the area, and are regular consumers of relevant information." While there is an attentive public for almost every specialized issue, "...most citizens who follow public policy issues at all tend to be attentive to two, three, or four issue areas."
Miller's research points out that the attentive public are self-selected individuals who read about the issues and discuss policy alternatives with friends and colleagues who have similar interests. He notes, "...the attentives do not formulate the national policy agenda or play a significant of a role in the daily negotiations of public policy relevant to science and technology." However, when there is a conflict or dispute in the system, typically when the decision makers and policy leaders cannot find a solution, the system turns to the attentive public to resolve the issues through letter-writing campaigns, direct contact with legislators, or other vehicles. The problem is that many of those attentive for a particular issue, making them willing to actively engage themselves in the public policy debate, are not themselves scientifically literate.

Miller summarizes the need for scientific literacy among the attentive public:

When an issue or controversy cannot be resolved at the leadership level, it is essential that there be a sufficient number of citizens who are attentive to that area and who are able to listen to and comprehend the debates among the leaders about the issue. While it is essential that attentive citizens think of themselves as being sufficiently well informed to enter the policy debate via letters or direct contacting, it is also important that these attentives also know enough about science, mathematics, and technology—to be scientifically literate—to follow and evaluate the major competing arguments about an issue.

The sad state of affairs is, as Miller's 1990 survey indicates, "...the overwhelming majority of the members of all of the attentive publics relative to science and technology policy fail to meet the minimal standards for scientific literacy." Relating Miller's findings to the

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38Ibid., 38.
39Ibid., 38.
40Ibid., 38-9.
41Ibid., 13 and 39. For the purposes of Miller's studies, he defines an "Index of Scientific Literacy" where scientific literacy is defined as having a minimal understanding of the processes of science, a minimal understanding of the scientific terms and informedness concepts, and a minimal understanding of the impact of science on society.
demographics in the U.S., while 36 million Americans were attentive to science and policy issues (with two-thirds having not completed a baccalaureate), only about three percent of Americans adults are both attentive and minimally scientifically literate—or only about five million of 180 million adults.\(^{42}\) It is clear there is still room for improvement in the level of scientific literacy of the attentives as well as in mobilizing more citizens to become attentive to issues in the first place.

**INTERESTED PUBLIC**

The interested public is comprised of citizens who show "...a high level of interest in an issue area, but who do not think they are very well informed about it."\(^{43}\) While normally not likely to engage in public policy debate, the interested public may actually become attentive to a specific issue, especially during a time of controversy, especially if they were to perceive that they became better informed about the issue.\(^{44}\) It is important to note that "...an individual's decision to become involved in the policy formulation or conflict resolution process is based on his or her perception of being well informed, not on an objective measurement of level of information.\(^{45}\)

Table 1 illustrates survey results of respondent's self-perception of their interest in, informedness about, and attentiveness to selected science and technology policy issues as reported in Miller's 1990 study:

\(^{42}\)Ibid., 36-9.
\(^{43}\)Ibid., 30.
\(^{44}\)Ibid., 30.
\(^{45}\)Ibid., 27.
### TABLE 1
**INTEREST IN, INFORMEDNESS ABOUT, AND ATTENTIVENESS TO SELECTED PUBLIC POLICY ISSUES, 1990**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Very Interested</th>
<th>Very Well Informed</th>
<th>Attentive Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issues about new scientific discoveries</td>
<td>39%</td>
<td>14%</td>
<td>8%</td>
</tr>
<tr>
<td>Issues about new medical discoveries</td>
<td>68</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>Issues about the use of new inventions and technologies</td>
<td>39</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Issues about the use of nuclear energy to generate electricity</td>
<td>42</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Issues about space exploration</td>
<td>26</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Issues about environmental pollution</td>
<td>64</td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td>Economic issues and business conditions</td>
<td>51</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>International and foreign policy issues</td>
<td>48</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>Issues about military and defense policy</td>
<td>55</td>
<td>26</td>
<td>17</td>
</tr>
<tr>
<td>Agricultural and farm issues</td>
<td>24</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Local school issues</td>
<td>50</td>
<td>32</td>
<td>27</td>
</tr>
</tbody>
</table>

n=2033

**NON-ATTENTIVE PUBLIC**

Showing both a low level of interest in and knowledge about a given policy area, the non-attentive public does retain its political veto power over issues should it become sufficiently unhappy about a particular policy. Because all citizens are non-attentive to many areas and issues at any given time (Miller's earlier findings indicate that the time, energy, and resources an individual is willing to devote to becoming and remaining involved in policy issues and public affairs is limited), it does not necessarily mean that an individual might not be mobilized into attentiveness to a new issue should the decision to refocus their efforts be made.

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GOVERNING SCIENCE AND TECHNOLOGY DEMOCRATICALLY

To engage individuals in the public policy process, it is important to keep in mind Miller's contention that only a very small percentage of the population is actually attentive to science and technology issues—and a vast majority of those do not have a sound intellectual backing or real understanding of the issues. This pervasive level of scientific illiteracy is one of the key elements to consider when designing and targeting informational and educational campaigns designed to bring more individuals into the democratic policymaking process. Not only must the policy players become attentive to and engaged with the issues, but they must also be properly educated as to the complexities of the issues, aware of how, where, and when to interject themselves into the policymaking process.

Malcolm Goggin's framework for democratic science and technology public policy formulation and governance (see Table 2) assesses the changes taking place in science, technology, and society; the challenges posed by changes; the opportunities for response to the challenges and their inadequacies; and the possible solutions to the crises of who should govern, when governing should take place, and where the authority for governance should be lodged.
<table>
<thead>
<tr>
<th>Changes</th>
<th>Challenges</th>
<th>Responses</th>
<th>Policy Problems Arising from Democratic Governance</th>
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<td>1) Scale and complexity of science and technology</td>
<td>a. Fraud and abuse of human subjects</td>
<td>a. Committees</td>
<td>Who should govern?</td>
</tr>
<tr>
<td></td>
<td>b. Hazardous technologies</td>
<td>b New laws, agencies, and regulations</td>
<td>• A few</td>
</tr>
<tr>
<td></td>
<td>c. Politicization of policy process</td>
<td>c. Reassessment of peer review</td>
<td>• Many</td>
</tr>
<tr>
<td>2) Revolution in biology</td>
<td>a. Commercialization of biology and medicine</td>
<td>a. Litigation</td>
<td>When should governors govern?</td>
</tr>
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<td></td>
<td>b. Conflict of interest</td>
<td>b. Committees</td>
<td>• Inception</td>
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<td>3) New frontiers in basic and applied research</td>
<td>a. Scientist-entrepreneur</td>
<td>a. Committees</td>
<td>• Research protocol</td>
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<td></td>
<td>b. &quot;Disputed&quot; science and technology</td>
<td></td>
<td>• Interpretation</td>
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<td>Where should authority be lodged?</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Centralized</td>
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<td>• Decentralized</td>
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<td>5) Scientific and technological illiteracy</td>
<td>a. Erosion of state and local control</td>
<td>b. New Federalism in science and technology</td>
<td>To what ends should science and technology be directed?</td>
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<td>• Military/commercial</td>
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<td>• Social ends</td>
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49 Goggin, Governing Science and Technology in a Democracy, supra note 10, 8.
50 Title modified by the author.
It is the difficulty (and need for urgency) in answering the very questions raised in Goggin's outline that seem to have an overbearing effect on the push today for a more scientifically and technically literate public. Yet even as far back as the early 1960s, ecologists like Eugene Odum were making their case for a more informed citizenry:

It is mandatory that every young scientist, and indeed every educated person, become acquainted with at least the over-all environmental processes and conditions that make possible the very survival...of individual organisms... In a democracy it is not sufficient just to have a few trained persons who understand...there must also be an alert citizenry.51

Sheila Jasanoff, writing in 1990 in The Fifth Branch: Science Advisors as Policy Makers, describes three phases in the evolution of environmental literacy beginning with the 1960s characterized as "Phase One: Rise of Environmental Consciousness."52 As scientists and the public entered into an era of new environmental awareness, nature and the environment became a subject for public debate. The public generally suffered from a lack of information about emerging environmental issues, and the scientific community was charged with gaining a new understanding of the human uses of nature.53 "Phase Two: The Transition of a Scientific to a Social Movement" encompassed the years 1969 to 1973. There was a peak of interest in environmental issues and the media and public attention was even further focused on environmental issues after the 1972 UN Conference on the Environment. This was also time of passage of environmental legislation such as the Coastal Zone Management Act and the Clean Water Act, issuing in a new era of regulatory

53 Ibid., 96-7.
science which differed from traditional scientific research in that its goals were to provide, where possible, a scientific basis for the policies and regulations being issued under the new laws. During this time, the interests of scientists and environmental activists temporarily merged, and the environmental movement at the time was primarily involved in "spreading knowledge rather than producing it." By 1974 the environment had come to be viewed as a political problem, and environmental groups found it necessary to begin taking specific political stands on environmental issues. The period 1974 through the mid 1980s is characterized as "Phase Three: The Fragmentation of Knowledge Interests." At this point, participation shifted toward use of coercion and power, and scientists began to distance themselves from politically motivated activists.

Out of these tumultuous three decades, clearly distinct sets of goals, incentives, and standards for regulatory science and research science had emerged as described by Jasanoff (see Table 3).

APPROACHES TO PUBLIC POLICY FORMULATION

Different authors describe various approaches to public involvement in the formation of public policy of a scientific and technical nature. In their book, Science, Technology, and Policy Decisions, Hiskes and Hiskes describe three approaches to science and technology policy making: extreme democratization, a conservative approach, and a moderate approach. In extreme democratization, the public is involved at all stages of decision making, although the authors acknowledge that the public is rarely "up to the task

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54Ibid., 98-100.
55Ibid., 102-3.
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<tr>
<th><strong>TABLE 3</strong></th>
<th><strong>REGULATORY SCIENCE AND RESEARCH SCIENCE</strong>&lt;sup&gt;56&lt;/sup&gt;</th>
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<tr>
<td><strong>Regulatory Science</strong></td>
<td><strong>Research Science</strong></td>
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<td><strong>Goals</strong></td>
<td>&quot;Truths&quot; relevant to policy</td>
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<td><strong>Institutions</strong></td>
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<td><strong>Products</strong></td>
<td>Studies and data analyses, often unpublished</td>
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<td><strong>Incentives</strong></td>
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<td><strong>advancement</strong></td>
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<td><strong>Time-frame</strong></td>
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<td>Political pressure</td>
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<td><strong>Options</strong></td>
<td>Acceptance of evidence</td>
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<td><strong>Accountability</strong></td>
<td>Congress, courts, media</td>
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<td><strong>Institutions</strong></td>
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<td><strong>Procedures</strong></td>
<td>Audits and site visits</td>
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<td>Regulatory peer review</td>
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<td>Judicial review</td>
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<td>Legislative oversight</td>
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<td><strong>Standards</strong></td>
<td>Absence of fraud or misrepresentation</td>
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<td>Conformity to approved protocols and agency guidelines</td>
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<td>Legal tests of sufficiency (e.g. substantial evidence, preponderance of the evidence)</td>
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of making complex decisions nor do they want that responsibility." 57 In their conservative approach, citizens "...act as sources of relevant information to be used by governmental policy makers at their discretion." 58 A more moderate approach utilizes the public to actually help define various policy options and their impacts. 59

Hiskes and Hiskes summarize:

Achieving a harmony between science and technology and the interests and concerns of the public is one of the great challenges of the twentieth century. To meet this challenge governmental policy makers must acknowledge the intrinsic ethical and social dimensions of science and technology policy issues and thus expand the range of relevant "experts" beyond scientists and engineers to include members of the general public. At the same time the public must acknowledge the social and ethical significance of scientific and technological developments and prepare for its new role as an "expert" by being informed about the relevant types of consequences. Democracy flourishes only through the joint efforts of a society and its government. 60

Even if citizens do choose to exercise their democratic right to become involved in the policymaking process, Dahl expresses concern for the equality of power they can actually wield:

Now it has always been held that if equality of power among citizens is possible at all—then surely considerable equality of social conditions is a necessary prerequisite. But if, even in América, with its universal creed of democracy and equality, there are great inequalities in the conditions of different citizens, must there not also be great inequalities in the capacities of different citizens to influence the decisions of their various governments? And if, because they are unequal in other conditions, citizens of a democracy are unequal in power to control their government, then who in fact does govern? How does a "democratic" system work amid inequality of resources? 61

58Ibid., 184.
59Ibid., 185.
60Ibid., 185.
But in reality, in the United States, the public is not generally actively involved in the science and technology policy formation process. It is not necessarily a "democratic" system. Most research and regulatory science is funded by federal agencies with the public having little say one how much is spent and to whom research grants and contracts are awarded. When the scientific and technological issues themselves are not in a crisis or dispute situation, the science and technology policy agenda is "...defined by the science and technology policy leaders, and ratified by the decision makers." Miller notes, "When there is substantive agreement between science and technology policy leaders and decision makers, policy is made and there is not further involvement of the attentive public or the electorate."63

Because the formulation of science and technology policy in the United States is generally carried out via a non-electoral process,64 and many of the decision makers outlined earlier by Miller and Almond are not generally elected by the public, voting is not always enough if one wishes to become an active participant in policy formulation. Therefore, the opportunity for involvement of the public in the policy making process is often limited unless a controversy arises, generating pressure to more actively involve the "lower" levels of "attentive" or "interested" publics. But it must be remembered that the policy-making process moves forward irrespective of the consensus of the scientific community. There are always tradeoffs. On the one hand, the merit of available scientific and technological information may be taken into account. On the other, overriding political and social considerations may play a larger role in the outcome of policy decisions. Howell offers a caution: "Scientists will say the jury is still out, while judges and juries (and other

63 Ibid., 110.
64 Ibid., 109.
formulators of policy) decide the issue anyway. While the scientists are still searching out the relevant facts, the formulators of policy will evaluate the available scientific evidence, will make their decisions, and assign responsibilities. 65

PLACING SCIENTIFIC AND TECHNOLOGICAL ISSUES ON THE POLITICAL AGENDA

It is important to remember that it is public pressure that brings many issues to the table in the first place. As Harvard University's Harvey Brooks notes:

The first step toward the resolution of policy issues with high scientific or technical content is the placing of these issues on the agenda of political leaders and their scientific advisors. Unless the issues are recognized as important ones deserving attention, they will be passed over amidst the multitude of questions faced by governmental leaders. 66

In referring to policy reaction and agenda setting relevant to the DDT issue, the impact of Rachel Carson's book, Silent Spring, had startling and far-reaching consequences because, "...certain moments in time are ripe for such controversies...there are two kinds of ripeness...scientific ripeness and political ripeness." 67

Brooks also offers his rationale for how and why issues involving science and technology find themselves "politically and scientifically ripe" 68 for the public policy agenda. Brooks describes a ripening process that often requires at least ten years from notice by the scientific community to attention of decision makers. He lists examples (see

65 Howell, Scientific Literacy, supra note 11, 35.
67 Ibid., 231.
68 Ibid., 12.
Table 4) of mechanisms for garnering enough interest in a particular issue for it to become a priority on the political agenda:

### Table 4
**MECHANISMS FOR PLACING ISSUES ON THE PUBLIC POLICY AGENDA**

1. Scientific publicists (e.g. Rachel Carson).
2. Public sentiment (e.g. the threat to German forests and endangered species).
3. Legitimation by international institutions.
4. Serendipity (e.g. research on ozone layer depletion from SST led to identification of fluorocarbons as a potentially more important source of ozone depletion).
5. Random events (i.e. low probability, potentially high consequence events whose actual time of occurrence is unpredictable such as Three Mile Island and Bhopal).
6. Dissenting scientists who go public when they cannot attract the attention of their peers.
7. Media attention to an issue, usually initially stimulated by dissident scientists, but becoming self-sustaining.
8. Launching of a major public investment project (e.g. USSR proposed water diversion to Caspian).

Brooks also expresses concern that this "highly pluralistic style of agenda setting" in the United States can sometimes establish priorities that are not necessarily reflective of objective public needs. He observes:

Relatively minor problems may receive priority treatment because of attention from the media or influential lobbying groups, while more consequential problems remain on the "back burner" until public attention is drawn to them by some random, but well publicized, incident.70

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69Brooks, *Science for Public Policy*, supra note 66, 8
70Ibid., 9.
Another challenge facing democratic policy formulation, which is exacerbated by scientific illiteracy, is whether public policy is going to submit to the "multitude of vociferous voices" or attempt to meet real public needs. In relating a personal conversation with Henry Brehm of Boston University's Center for Technology and Policy in 1987, Dorothy Howell comments, "In recent years this requisite distinction (between inconsistent demand and real public needs) has been acknowledged with reference to the silent majority, often out-shouted by vocal minorities as expressed by self-appointed advocates." She summarizes:

What is clearly before us as we enter the 1990s is whether our public policy is going to continue to respond to public demands or instead will go about the business of meeting public needs. We have much to accomplish before that basic alteration of course is a realistic prospect. We first have to reenfranchise society by overcoming scientific illiteracy in hope of fostering articulation of real needs.

BARRIERS TO PUBLIC PARTICIPATION

In pondering how science and technology could be governed more democratically, Goggin urges removing the impediments to public participation in science and technology policy making. He cautions that an "apathetic, scientific illiterate citizenry" may never become interested enough or informed enough to engage in the policy-making process. Scientists are part of the problem as well.

Those who are not open about the research being conducted in their private "republic" thwart the involvement in the public in understanding their mission and the

71 Howell, Scientific Literacy, supra note 11, 154.
72 Ibid., 154.
73 Ibid., 156.
results of their research endeavors. Goggin highlights a more "sinister" reason for poor citizen participation. In trying to secure their privileged positions, Goggins notes that scientists and engineers may use their expertise to "mystify science and technology." University administrations and professional associations may further discourage outreach and communication to the public by scientists. Evaluation criteria in the traditional promotion and tenure processes have created a reward system that generally offers no incentives, and sometimes creates distinct disincentives, for the scientists to become active in the public policy formulation process as well as in formal and informal/nonformal education activities, community service, and outreach. Some American scientists feel "the spread of lay involvement in technical issues is a source of anxiety." While opinion polls indicate that most Americans feel final decisions on technical issues should be left to the experts, there surely must be a compromise between public involvement and professional expertise in public policy decision making. Brooks writes about striking this balance:

Citizen commissions, which are analogous to juries, have a fairly good record in dealing with complex technical issues when they have adequate access to experts and when there are ample opportunities for questioning and dialogue. But if such lay decision mechanisms come to be relied on excessively and are used for appeals over the heads of experts every time some interest group fails to get the decision it wants, the right of ultimate appeal to the public will become a sham.

Goggin also expresses concern that universities, the last bastions of academic freedom where scientists have traditionally been responsible for choosing their own topics

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75 Ibid., 254.
of study, are now becoming less autonomous in their decisions about what areas to
explore. Being forced to focus their research efforts on mandated programs stressing
economic development, some feel that the generation of knowledge for the sake of mankind
will suffer. These overriding economic concerns also encourage the short-sightedness in
the corporate community where investment strategies are often designed to focus on short-
term economic gain rather than long-term benefit.78

From a public point of view, the question remains, who actually does get involved?
Miller's study shows:

Citizens who have a high level of interest in an issue, who think that they
are reasonably well informed about it, and who follow that issue in the
news are significantly more likely to make a voting decision based on that
issue, to write a legislator or government officer about that issue, or to
engage in overt political meetings or contacting in pursuit of a particular
policy than other citizens... It is the perception of the citizen that he or she is
well informed that influences the decision to become involved in the policy
formulation/conflict resolution process, not the objectively measured level
of information.79

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78 Goggin, "Reconciling Science and Technology with Democracy," in Goggin, Governing
Science and Technology in a Democracy, supra note 10, 262.
79 Miller, "Public Understanding of Science and Technology in the United States," supra
note 1, 27.
IV. THE STATE OF SCIENTIFIC LITERACY

Of the more than 300 national reports on education issued since 1983, many point to the "deplorable state of American scientific literacy."80 In this country and abroad, there appears to be consensus that the American public is "...not only suffering from scientific illiteracy, but also from a more fundamental general illiteracy. It is clear that general illiteracy is a fundamental impediment to scientific and technological literacy."81 It is also clear that "...concern about the gap between the world of science and the world at large is nothing new." 82

In the late 19th century, organizations such as the British Association for the Advancement of Science were founded to translate their work to public audiences. At about the same time in the U.S., organizations such as the National Geographic Society began their ongoing role in support of scientific literacy. Founded in 1890, "...for the increase and diffusion of geographic knowledge," National Geographic has kept its focus on "...adding knowledge of the earth, sea, and sky."

Although the debate over the state of American education in general has escalated since the late 1950s and the Sputnik era, over the last decade, one very active part of that debate has focused on the quality of science and mathematics education.83 Calls for major improvements in scientific literacy echo through two major reports released in 1983: A

81Howell, Scientific Literacy, supra note 11, 152.
83Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 87.
Nation at Risk by the National Commission on Excellence in Education and Educating Americans for the 21st Century by the National Science Board. Subsequently, other more recent efforts to enhance science education are making the headlines, fanning the flames of reform. These initiatives include Project 2061, the interdisciplinary science education program launched by the American Association for the Advancement of Science in 1989, and America 2000, the comprehensive national policy announced by President Bush in 1991 for achieving six National Education Goals by the year 2000. Project 2061, named for the next arrival of Halley's comet, defines a general set of science concepts and principles that should be known by all 12th graders, and deemphasizes the need for memorization of excess detailed information. America 2000 deals with four parts of the education reform agenda: 1) to create better schools that are more accountable for results; 2) to invent new, future-oriented schools designed to meet demands of a new century; 3) to emphasize life-long learning, and 4) to focus what happens in classrooms on communities and families. Table 5 lists three of the national goals in America 2000 expressly focus on the improvement of mathematics, science, and technology education.


87Ibid., 6 and 745.


TABLE 5
NATIONAL EDUCATION GOALS RELATING TO
MATHEMATICS AND SCIENCE EDUCATION

Goal 3: By the year 2000, American students will leave grades four, eight and twelve having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography and every school in America will ensure that all students learn to use their minds well so that they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.

Goal 4: By the year 2000, U.S. students will be first in the world in science and mathematics achievement.

Goal 5: By the year 2000, every adult American will be literate and will possess knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.

Some of the most comprehensive and contemporary assessments of public understanding of science and corresponding literacy issues have been put forth by studies in the U.K. and U.S. In 1985, the Royal Society published its comprehensive report, The Public Understanding of Science, in it claiming "...people must understand science to be able to participate fully in social decisions." This report served as a catalyst for a resurgence of interest in the scientific community in ways of encouraging greater public interest in its activities. It also paved the way for three British groups—the Royal Institution, the British Association for the Advancement of Science, and the Royal Society—to form a coalition to deal with literacy issues under the auspices of an ad hoc Committee on the Public Understanding of Science (COPUS). With the public's

90Bromley, Alan D. "By the Year 2000: First in the World." Report of the FCCSET Committee on Education and Human Resources (January, 1992), ii.
92Birke, "Selling Science to the Public," supra note 19, 40.
93Dickson, David. "Raising the Image of Science in Britain." Science 235: (March 6, 1987), 1134.
understanding of science now placed firmly on the U.K. scientific community's agenda, COPUS is working through a variety of research and educational initiatives to improve the relationship between science and technology and the political, educational, and media interfaces. The program of research is designed as a follow-on to the Royal Society report and focuses on three questions: "What do people say about science in general? How do people use science? How is scientific knowledge supplied and received?"

Of all the studies on public understanding of science and science education conducted in the United States, it is those of Jon D. Miller and his colleagues at the International Center for the Advancement of Scientific Literacy at the Chicago Academy of Sciences that have received the most attention. Funded by the National Science Foundation, Miller's most recent report in 1990 follows his previous studies carried out in 1979, 1981, 1985, and 1988. In his studies Miller argues that scientific literacy demands:

1) a basic vocabulary of scientific and technical terms and concepts,
2) an understanding of the process or methods of science for testing our models of reality, and
3) an understanding of the impact of science and technology on society.

The results of Miller's 1990 survey estimating scientific literacy, which combine the three indices depicted below, show that while significantly more respondents had an understanding of one or two of the criteria for scientific literacy posed by Miller, only about seven percent of American adults qualify as scientifically literate on all three indices (see

95Zinman, "Public Understanding of Science," supra note 82, 100.
96Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 5 and 13.
Table 6—showing "...little improvement" over the results of studies during the previous decade when the results varied from five to seven percent.97

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<td>SCIENTIFIC LITERACY IN THE UNITED STATES, 199098</td>
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<tr>
<td>Estimate of scientific literacy</td>
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<tr>
<td>Understanding of scientific process</td>
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<td>Understanding of scientific terms and concepts</td>
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<td>Understanding of the impact of science and technology</td>
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With such a small percent of Americans meeting minimal tests of scientific literacy, Miller raises concern that while more than a third of American adults can understand the vocabulary, only thirteen percent understand the process. He summarizes, "...a significant portion of American adults may be able to read news reports about scientific issues and controversies, but ...they would be unable to recognize the difference between arguments based on scientific investigation and arguments based on pseudoscience." Relating his concerns back to public participation in policy formulation, he concludes, "If democratic processes are to survive into and through the 21st Century, it is imperative that a significantly larger proportion of Americans become and remain scientifically literate."99

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97 Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 13-14.

98 Ibid., 14.

99 Ibid., 22.
V. PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

In the preface of their book, *Progress and its Discontents*, editors Gabriel Almond, Marvin Chodrow, and Roy Harvey Pearce, repeatedly express one of themes of their book, "...mankind has reached a stage at which our problems and their solutions are dominated by science and technology."\(^{100}\) Thus, the public's attitudes toward science and technology affect which problems are brought to the forefront and whether resources are put to their solutions. Almond, et al, identify the different attitudes of the public towards science as those of an "adversary culture" and a "critical establishment."\(^{101}\) He describes the adversary culture as having "...a mood of distrust of and resistance to scientific and technological growth among a substantial part of the educated populations of advanced industrial nations."\(^{102}\) The critical establishment "...consists of a collection of interest groups and lobbies which influence public opinion and public policy as they affect scientific activity and technology."\(^{103}\) Although the attitudes of the adversary culture may often be at odds with those of the critical establishment, both have a role to play in shaping the opinions of the public and the decision-makers involved in science and technology policy formulation.

While it is clear that science and technology have produced many positive gains, they have also created some environmental, economic, health, and ethical disasters further shaping public attitudes toward science and technology. Solving of real problems requires the constructive interactions of people on all sides of the issues. Harvey Brooks observes:

\(^{101}\)*Ibid.*, 12.
\(^{102}\)*Ibid.*, 12.
\(^{103}\)*Ibid.*, 12.
...the obstacles to continued material progress in the world are social, political, and institutional; they are determined not by the relations between humans and nature, but by the relations of humans to one another...the rate of change is paced more by the rate of population increase than by the absolute level of population.104

The benefits and risks of scientific progress are affecting public attitudes and concerns about scientific progress in general. People's attitudes about science are changing as they are beginning to realize that there are social as well as economic costs associated with the benefits of science and some of these costs are not to be taken lightly. Table 7 lists Davis' ten reasons for a growing disaffection with science. Further, in his essay on "Fear of Progress in Biology," Bernard Davis offers this perspective:

For centuries the scientific community enjoyed virtually complete autonomy in choosing the directions of its research and also in regulating any attending hazards; and the record seemed to be one of almost pure benefit and achievement. In recent years, however, we have seen increasing concern about where science is taking us and increasing demands that the public determine what scientists may or may not do.105

Amazingly, even with a menacingly low level of scientific literacy in the U.S., science remains in an enviable position. Miller's 1990 survey shows the American public has a strong positive attitudes toward the scientific community and its work. His results emphasize a strong and continuing belief that science and technology are responsible for improvements in the American standard of living and that the benefits of scientific research outweigh any harmful consequences of science or technology.106 Over 80 percent of

105Davis, Bernard D. "Fear of Progress in Biology." in Almond, Progress and its Discontents, supra note 100, 182.
106Miller,"Public Understanding of Science and Technology in the United States,"supra note 1, 61.
Americans continue to believe that science and technology are making their lives "healthier, easier, and more comfortable."\textsuperscript{107}

\begin{table}
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\caption{TEN REASONS FOR DISAFFECTION WITH SCIENCE\textsuperscript{108}}
\begin{tabular}{|p{1\textwidth}|}
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1) The rapid advances in many areas of science have caused even the most improbable future projections to be taken seriously. \\
2) Many short-term benefits of technology have turned out to have long-term costs, and the scale is growing. Technological advance in general has therefore become suspect. \\
3) Because of the success of science and technology in reducing many of mankind's traditional ills and hazards, expectations of absolute security have replaced a mature recognition that costs generally accompany benefits. \\
4) The important distinction between science and technology is often blurred. \\
5) Since science is inherently elitist (in a sense depending on ability and achievement rather than on social origin), the egalitarian thrust of our era has created guilt among many scientists and has weakened their confidence in the moral status of their enterprise. This development and the increasing dependence of research on public funds have encouraged acceptance of the neo-Marxist view that science is primarily an instrument of the prevailing political system rather than a methodology for seeking universal, objectives truths about nature. \\
6) Major failures of our political institutions, often linked to advice from academic experts, have led to a general mistrust of institutions and experts. \\
7) As science and technology become more complex, they influence the life of the ordinary citizen more, while at the same time he understands them less. The disparity, as well as the speed of the resulting changes in our way of life, generates uneasiness. \\
8) When scientists hold conflicting views, the mass media find it hard to assess their judgement and credentials, and those with more sensational claims of hazard are likely to be featured. \\
9) The cohort of activist students of the 1960s has now reached influential positions in the media, and also in science. In particular, such groups as Science for the People have chosen genetics, rather than our political and economic structure, as their focus and they have acquired attention far beyond their numbers. \\
10) The program of the Enlightenment has failed: the relative freedom from want created by technology and the spread of rationality encouraged by science have not resulted in general moral progress. In fact, science has undoubtedly contributed to a weakening of the moral order by undermining the traditional supernatural foundation for a moral consensus without providing an alternative. \\
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\textsuperscript{107}ibid., 47. \\
\textsuperscript{108}ibid., 182-83.
VI. THE OVERRIDING ISSUE OF SUSTAINABILITY

A final point worth noting here is the emerging attitude of the public that mankind may be able to utilize its ever-increasing knowledge of science and technology as a "fix" for environmental and economic woes. This attitude is countered by those who promote public participation and education based on principles of sustainability as a way to approach critical environmental and economic problems. Sustainability deals with environmental threats and human problems—degradation of land, water, and atmospheric resources, pollution, climate change, loss of biodiversity, poverty, and uneven economic growth. 109

Defining sustainability is a complicated problem in and of itself, and has generated much controversy. As World Resources Institute authors note, sustainability focuses on "...coming to grips with underlying trends that make these problems far worse." 110 Whether the definition focuses on the physical aspects of sustainable development or on economic concerns, sustainability deal with issues of equity—"...equity for generations yet to come, whose interests are not represented by standard economic analyses or by market forces that discount the future, and equity for people living now who do not have equal access to natural resources or to social and economic goods." 111 Another newer definition, provided by the World Conservation Union, defines sustainable development as "improving the quality of human life while living within the carrying capacity of supporting ecosystems." 112 No matter what the definition, many authors, such as David Orr, express a sense of urgency regarding sustainability:

110 Ibid., 1.
111 Ibid., 3.
Grass-roots participation will be essential in the process of reorganizing systems supplying energy, water, food, resources, and economic support in order to minimize environmental damage, shorten supply lines to reduce energy costs, convert to renewable sources of energy, and to develop means for recycling wastes. Many of these things can best be done at the local or even household level. Hence the transition requires people who know a great deal about such things as solar design, horticulture, waste, composting, greenhouses, intensive gardening, food preservation, household economics, and on-site energy systems. These, in turn, will require mastery of biology, chemistry, physics, engineering, architecture, community dynamics, and economics...Education for sustainability will...connect disciplines as well as disparate parts of the personality: intellect, hands, heart. 113

Orr further offers his pointed explanation of the urgency of the problems associated with educating people about sustainability:

The crisis of sustainability, the fit between humanity and its habitat, is manifest in varying ways and degrees everywhere on earth. It is not only a permanent feature on the public agenda; for all practical purposes it is the agenda....Sustainability is about the terms and conditions of human survival, and yet we still educate at all levels as if no such crisis existed.114

The crisis outlined by Orr echoes that of Rachel Carson's earlier plea. In the mid 1960s, spurred by the overwhelming reaction to Silent Spring, the public attitudes did begin to change. Carson's call challenged the public to consider the the ramifications of technological power over nature and brought to the forefront the realization that there existed real limitations on sustainability. Carson opens her famous alarm with a quote from Albert Schweitzer: "Man has lost the capacity to foresee and forestall. He will end by destroying the earth." She further offers a quote by E.B. White:

I am pessimistic about the human race because it is too ingenious for its own good. Our approach to nature is to beat it to submission. We would stand a better chance of survival if we accommodated ourselves to this

113Orr, Postmodern World, supra note 3, 137.
114Ibid., 83.
planet and viewed it appreciatively instead of skeptically and
dictatorially. 115

Carson goes on to describe the dilemma in her own way:

The history of life on earth has been a history of interaction between living
things and their surroundings. To a large extent, the physical form and the
habits of the earth's vegetation and its animal life have been molded by the
environment. Considering the whole span of earthly time, the opposite
effect, in which life actually modifies its surroundings, has been relatively
slight. Only within the moment of time represented by the present century
has one species—man—acquired significant power to alter the nature of the
world.116

As man proceeds toward his announced goal of the conquest of nature, he
has written a depressing record of destruction directed not only against the
earth he inhabits, but against the life that shares it with him.117

Malcolm L. Goggins, in his writings about public attitudes toward the governance
of science and technology, observes "...the public seems to believe that science can solve
any problem, even ones that are primarily social and political in nature."118 Orr offers his
plea for "...studying environmental problems as a preface to studying, designing, and
implementing solutions to the overwhelming issues we face."119 Orr urges, "The
mistake...is the belief that we can technologize our way out of the crisis (of global
degradation), that is, that science and technology will rescue us from the consequences of
stupidity, arrogance, and ecological malfeasance." 120 Later, in his book of essays, Orr

116Ibid., 6.
117Ibid., 85.
118Goggin, Governing Science and Technology in a Democracy. supra note 10, 105.
119Orr, Postmodern World, supra note 3, 94 and 137.
120Orr, David W. "Ecological Literacy: Education for the Twenty-First Century," Holistic
Education Review 48 (Fall, 1989), 49, cited in Howell, Scientific Literacy, supra
note 11, 16.
offers two additional statements expressing his concern over the assumption that technology can solve our problems:

It is a mistake, however, to think that all we need is better technology, not an ecologically literate and caring public willing to help reduce the scale of problems by reducing its demands on the environment and to accept (even demand) public policies that require sacrifices. It all comes down to whether the public understands the relation between its well-being and the health of the natural environment.  

The symptoms of environmental deterioration are in the domain of the natural sciences, but the causes lie in the realm of the social sciences and humanities. To assume that technology will absolve us from our own folly is only to compound the error. Whatever its many advantages, technology has varying political, social, economic, and ecological implications that we are now only beginning to recognize. Without political, social, and value changes, no technology will make us sustainable. More to the point, do we equip students morally and intellectually to be part of the existing pattern of corporate-dominated resource flows, or to take part in reshaping these patterns toward greater sustainability?

121Orr, Postmodern World, supra note 3, 90.
122Ibid., 146.
VII. COMBATING SCIENTIFIC ILLITERACY

Attitudes are not the only factor determining if a member of the public becomes attentive or interested in one or more public policy issues. A true sense of being scientifically literate, acquisition of knowledge, and knowing how and when to use it, is also critical. Brooks comments:

...there is knowledge that, for all practical purposes, nobody knows exists, not even to look for it, never mind knowing where to look for it. There is also ignorance that is contextual: the knowledge actually exists, but the people—policy makers and experts—who are in a position to apply the knowledge are unaware of its existence, and the few people who have mastered the knowledge are not aware of its policy significance.\(^{123}\)

If citizens are to be expected to be aware and make informed decisions on complex and often controversial issues such as nuclear energy, hazardous waste, environmental pollution, public access, natural resource allocation, wastewater treatment, multiple-use scenarios, personal health and nutrition, energy policy, economic competitiveness, space and ocean exploration, national defense, and other science and technology based issues that will affect their lifestyles,\(^{124}\) it is essential that we "...create citizens who understand science in multidimensional, multidisciplinary ways that will enable them to participate intelligently in critical thinking, problem solving, and decision making about how science and technology are used to change society."\(^{125}\)

\(^{123}\)Brooks, Science for Public Policy, supra note 66, 5.

\(^{124}\)Ogens, "A Review of Science Education," supra note 30, 201.

No one group or institution is to blame for the current state of affairs relating to scientific illiteracy among both children and adults. Yet, the hope for "reenfranchisement of our citizens"\textsuperscript{126} can be found in new programs and initiatives being launched by existing formal and informal/nonformal education institutions that are willing to throw out traditional approaches to science and technology education and replace them with ones featuring renewed vigor, innovative partnerships, and new ideas and expectations. Educators, the scientists themselves, and the media must join forces as champions of scientific literacy and embark upon a full blown, revolutionary effort to change the way we approach increasing the level of scientific literacy to promote a more widespread and realistic, yet thorough, public understanding of science.

Many feel that we indeed have the tools (our existing institutions—elementary and secondary schools, colleges, federal and state government agencies, education outlets such as museums, aquaria and nature centers, and a far-reaching print and electronic media system) to combat scientific illiteracy at all levels. The problem is that redirecting these institutions to advance a broadly-based scientific literacy means breaking down barriers and ingrained traditions within these institutions. And as Howell states, "We are far from any such achievement."\textsuperscript{127} Orr echoes Howell's assessment, but adds his note of urgency, "The survival of the planet depends on whether future generations can be educated in ecological literacy—an awareness of the interconnectedness of all life. Such an education requires fundamental changes in many of our present assumptions about schooling."\textsuperscript{128}

\textsuperscript{126}Howell, \textit{Scientific Literacy, supra} note 11, xiv.
\textsuperscript{127}\textit{Ibid.}, xv and 157-8.
\textsuperscript{128}Orr, \textit{Postmodern World, supra} note 3, 153.
THE STATE OF FORMAL SCIENCE EDUCATION

Jon Miller's ongoing research has found, "...consistent with the educational stratification of American society, those citizens with the highest levels of formal education and the most formal training in science and mathematics are most likely to be attentive to one or more facets of science and technology policy."¹²⁹ Former National Science Foundation Director, John Slaughter, warns of a "growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component."¹³⁰ For efforts to enhance scientific literacy to reach beyond the "elite" to all Americans, eliminating economic or social bias, these efforts must become successful in the formal education setting, especially at the elementary and secondary level. Miller points out, "...the essential point here is not that the attentive public for science and technology policy accurately reflects the full electorate, but rather that it includes significant numbers of citizens from all sectors of American life and is not elitist in that regard."¹³¹

The goals of formal science education are varied. In addition to the National Education Goals mentioned earlier that focus on science and mathematics competency and achievement, others have offered their goals for science education in more specific terms. In an article in the International Journal of Science Education, Jerry Wellington expresses his opinion:

...one of the goals of formal education is surely to enable future citizens to make sense of and examine critically the science-related material they are likely to read in the large chunk of their lives after formal education ceases.

¹²⁹ Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 33.
¹³¹ Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 113-4.
My argument, therefore, is that school science should take responsibility for teaching ways of looking critically, but constructively, at science in the newspapers.\textsuperscript{132}

Miller is emphatic in stating:

Scientific literacy will be no less essential (than basic literacy) to the graduates of American high schools in the years ahead, and it is imperative that states begin to require the achievement of scientific literacy during the high school years in the same spirit as basic literacy is required today.\textsuperscript{133}

Some startling statistics relating to the state of formal science education in the United States further highlight the need for science education reform:

- On average, elementary students spend only 23 minutes per week on science.\textsuperscript{134}
- In teaching science, 95\% of the teachers use a textbook 90\% of the time.\textsuperscript{135}
- There are more new words in a high school science course than in an introductory foreign language course.\textsuperscript{136}
- In U.S. public and private high schools, 29\% have no physics teacher, 17\% have no chemistry teacher, and 8\% have no biology teacher.\textsuperscript{137}
- Nearly 30\% of high schools offer no courses in physics, 17\% offer no chemistry courses, and 70\% offer no earth or space science classes.\textsuperscript{138}
- In a 1991 National Science Board survey, 30\% of seventh graders expressed preference for a career in science or engineering, but by the 12th grade, only 25\% of boys and 10\% of girls still chose such a career.\textsuperscript{139}

\textsuperscript{133}Miller, "Public Understanding of Science and Technology in the United States," \textit{supra} note 1, 118.
\textsuperscript{134}Ogens, "A Review of Science Education," \textit{supra} note 30, 199.
\textsuperscript{136}Ogens, "A Review of Science Education," \textit{supra} note 30, 199.
\textsuperscript{137}Foderaro, "High Hopes," \textit{supra} note 135, 21.
\textsuperscript{138}Bromley, "By the Year 2000," \textit{supra} note 90, 5.
• Of every 4,000 seventh graders in school today, only six will ultimately receive a Ph.D. in science and engineering. Of these six, only one will be female.\textsuperscript{140}

• Only 3-5\% of secondary school graduates will complete a college degree in the natural or physical sciences, yet the majority of high school classes are designed for this group.\textsuperscript{141}

• In 1989, 861 doctoral degrees were granted in mathematics, only 45\% went to American students; 15,478 doctoral degrees were awarded in science and engineering, only 60\% went to Americans.\textsuperscript{142}

• Only 8\% of bachelors degrees and 4\% of all Ph.D. degrees in science and engineering are awarded to blacks and Hispanics when, by the year 2000, minority students will represent 40\% of the pre-college population.\textsuperscript{143}

• When compared with 15 other nations, the U.S. ranked in the bottom fourth on calculus and algebra achievement and ranked last out of thirteen nations in senior level "advanced placement" biology.\textsuperscript{144}

Marcia Linn, at the University of California/Berkeley, characterizes how students gain scientific knowledge in a review contrasting the work of Hazen and Trefil in their book, \textit{Science Matters}.\textsuperscript{145} and that of her own work with N.B. Songer, a collaborative research project called The Computer as Lab Partner (CLP)." Hazen and Trefil propose a "knowledge telling approach to reform involving a year-long science appreciation course featuring '20 great ideas in science'." Their argument is simple, "If you expect someone to know something you have to tell him or her what it is."\textsuperscript{146} While both \textit{Science Matters} and the CLP present similar goals—to attract a broader mix of students into science courses and careers—the CLP works on the premise that learning science involves integrating science

\textsuperscript{140}Fisher, "Crisis in Education, Part 2," supra note 88, 50.
\textsuperscript{142}Fisher, "Crisis in Education, Part 1," supra note 139, 63.
\textsuperscript{143}Bromley, "By the Year 2000," supra note 90, 7.
\textsuperscript{144}\textit{Ibid.}, 5.
knowledge with instruction that links useful and relevant science principles to observations. Linn describes three different ways in which students approach their science education—some have a static view, some a relative view, and others a dynamic view toward scientific knowledge. Students with "static" views of science feel that "...science is best learned by memorization, that science does not apply to everyday experiences and that everything in the science book will always be true." Students with "relative" views of science argue that "scientists all have different opinions, science is constantly changing, and that no one is sure about anything." In contrast, students with "dynamic" views of science believe "...science proceeds by fits and starts, that scientists seek to explain diverse phenomena with broad principles, that conclusions are based on evidence, and that the way to learn science is to make an effort to understand complicated ideas."

Current science textbooks and methods of testing, especially those that rely on memorization of terminology and isolated facts, certainly engender the static and relative views in students. Such views are currently held by 85% of eighth grade students, a trend that national assessments have shown does not fluctuate much as students get older. The key to shifting students toward a dynamic view of science appears to be the adoption of educational reforms that teach students to apply scientific principles to their everyday lives, and highlight how science works and its impact on individuals, society, and the

147bid., 828.
148bid., 824.
149bid., 825.
150bid., 825.
151bid., 824-5.
152bid., 829-30.
biosphere.¹⁵³ Linn's research concludes with five recommendations (see Table 8) for moving science education researchers and the practicing education community toward education reforms designed to shift students toward a dynamic view of scientific knowledge:

<table>
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<th>TABLE 8</th>
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<td>RECOMMENDATIONS FOR SCIENCE EDUCATION REFORM¹⁵⁴</td>
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<tr>
<td>1) Foster and sustain collaborative investigation.</td>
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<tr>
<td>2) Incorporate computers as learning partners in science education reform.</td>
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<tr>
<td>3) Expand collaborations and communications to include all involved with science education.</td>
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<td>4) Create materials that help student view themselves as competent science learners.</td>
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<tr>
<td>5) Ensure that science courses provide equitable opportunities for all learners and that these ideas are carried forth into the workplace.</td>
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Much of what is being put forth as science education reform today centers around the problem that students in the classroom are not being motivated and are not being taught to see the relevance of science to the everyday lives. Additionally, what is taught must be made relevant to all students—those who expect to go on to college, including the small percentage that will earn a bachelor's degree or higher in a science or engineering discipline, as well as those who choose to enter the workforce after high school graduation or opt for additional vocational training.

¹⁵³ Levine, J., "Scientific Illiteracy: We Have Met the Enemy and He Is Us." Oceanus 33 (Fall, 1990), 72.
¹⁵⁴ Linn, "Science Education Reform," supra note 146, 834-6.
Many of Jon Miller's arguments for reform have found their way into efforts over the past decade in the formal education arena through science education involving a Science-Technology-Society (STS) approach (see Table 9). STS education is said to focus on society and human dilemmas brought about by technology. A 1982 statement from the National Science Teachers Association reiterates the importance of STS:

The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence on another, and who are able to use this knowledge in everyday decision making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual networks, and process skills which enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.

| TABLE 9

**ESSENTIAL ELEMENTS OF THE STS APPROACH**

- Local and community relevance
- Applications of science
- Social problems and issues
- Practice with decision-making strategies
- Career awareness
- Cooperative work on real problems
- Multiple dimensions of science
- Evaluation concerned for getting and using information

The Global Thinking Project, an international networking project which links U.S. and Russian science and social science teachers and teacher educators, is one example of

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STS education approached on a global scale. The project, based at Georgia State University, fosters the notion that "solving environmental problems such as air pollution, the depletion of the ozone layer, and rain forest destruction must involve the cooperative efforts of many nations. Thus, the computer will be used to facilitate cooperation between partner teams, as a model for cooperative problem solving between nations. Cooperation is a key to global thinking." The "global classrooms" created by this project are "...giving students access to new tools that empower them to ask more questions." Formal education initiatives that challenge students to develop their thinking, communication, and computational skills while working on real problems are the backbone of many forward-thinking reform efforts.

In his analysis, Miller reaffirmed the need for reforms that encourage greater participation in science and math coursework: "...the level of formal education, the number of high school science courses, the number of high school math courses, and the number of college-level science courses are the four measures that are strongly and positively associated with the distribution of scientific literacy." He further explains that his analysis "...demonstrates the general influence of formal education and the direct influence of science and math instruction on developing scientific literacy among adults in the U.S." Miller emphasizes:

There can be little doubt that the primary engine driving the level of scientific literacy in the United States is the exposure of citizens to science and mathematics instruction and these data indicate that vast numbers of American adults have had minimal formal training.

159Ibid., 47.
160Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 18.
161Ibid., 19.
He also urges:

Looking at all dimensions of this analysis, it appears that formal education in science and mathematics is the primary source of scientific literacy and that these educational experiences also stimulate participation in informal science education activities.\textsuperscript{162}

As we struggle to change many of our assumptions regarding how and what to teach to our school children when it comes to science, some help in the form of increases in science education awareness and availability of research dollars has come from the federal government. Although with many states struggling with shrinking education budgets, even the multi-million dollar science education reform efforts of the National Science Foundation underway in many states under NSF's Statewide Systemic Initiative (SSI) will not be effective unless teachers, administrators, parents, students, and members of the community, including local scientists and engineers, work together to foster the change.

Even with the difficulties and differences of opinion brought about by educational reform, formal science education is finally coming into its own. The results of Miller's surveys point to the crying need keep up the momentum for improving formal science education as well as build a strong framework of informal and nonformal science education opportunities that foster lifelong learning. Miller's surveys make it clear that "previous formal study of science and mathematics appears to be the strongest single predictor of scientific literacy among adults. But he also notes, "...there has been much debate about the role of informal science education in fostering and maintaining scientific literacy."\textsuperscript{163}

\textsuperscript{162}Ibid., 104.
\textsuperscript{163}Ibid., 102.
LIFELONG LEARNING THROUGH INFORMAL AND NONFORMAL SCIENCE EDUCATION

John Zinman, director of the Science Policy Support Group at Bristol University in the U.K., has been a very outspoken proponent of overcoming people's scientific ignorance via a broad-based formal and informal/nonformal education approach. He observes:

...this degree of public ignorance is very distressing, indeed, and would seem to call for a very determined effort of education and reeducation, through formal schooling and the media. But this type of policy response attaches a great deal of weight to the weaknesses in people's formal scientific knowledge.\footnote{Ibid., 102.}

He further states:

It is quite clearly the responsibility of every scientifically literate person to combat the extreme ignorance of most elementary scientific facts and theories that we find even among the best educated of our friends and colleagues. Every possible means should be taken to improve the transfer process in the science museum, in the schools, in the media, or wherever.\footnote{Ibid., 100.}

It is clear that "...prior education exposure to science and mathematics is an important factor in the acceptance and comprehension of scientific and technical information,"\footnote{Miller, "Public Understanding of Science and Technology in the United States," supra note 1, 104.} from whatever the source. Many formal education initiatives are addressing the long-term need for increased public understanding of science, but many
informal and nonformal education solutions can affect public acceptance and support of the long-term science education goals. It is these same informal and nonformal education initiatives that will continue to service the public's science and technology knowledge and information needs long after their formal schooling is complete.

Whenever and wherever the learning takes place, scientists, the media, and other information and education outlets play key roles in interjecting science education into the lifelong learning process for "students" of all ages and backgrounds.

A GROWING RESPONSIBILITY FOR THE SCIENTIFIC COMMUNITY

For many reasons, most scientists, until relatively recently, have not embraced personally the notion of positioning themselves as part of the solution to the crisis of scientific illiteracy. Compounding the matter, the promotion and tenure process at most research universities has not looked kindly on involvement of scientists in pre-college or adult education and communications activities. In recent years, the well-respected British journal, New Scientist, has taken an outspoken position on the role of scientists in enhancing a public understanding of science:

The scientific community should be prepared to acknowledge and reward (rather than ostracize) those prepared to go public. It could do this both by finding ways of using such experience to enhance career prospects, and by emphasizing that telling the public about one's work is an important part of any scientist's responsibility to society.167

Many believe that scientists are indeed becoming more patient and willing to interact with the public. For some it is due to a feeling of social responsibility, for others it may be

due to more selfish, economic reasons. An overwhelming amount of research conducted in
the U.S. and around the world is funded by government grants and contracts.
"Accountability" for the spending of public tax dollars on scientific research is now more of
a concern than ever before as the research enterprise undergoes closer scrutiny by those
who pay the bills. "Scientists have come to realize the need to justify what they spend. If
people knew more about science, the argument goes, they might be more willing to support
it."168 But knowing more about science may not be enough. As Richard Atkinson, AAAS
president in 1990, notes, "Public support for science and engineering depends not so much
on the discoveries and inventions produced, but on how closely values of scientists
coincide with those of the larger society." He further notes, "Obtaining funds to pursue
even a fraction of the research opportunities on the horizon will be difficult. Finding trained
scientists and engineers to further those opportunities will be a still more daunting task."169

For whatever the reason, altruistic or selfish, scientists must become actively
involved in the fight against scientific illiteracy and help find ways to overcome the lack of
scientists and engineers in the educational pipeline. They must interject themselves into
appropriate places in the formal education system and strive to reach out through
informal/nonformal science education venues. David Hershey in his "Viewpoint" in
Bioscience comments:

Science literacy can be achieved if scientists truly make it a priority instead
of merely pay it lip service. Despite all the official reports on science literacy
by blue-ribbon committees, scientists know that the science establishment
regards research accomplishments much more than achievements in
teaching. There is no Nobel Prize for science teaching, yet success in
research is partly attributable to the teachers of the researcher.

168Birke, "Selling Science to the Public," supra note 19, 40.
169Atkinson, "Supply and Demand for Scientists and Engineers," supra note 17, 432.
Science literacy could be achieved if professors were allowed and encouraged to live up to the true definition of their titles and be excellent teachers. Declining enrollments in college science curricula could be reversed if more science professors got out into the elementary and high schools to inspire students and assist public school science teachers. Colleges train public school science teachers, but typically provide little consumer support for graduates.

Attainment of science literacy will likely require science to reverse its negative public image. Science is too often taught in a vacuum and at too basic a level for the typical student. Science should be linked to everyday life and current headlines.  

University scientists have a unique opportunity to make a difference in pre-college education. As Atkinson expresses:

...we need to do more than simply try to ensure adequate funding for programs that attract students to science and engineering. We also need to ask whether we, as scientists, are communicating, through our actions, the values that attracted us to science in the first place. Our universities take justifiable pride in the world-class research facilities on their campuses. Yet few research professors pay attention to teacher training programs at their university, and fewer still would willingly sacrifice even a small percentage of their budget to improve such training programs. Research universities take pride in the quality of the Ph.D. students they produce. Yet few of the research professors who bemoan the condition of pre-college instruction in science would advise their graduate students to devote substantial time to the preparation of curriculum materials for grades K through 12. In addition, few advise seniors to consider careers in high school teaching.  

Scientists associated with industry laboratories, research institutions, and universities do have a unique opportunity to help their institutions serve as "centers of propagation" for fostering the transfer of knowledge about environmental understanding, ethic, and action in the community. Graeme Buchan outlines the following benefits of a

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170Hershey, David R. "Viewpoint: Science Literacy is Possible." Bioscience 40 (July-August, 1990), 482.
171Atkinson, "Supply and Demand for Scientists and Engineers," supra note 17, 432.
'vacation school' experience for upper-level high school students at Lincoln University in New Zealand:

1) Promote the university...environmental science provides an obvious theme
2) Encourage interest in the science of the environment
3) Stimulate an integrative view of environmental issues
4) Convince young people of the need for their action toward conservation
5) Provide pointers of action, such as changes in personal lifestyle and resource use
6) Provide an opportunity for young people to contribute to the program
7) Help the university itself identify and focus more clearly on its own objectives and future areas of specialization173

Another academic institution, the University of Washington, has launched a Science Outreach Program designed to quench a "thirst for up-to-date scientific information concerning mankind's effect on the environment."174 College undergraduate students are recruited and trained and paired with faculty to serve as leaders of discussions in high school science classes. Not only do teachers in schools visited by the trained students learn about current scientific information relating to specific environmental issues, but the students themselves benefit in a number of ways:

1) College undergraduates learn the science behind pressing environmental issues
2) Students are given many hours of speaking experience
3) Students have the opportunity to meet university faculty members and other interested students in an informal, educational setting
4) Students build self-confidence and leadership skills175

173Ibid., 11.
175Ibid., 1022.
Like some academic scientists, industrial and research scientists are also taking up the challenge of science literacy. The Argonne National Laboratory and Illinois Institute of Technology have developed an "Academy for Mathematics and Science Teachers" designed to teach children and teachers how to apply principles learned in science and mathematics to real-life situations. Brookhaven Laboratory's scientists staff a visitor's bureau and offer a physics-oriented Saturday-morning program for junior high school students.

Although not actively practiced today by most scientists, the notion of "spreading the scientific attitude" is not new. John Dewey, a mentor to former AAAS president Wesley C. Mitchell, is quoted in Mitchell's pre-World War II AAAS presidential address as saying:

As teachers in schools and college we can help thousands to develop respect for science... We can promote general understanding of the methods and results of science through our own writings... These things we should do, not as high priests assured that they are always right, but as workers who have learned a method of treating problems that wins cumulative successes, and who would like to share that method with others.

Some authors, such as Stephen Shapin, are calling for the scientific community to also open their scientific workplace to the public. Shapin contends that scientists have a commitment to tell the public, "how, with what confidence, and on what bases, scientists come to know what they do." He believes that scientists should show the people, and explain to the public:

179 Ibid., 95.
...the collective basis of science, which implies that no single scientist knows all of the knowledge that belongs to his or her field; the ineradicable role of trust in scientific work, and the consequent vulnerability of good science to bad practices; the contingency and revisability of scientific culpability, being judged wrong tomorrow; the interpretative flexibility of scientific evidence, and the normalcy of situations in which different good-faith and competent practitioners may come to different assessments of the same evidence.181

Even Albert Einstein was concerned about opening the scientific process to the public: "It is of great importance that the general public be given the opportunity to experience...the efforts and results of scientific research...It is not sufficient that each result be taken up, elaborated and applied by a few specialists."182

Eminent British biologist John Maynard Smith, commenting on how most science stories today are told by science journalists rather than the scientist themselves, emphasizes, "Because science is no longer presented by scientists, it appears as an impersonal and mysterious edifice and not something done by human beings." Maynard advocates "...getting the scientists out from behind the protective camouflage of the lab bench." 183 Other authors echo Maynard's concern and are calling for studies of "scientist's understanding of the public"184 and for scientists to "embark on a self-educational exercise to understand the broad society of human concerns and interactions in which science and technology must find its place."185

181/bid., 28.
183Wilke, Does Science Get the Press It Deserves?" supra note 13, 579.
184Birke, "Selling Science to the Public," supra note 19, 40-41.
185Wilke, Does Science Get the Press It Deserves?" supra note 13, 581.
Becoming involved in elementary and secondary education, via the formal or informal/nonformal education setting, is one option for university, government, and industrial scientists to begin "reaching out." Whether through in-laboratory internships for teachers or the direct involvement of scientists in classroom or field activities, studies have shown that forming "close bonds between classroom teachers and working scientists" is a productive area of interaction. 186 Scientists may need the help of "master teachers" to bridge the gap between scientists and teachers, but personal interaction that gives the teachers the strong science background and confidence they need to present science concepts and respond to questions in the classroom appears to be a key to success.

Douglas Lapp, director of the National Science Resource Center (founded by the Smithsonian Institution and the National Academy of Science for improving science education), comments on a pilot program in physics launched by Caltech: "The scientist comes in as a coach. It's a wonderful role...because the scientist doesn't preempt the teacher's expertise." 187 Another option for involvement of scientists is taking the time to sit on panels that formulate science curricula for state boards of education. Science educators may understand teaching methodologies, but do not necessarily have the same solid grounding in the science content of proposed curricula that a working scientist may have. 188

With so many opportunities for interjecting themselves into education aimed at increasing the public understanding of science at so many different levels, scientists can

186Barinaga, M. "Scientists Educate the Science Educators.," Science 252 (May 24, 1991), 1061.
187Ibid., 1062.
find a niche that meets their own personalities, teaching and research styles, and institutional biases, opportunities, or barriers. At the same time, they must remember that in this era of specialization and exploding volumes of data and information, all scientists remain members of "the public with respect to the knowledge produced in the laboratory across the street."189

THE EVOLVING NATURE OF SCIENCE COMMUNICATIONS AND THE MEDIA

The print and electronic media are also in a unique position to influence the level of scientific literacy for audiences of all ages, in an out of school, through news and specialized communications. Some communications are designed to increase scientific literacy, some provide information about or stimulate political participation in public policy issues, and others are designed to sell products that have certain scientific or technical features.190 Science and technology issues span the headlines of every newspaper. Major commitments to reputable reporting of science and technology issues have been made by major newspapers including the prestigious New York Times, whose stories are reprinted by smaller newspapers throughout the U.S. and around the world, and newspapers with smaller, more targeted readership such as the well-respected Christian Science Monitor. Weekly news and children's magazines devote a growing amount of space to science, environment, and health-related issues. Parents and children alike delight in watching well-regarded public broadcasting programs that feature science and technology such as Nova, Nature, and special programming of the National Geographic Society.

190Miller,"Public Understanding of Science and Technology in the United States," supra note 1, 92-3.
For many, the reality of science comes from the media—what is read in the newspapers, featured in magazines, or seen on television or in motion pictures. The "filter of journalistic language and imagery"191 shapes the public's perception of what is important. Schwartz offers three bits of advice to those writers who assume the role of populizers and teachers of science—"know your subject and your audience, be honest and realistic, and be balanced and fair."192 He further outlines six potential dichotomies (see Table 10) that are routinely confronted by those who engage in the popularization of science:

![Table 10]

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<th>POTENTIAL DICHOTOMIES FOR POPULIZERS OF SCIENCE193</th>
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<tr>
<td>• Science and Technology</td>
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<td>• The Applications and Misapplications of Science</td>
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<td>• Scientific Fact and Scientific Methodology</td>
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Some members of the media are better at explaining these dichotomies than others. But the fact remains that Americans rely heavily on the media as a source of information.194 The following statistics give an idea of the widespread impact that newspapers, television,

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192 Schwartz, A. T. "Some Unsolicited Advice to Populizers (and Teachers) of Science." *Journal of Chemical Education* 67 (September, 1990), 755.
194 Miller, "Public Understanding of Science and Technology in the United States," *supra* note 1, 93-99.
radio, and informal venues for science and technology information can have on those who choose to avail themselves of these opportunities for learning:

- 57% read a newspaper every day (down 3 points from 1979 and 17 points from 1957—90% of the "attentive" public report that they read a newspaper every day)
- 23% read a news magazine regularly (38% of the attentive public for science and technology)
- 75% watch a television news show regularly (an additional 22% report they watched news occasionally)
- nearly 50% listen to radio broadcasts at least one hour per day
- 10% read science magazines regularly (plus 15% who read them occasionally)
- 20% watch science television shows regularly and 60% claim to watch them occasionally
- nearly 60% have visited at least one science learning facility such as a museum, zoo, aquaria, planetarium, or nature center (42% report visiting two or more in the preceding year)

Robert Dahl said of the media of mass communications:

...newspapers, radio, television, and magazines enjoy immediacy and directness in their contact with citizens. They regularly and frequently enter the homes of citizens: newspapers once or twice a day, magazines once a week, television and radio several hours a day. They do not force their way in; they are invited.195

He further clarifies the importance of the media in the political process:

The mass media are a kind of filter for information and influence. Since few citizens ever have much immediate experience in politics, most of what they perceive about politics is filtered through the mass media. Those who want to influence the electorate must do so through the mass media.196

Despite their importance in reaching audiences with needed information, the press, in reporting on science and technology, have not gone without criticism (see Table 11):

196Ibid., 256.
### Table 11

**Factors Leading to Criticism of the Press**

1. To be highly selective in choice of materials and to use a variety of questionable selection criteria.
2. To oversimplify, and hence to misrepresent, the methods and the character of scientific inquiry.
3. To treat scientific news as discrete events and hence to create another false conception of science.
4. To draw undue inferences about the meaning and significance of particular lines of research.
5. To report on inadequate, incomplete, and poorly designed research as readily as on competent research, as long as the subject matter is relevant to immediate popular concerns.
6. To raise false expectations of what science is capable of doing.
7. On occasion, to create stress among readers more damaging than the real risks being reported on.

Not only do the public and the policymakers find reasons to criticize the press, but sometimes the scientists do as well. However, in a study by John Wallace, journalism coordinator at the Royal Melbourne Institute of Technology, he suggests that the reporting of science is generally more professional than scientists believe. He notes, "...scientists may be a little less critical the news process when they themselves are getting publicity."\(^{198}\)

Colin Blakemore, host of the BBC series *The Mind Machine*, notes that for many scientists, seeking publicity is an "egocentric exercise." But he emphasizes:


relay the optimistic perspective of the scientist-entrepreneur—than to become educated to the full implications of the new technology and seriously to discuss costs and risks as well. The media both feed on and reinforce the aura of knowledge, authority, and beneficence projected by the scientist, foretelling new technological wonders.\(^{203}\)

In referring to standards for the media, Almond comments:

...we encounter interest bias, sensationalism, or the assertion of a formal neutrality on controversial policy problems. ...The few newspapers and columnists that adhere to a higher standard have only a small readership among the "attentive" public. The mass media tend to accentuate crisis and deepen complacency; in general, they play up to the mood susceptibilities of the mass audience.\(^{204}\)

The media can certainly be influential shapers of public opinion. Goggins asserts:

In its reporting and editorializing about scientific and technological subjects, the press is highly instrumental in shaping public opinion. At the same time, the press reports on various expressions of public opinion, so, in addition to shaping opinion, reflects and sometimes amplifies attitudes held by specific attentive and interested publics.\(^ {205}\)

The role of journalists reporting on scientific and technical issues is still evolving. Even in the early post World War I days, chemist Edwin Slosson, the first editor of Science Service (the first U.S. syndicate for the distribution of science news), observed, "...it is not the rule but the exception to the rule that attracts public attention. The public that we are trying to reach in the daily press is in the cultural stage when three-headed cows, Siamese twins, and bearded ladies draw the crowd at side shows."\(^{206}\) From the early beginnings of the National Association of Science Writers in the 1930s, when scientists accused science writers of sensationalizing and oversimplifying their work, to the early

\(^{203}\)Ibid., 105.
\(^{204}\)Almond, The American People and Foreign Policy, supra note 25, 151-2.
\(^{205}\)Goggin and Florig, "The Scientist-Entrepreneur and the Paths of Technological Development," in Goggin, Governing Science and Technology in a Democracy, supra note 10, 105.
\(^{206}\)Nelkin, "Selling Science," supra note 191, 44.
1970s, when scientists began to encourage the media to present the benefits of science to win support for their work, science journalists have found themselves playing many roles. In the 1980s, scientific institutions mounted concerted efforts to attract favorable attention. At the same time individual scientists were beginning to feel pressure to speak out on the social, ethical, and political dilemmas that advances in science and technology were presenting. Scientists were also beginning to see the benefits of reaching out beyond their scientific journals to seek national visibility, and hence increased public support, for their large-scale, high price-tag research projects.

Scientists and journalists today still experience differences of opinion as to what is considered news and when information about scientific discoveries and technological advances are ready to be released to the public. In the flurry of tabloid journalism, one sometimes loses sight of what Dorothy Nelkin, professor of sociology and law at New York University and author of the 1987 book, *Selling Science: How the Press Covers Science and Technology*, means when she challenges scientists and journalists to "...encourage a spirit of critical inquiry in science journalism." She further emphasizes, "The purpose of science journalism, after all, is not to promote science but to help create an informed citizenry aware of the social, political, and economic implications of scientific activities, the nature of evidence underlying decisions, and the limits as well as the power of science as applied to human affairs." Tom Wilke adds a further caution when he points out that "the newspaper audience seeks news, not science, and that it is unreasonable

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207 *ibid.*, 44.  
208 *ibid.*, 44-5.  
209 *ibid.*, 45.  
210 *ibid.*, 46.  
211 *ibid.*, 46.
to expect newspapers to fill the role of the specialist instructional medium for scientific literacy sometimes given to them by advocates of the popularization of science."212

**A SPECIAL NICHE FOR SCIENCE CLUBS, MULTIMEDIA, AND SCIENCE MUSEUMS/NATURE CENTERS**

In the 1990s, informal (and what is sometimes called "nonformal")213 learning in science is poised to go well beyond interaction with traditional media such as newspapers, science magazines, and public television to complement that which is taught in traditional formal education settings.214 Today, nonformal and informal science activities include a whole new realm of offerings ranging from visits to interactive museum exhibits and innovative nature centers to participation in science clubs to personal involvement with interactive computer/video games and casual exploration of electronic encyclopedias, electronic bulletin boards, and network servers.

Contrasting the characteristics of formal education with that offered in the context of informal and nonformal learning (see Table 12), Pinchas Tamir's study of 10th grade students found positive correlations between participation in informal/nonformal science activities and number of factors:

1) the extent to which school science is conceived to be related to everyday life
2) attitudes toward science and science learning
3) parents' occupations
4) school environment

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212Wilke, Does Science Get the Press It Deserves?" supra note 13, 497.
5) intentions for further study, and
6) career aspirations.215

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Formal</th>
<th>Nonformal</th>
<th>Informal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place</td>
<td>Classroom, school</td>
<td>Nonschool institution</td>
<td>No special institution, home</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>May be repressive</td>
<td>Usually supportive</td>
<td>Supportive</td>
</tr>
<tr>
<td>Learning environment</td>
<td>Pre-arranged</td>
<td>Pre-arranged</td>
<td>Not arranged</td>
</tr>
<tr>
<td>Study mates</td>
<td>Externally imposed</td>
<td>Not imposed</td>
<td>Not imposed</td>
</tr>
<tr>
<td>Attendance</td>
<td>Compulsory</td>
<td>Voluntary</td>
<td>Voluntary</td>
</tr>
<tr>
<td>Subject matter</td>
<td>Structured</td>
<td>Structured</td>
<td>Not structured</td>
</tr>
<tr>
<td>Motivation</td>
<td>Typically more extrinsic</td>
<td>Typically more intrinsic</td>
<td>Mainly intrinsic</td>
</tr>
<tr>
<td>Management of learning</td>
<td>Teacher</td>
<td>Teacher/students</td>
<td>Students</td>
</tr>
<tr>
<td>Assessment</td>
<td>Included/expected</td>
<td>Not expected</td>
<td>None</td>
</tr>
</tbody>
</table>

Science clubs are one vehicle that fosters "hands-on" involvement with science for K-12 age students. Whether carried out as part of the regular classroom curriculum, individually outside of class, or in association with scout troops, camps, or other non-school organizations, science clubs can bring students into contact with a variety of positive role models. Clubs that arrange visits to natural areas for interaction with forest rangers,

215 Ibid., 34.
wildlife biologists, fishing and hunting guides, and recreational managers or to research institutions to interact, in an informal, yet structured setting with working scientists and engineers and their graduate students and research assistants can be very positive experiences for young people. Besides adding relevance to learning about science, one benefit of the student's association with experts through science clubs is that they may become more interested in and better informed about scientific and technological careers.217

The information explosion has opened up yet another venue for informal/nonformal science education—multimedia. During the past decade, the sciences have undergone a revolution in the use of scientific data and technical information. Rapid increases in the ability to collect detailed information about the environment have spawned a whole new field of scientific visualization based on real and modeled observations. The enormous quantity and global nature of real-time and archived data and information provide scientists and educators with new challenges in "presentation" of this material making it "viewable" for their broad-reaching audiences—students of all ages, teachers, colleagues, and the general public. A quick look at any software catalog today reaffirms the fact that what has come to be called "multimedia" is becoming a force in science education, both in the classroom and museums/science center setting and at home.

Research has shown that people retain about 20% of what they hear, 40% of what they hear and see, and 75% of what they hear, see and do.218 Revolutionizing the way teachers teach and the way students learn, modern multimedia blends data, computers, text, and television into powerful new ways of communicating. Advanced multimedia

applications are creative couplings of video images, text, graphics, and audio that emerge as video productions; CD-ROMs with still and moving images, sounds and text; laser disc images; or computer programs filled with visualizations and animations. These resulting learning tools are the backbone of a new generation of information, adding the "see" and "do" component to the learning process. While some of these new materials are published in a variety of electronic forms, others are being placed directly on network servers where they are readily updatable and available through the Internet and other electronic information services. Their ease of use is likely to make a significant impact on access to general science and technology information and background material. Training a new generation of educators, students, and adults to capitalize on the multimedia approach to learning, via use of hard copy multimedia programs and access to the information super highway, will open up new avenues for better understanding science and technology.

The accelerated thrust for improving science and mathematics education nationwide has promoted access to other informal or nonformal science education opportunities which are expanding rapidly as well. With tightening instructional budgets in schools, science museums, zoos, aquaria, and other science and nature centers are emerging as alternative sources of instruction, filling an instructional gap brought about by the loss of budgets for school science specialists. In the U.S. alone, more than 400 science, technology, and natural history centers and museums, aquaria and nature centers, and children's museums service more than 50 million annually. Referred to by some as "the sleeping giants of

science education," these unique institutions provide valuable out-of-school learning experiences for all ages. For those museums and science centers aimed at younger audiences, one goal is enhancing their roles as "educational partners with the family and schools." Because science museums are a draw for all age groups, Susan Kendall of the Association of Science-Technology Centers noted, "...the whole family gets an education." One NSF-funded study, called "Out of School Experiences," found "the teaching and learning that takes place within a family is considered by some indicators to be one of the most important of all educational experiences." When these family experiences can be reinforced in the informal education setting, such as the museum/science center, they become even more valuable.

Today's museums and science/nature centers are no longer combinations of static, moth-eaten dioramas, unapproachable glass cases, poorly-placed labels, and dusty artifacts. Modern science centers feature manipulative exhibits within a free-choice format that invite visitors to "explore by looking, touching, manipulating, and hopefully thinking...(and) allow visitors to exercise control over one or more variables in the exhibits." The first of the new generation of science centers were launched in 1969 with the opening of the Exploratorium in San Francisco and the Ontario Science Center in Toronto. Their uniqueness was a completely new medium for communicating science: the interactive exhibit. These modern science exhibits feature an open-ended outcome which is

225Eratuuli, Matti and Cary Sneider. "The Experiences of Visitors in a Physics Discovery Room." Science Education 74.4 (July 1990), 481.
dependent on visitor input and are designed to stimulate curiosity while often featuring creative explanations of natural phenomena and playful demonstrations of scientific principles and technological applications. Focusing on the Lawrence Hall of Science at the University of California, Berkeley, which attracts 250,000 visitors per year (including 40,000 elementary and middle school students), in Table 13 Matti Eratulli and Cary Sneider offer their general observations and suggestions for enhancing the visitor experience to one special area of the facility, the Wizard's Lab, which alone attracts over 50,000 visitors annually:

<table>
<thead>
<tr>
<th>TABLE 13</th>
<th>OBSERVATIONS ON VISITOR EXPERIENCES AT THE LAWRENCE HALL OF SCIENCE</th>
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<tbody>
<tr>
<td></td>
<td>• A large majority of visitors in a science discovery laboratory do not restrict their activities to random manipulations, but engage in the kinds of learning activities that lead to both enjoyment and understanding.</td>
</tr>
<tr>
<td></td>
<td>• Teamwork is an important aspect of visitor interactions, especially between parents and children.</td>
</tr>
<tr>
<td></td>
<td>• Efforts that clarify, simplify, and call attention to instructions for using the equipment may increase visitor enjoyment and understanding.</td>
</tr>
<tr>
<td></td>
<td>• Illustrations, signs, brochures, or other efforts to encourage parents and children to work together may also increase enjoyment and understanding.</td>
</tr>
<tr>
<td></td>
<td>• Open-ended questions, illustrations, or encouragement by staff instructors may induce more people to use an exhibit creatively.</td>
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As learning environments distinct from school learning settings, science museum evaluator John Falk outlines specific characteristics of museums that make them ideal places for teaching science and technology. Museums are:

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227 Danilov, "Discovery Rooms," supra note 222, 6 and 8.
228 Eratuuli, "Physics Discovery Room," supra note 225, 492.
1) free-choice environments
2) individuals establish their own goals for the visit
3) nonevaluative and noncompetitive
4) conducive to and supportive of very specific kinds of learning
5) cater to a heterogeneous set of learners with regard to age, social background and motivation
6) social settings that encourage group learning and social groupings of the visitor's choice
7) places where learning cannot be judged with the same precision as classroom learning and one never knows with certainty what impact they have on the publics they serve.\textsuperscript{229}

Based on their experiences with the Natural History Museum in London, Roger Miles and Alan Tout offer a listing of attributes (see Table 14) of that should be considered when designing and fabricating science museum exhibits:'

<table>
<thead>
<tr>
<th>TABLE 14</th>
<th>SCIENCE MUSEUM EXHIBIT ATTRIBUTES\textsuperscript{230}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive:</td>
<td>Neutral:</td>
</tr>
<tr>
<td>- Makes the subject come to life</td>
<td>- Participatory</td>
</tr>
<tr>
<td>- Makes its point quickly</td>
<td>- Deals with subject better than textbooks</td>
</tr>
<tr>
<td>- Has something for all ages</td>
<td>- Is artistic</td>
</tr>
<tr>
<td>- Is memorable</td>
<td>- Makes a difficult subject easier</td>
</tr>
</tbody>
</table>


It is not only the visitors who benefit from associations with science museums and nature centers. Many museums and science centers maintain a modest professional staff supplemented by a wide range of volunteer and docent "explainers" and assistants who handle a spectrum of duties including teacher training, tour guide, curriculum development, demonstrations and educational programs, exhibit construction and maintenance, and resource center, audiovisual/multimedia and bookstore/gift shop assistance. The volunteer force is not limited to adults, and in many venues, like the famous Exploratorium in San Francisco, adolescent "explainers" are trained to serve as the primary staff on the museum floor. 231 The Explainer program has proven to help increase self-confidence in teenagers who participate in the program as well as develop skills for communication and learning to get along with people, cement realistic notions about jobs and careers, and provide stimulation for some to go on to college. One key to the success of this informal education program (that does contain a comprehensive, 50 hour, formal, non-school training component) is that although the youngsters are asked to perform a difficult job, they cannot fail. As Robert Oppenheimer, founder of the Exploratorium, noted, "No one flunks museum," including the explainers and the general public who visit the exhibits. 232 Although each adolescent explainer works at the Exploratorium for a four month period only, the experience has been found to "play a profound role in stimulating teenagers' social development, communication abilities, and interest in science." 233

Good science centers and museums are also becoming a valuable new form of public learning center integrating their innovative exhibits with libraries and resource

232 Ibid., 653 and 655.
233 Ibid., 655.
centers, access to information systems, video and demonstration theaters, preservice and inservice teacher training programs, and public education offerings. They can form an important bridge between formal science education and the community and can serve to "motivate children and adults to become more inquisitive...and encourage the development or redevelopment of curiosity"—essential ingredients in fostering positive attitudes toward science and technology through traditional education and lifelong learning.

\(^{234}\)Semper, R.J. "Science Museums as Environments for Learning." Physics Today 43 (November, 1990), 51 and 56.
VIII. CONCLUSION: A ROLE FOR UNIVERSITIES

In the decade that has passed since the publishing of *A Nation at Risk*, much has been said and done to enhance scientific literacy. Hundreds of reports highlighting the "deplorable state of American scientific literacy," widespread attempts at educational reform, increased media coverage of science and technology issues, pressure from scientific, public policy, and economic development organizations, and an explosion in the number of science museums and opportunities for informal science education have all combined to place solving the problems of scientific illiteracy firmly on the nation's agenda.

Today, universities are finding themselves at the center of the sphere of influence capable of fostering public understanding of science at many levels. When reporting science and technology stories, the media regularly turn to universities for input from experts. University science and journalism departments host seminars targeted at information dissemination for working journalists. Agendas for these seminars include presentations on the research being conducted at a particular institution or are organized to deal with a timely topic of interest to the media. Some universities, such as Massachusetts Institute of Technology, bring working journalists to their campuses for year-long academic programs, immersing a select group of journalism fellows in intensive study of an aspect of science and technology of interest to them.

It is also in colleges and universities where students are trained as the elementary and secondary school teachers and college professors of tomorrow. Similarly, universities are responsible for educating future librarians and science museum/nature center personnel. The vast majority of informal and nonformal science educators employed by environmental
advocacy organizations, conservation groups, and government agencies are also college graduates. Universities have a responsibility to provide future science teachers and educators with an adequate science and technical background so that when they leave college they will have the confidence to handle the subject matter and skills to locate and access a wealth of new and emerging information available via electronic or other means. Likewise, the general college student population, the group that represents one-third of those who choose to be active participants in the democratic process of governing science and technology policy in this country, hopefully graduates from college with at least the basic communication and inquiry skills needed for finding unbiased information about the issues to which they choose to become attentive.

University scientists still continue in their traditional role as generators of knowledge and scientific and technological information. But organizations like the American Association for the Advancement of Science and respected journals like Science and New Scientist have led a charge aimed at involving university scientists more directly in the scientific literacy solution itself. A cultural change appears to be taking place on university campuses, with scientists appearing more willing than ever to reach out to the various audiences that can use their talents the most—teachers, pre-college students, professional educators, the media, and the "attentive" and "interested" public.

Whether the driving force behind this cultural change at universities is a concern for accountability for the public-funded work conducted by the majority of university scientists or the sincere feeling of responsibility for passing on the excitement of science to others, the fact remains, more and more university scientists are making the effort to visit elementary and secondary school classrooms, host teacher interns in their laboratories, write science articles for lay audiences, assist members of the electronic and print media,
and work with professional educators to create new classroom and informal education science curricula, multimedia materials, and science center exhibits.

University scientists are opening their laboratories to teacher interns and a wide variety of teacher training programs are offered by university education and science departments. The University of Rhode Island Graduate School of Oceanography (URI/GSO) education personnel match secondary school teachers with scientists who host them in their laboratories, providing a for-credit summer teacher intern experience that culminates in the production of new curriculum materials based on the scientist's area of study. At URI/GSO large-scale teacher training programs are also held each year to provide teachers with access to new materials and the confidence to utilize them in their classrooms. The Eisenhower Fund for Mathematics and Science Education funds these intern and teacher training programs at URI/GSO and at numerous other colleges and universities across the country. In addition, URI/GSO and many other institutions have been recipients of funding from other large federal agencies such as National Science Foundation, Environmental Protection Agency, National Oceanic and Atmospheric Administration, and National Science Foundation, as well as the U.S. Department of Education, for their teacher enhancement efforts in the science and technology arena. URI/GSO and many other institutions also organize in-classroom or mobile classroom experiences, coordinating the involvement of faculty, graduate and undergraduate students, and volunteer speakers with the in-school needs of local classroom teachers. In addition, university scientists and educators have a growing role to play in the generation and dissemination of new curriculum materials and science and technology information that is useful to teachers who wish to keep up-to-date. Universities are in a position to use their direct access to the Internet and numerous bulletin boards and network servers on the information superhighway to carry information in emerging new formats, such as Mosaic, which are
capable of bringing science to life through bulletin boards and electronic libraries of interconnected text, moving and still graphics, and sound directly accessible via computer terminals in schools around the world.

In addition to scientists, many universities employ professional educators associated with a variety of science- and technology-oriented disciplines whose jobs are to engage in a variety educational outreach endeavors. Nearly ten percent of all science museums and centers in the U.S. are operated by universities. In addition, many universities have professional staff who carry out preservice and inservice teacher training, offer summer camps and training programs for pre-college students, coordinate citizen's monitoring and awareness programs, organize in-school science activities, administer broad-based public education short courses and lecture programs, and publish magazines and newsletters featuring science and technology intended for lay audiences.

With so much room for improvement in the level scientific literacy, the job of universities, the media, and the formal and informal/nonformal education communities has barely begun. The fast-paced changes taking place in the world today brought about by the dizzying pace of scientific and technological advances make it clear that scientific literacy will remain an issue on our educational, political, economic, and social agenda for decades to come.
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