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ABSTRACT

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Scientific Literacy for All:

Rationales and Realities

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Scientific Literacy for All: Rationales and Realities

Andrew C. Kemp

Abstract

This qualitative study is a critical examination of the rationales for the goal of scientific literacy for all in the United States. Eleven participants, mostly university-based science educators, were interviewed and their comments were analyzed using the methods of grounded theory (constant comparative analysis). The rationales the participants gave for the goal of scientific literacy for all can be grouped into at least 4 categories: Social Benefits of Science, Personal Benefits of Science, Promoting Humanity, and Control of Science. There are tensions between these categories because they have different implications for policy, programs, and practices. There is little empirical evidence for any of the rationales discussed here; the participants seem to feel rationales represent philosophical or value statements, and they are not concerned by the lack of research into whether or how scientific literacy actually benefits people. It is suggested the goal would be more likely to be achieved if the rationales were convincing to the public, and that empirical studies of scientific literacy's benefits would be a step in the right direction.

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Introduction

The goal of scientific literacy (a.k.a. science literacy) is a common focus for science education in the United States, especially at the K-12 level. For example, the National Science Teachers Association (NSTA) has taken the position that the "two major goals of science education are to achieve scientific literacy for all citizens and to ensure an adequate supply of scientists, engineers, and science teachers" (NSTA, 1990). A recent survey of more than 1700 NSTA members of found that 68% of those polled cite science literacy as "essential" for adults (Bayer Corporation, 1999). The National Association for Research in Science Teaching (NARST) declares in its Mission Statement "the ultimate goal of NARST is to help all learners achieve science literacy" (NARST 2000). Findings such as these lend credence to the view that scientific literacy for all is the "fundamental goal of science education" in the US (Bybee, 1997, p. 46).

Upon hearing statements such as those above, someone not too familiar with US science education might be tempted to ask two related questions: (1) Why is scientific literacy necessary or desirable? And (2) What is it anyway? This paper examines addresses science educators' perspectives on the first question. I address the second question in another paper (Kemp, 2000). Because there are a number of views on what scientific literacy encompasses (Kemp, 2000), for the purposes of this paper I will refer to the definition of scientific literacy (Figure 1) given by one of the most widely available policy documents, the *National Science Education Standards* (National Research Council [NRC], 1996). This document will also serve as a starting framework for discovering the rationales that support the goal of scientific literacy for all.

Examining the rationales (a.k.a. reasons, motives, purposes, benefits) for a goal widely held in high regard may seem to be merely an academic exercise. However, we are in the midst of a climate of reform in our public schools. It is difficult to see how educational policies, programs, and practices can be reformed if we are not first clear about educational purposes. In the case of scientific literacy, a number of rationales have accumulated over the past four decades (Atkin and Helms, 1993). That is to say, motives for promoting scientific literacy as an educational goal have been increased in number over time as new ones are added to the older list. Atkin and Helms (1993, p. 1) say that this accretion of rationales presents a problem because "seldom ... are questions raised about the operational consequences of espousing a particular goal, whether or not reaching it is feasible, or whether some goals are more important than others." Some of the rationales may have implications or consequences that conflict, so those people who promote one purpose may in turn clash with those who promote the contrary purpose, with the result that there is little progress in the pursuit of scientific literacy for all. Therefore, "those who claim interest in the future of science education would do well to engage in comprehensive and extended deliberation about the most desirable ways for young people to spend their time in science classes" (Atkin and Helms, 1993, p. 2).

The rationales for scientific literacy also received serious criticism in the 1990s, especially from Morris Shamos (1995). Shamos asserts there is no real reason why the majority of people should become scientifically literate. This is no idle remark coming as it does from an emeritus physics professor, a past president of NSTA, and former co-director of one of the large-scale science curriculum reform projects in the 1960s.

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Shamos (1995) says there is little to no evidence that scientific illiteracy hinders nonscientists in their personal or professional lives. Therefore, he concludes it is time to abandon "scientific literacy for all" and switch to another, less lofty and more achievable goal, such as the one he proposes to call "scientific awareness." Because Shamos' arguments against the rationales for the goal of scientific literacy were very influential in my thinking during this study, they are detailed in the next section.

Researcher Perspectives and Assumptions

Any research is influenced by the beliefs of those conducting the research. So that the reader may understand my assumptions and perspectives better, I will attempt to make some of them explicit.

Morris Shamos' Criticisms of Scientific Literacy Rationales

Shamos (1995) charges that the explicit goal of universal scientific literacy does not accord with the values science educators implicitly endorse. He states, "The need for widespread scientific literacy has been rationalized on several grounds, but when carefully probed most have a hollow ring to them" (p. 91). The actual goal of science educators, so Shamos alleges, is to perpetuate their careers and interests. Thus, Shamos (1) challenges the validity of the espoused rationales for universal scientific literacy; and (2) alleges that science educators have a hidden agenda that does not match their explicit goal.

First, Shamos (1995) says science is not necessary for everyone to know in either their public or private lives. Science educators claim there are many science-based societal issues that frequently affect the public, such as nuclear energy, depletion of genetic resources, genetic engineering, and so forth. Shamos points out that these issues are actually more related to technology than science. He maintains "the list of societal issues that are truly science based is very short indeed, encompassing mainly such questions as federal funding for research (e.g., space probes ... the Human Genome project), or whether certain types of scientific research should be discouraged, or even prevented (e.g., animal experimentation, genetic engineering, human gene transplants)" (p. 147). Furthermore, concerning public decisions about any of these issues, Shamos claims, "we really do not need *total* scientific literacy to profoundly alter the way that society deals with technical matters" (p. 196). Instead, he calculates that "if our national scientific literacy rate ... were in the order of 20 percent ... the chance of finding one or more such individuals in almost any deliberative group would become a near certainty" (p. 195). The scientific literate person in the deliberative group could persuade the others of the merits or perils of the proposed project, according to Shamos, thus ensuring that a scientifically sound decision is reached.

Shamos (pp. 97-98) says that if there is any truth to the

> popular argument generally offered ... that [scientific literacy] better prepares a nonscientist to function in business or professional life ... students fail to perceive it, and small wonder: they need only look at their own professional family members and friends, at wealthy businessmen and powerful public officials, at people in the arts and entertainment and professors of humanities--all successful and respected members of society and most, if not all, illiterate in

> science. After all, what bearing does a lawyer's *understanding* of the double helix have on the success of his practice? How many times does a banker call on the uncertainty principle to make an investment decision? Is it necessary for the mayor of New York ... to be versed in plate tectonics to run City Hall, or for a surgeon doing laser surgery to understand the physics of lasers? Would a knowledge of chaos theory have boosted the careers of Luciano Pavarotti or Laurence Olivier? The same question might be asked of all educated adults in the work force, with essentially the same answer: there is no convincing evidence that *understanding* science is important to them. While enjoying the everyday comforts and benefits derived from science and technology, society has managed to insulate itself from any actual or even perceived need to understand their origins.

Shamos concludes, "The sad but simple fact is that one does not need to be literate in science ... to be successful in most enterprises or to lead the 'good life' generally" (p. 98).

Thus, Shamos brings into question the real value of the overt rationales for the goal of universal scientific literacy. He also goes further by claiming that the explicit reasons given for pursuing the goal of universal scientific literacy are not in accord with the actual practices of science educators. Shamos says that the avowed purpose of science educators--to increase scientific literacy among all students and the public--is actually a front for their "primary" purpose, namely, "to ensure a steady supply of scientists and science-related professionals, including, of course, science educators" (p. 73). Shamos (1995) says there never was an educational "crisis" in science education, as was alleged in the 1980s, but that this declaration was a ruse to dupe the federal government into greater funding for science and science education programs. The ruse worked so well, he claims, that "scientific literacy has become too good a public relations 'prop' for the science education community to abandon at this point. It has served the community well as the rationale for increased support for science education" (p. 158). In other words, science educators think they owe their jobs to the explicit goal of universal scientific literacy, and so must keep their implicit goal of perpetuating science and science-related programs quiet, or else they risk losing their livelihoods.

<u>Additional Considerations</u>

I think it is important to note that I am a goal-oriented person. I believe improvement, or progress, comes from setting and then working towards goals. In part, this belief arose from my training as a teacher, where I learned about setting goals and objectives for my students. I have found that setting and working towards personal goals helps me improve myself as a teacher, researcher, and human being. Because it works for me, I believe goal-oriented behavior can also be important for others, such as science educators in general.

After reading Shamos' (1995) book *The Myth of Scientific Literacy*, I became acutely aware that it is possible little progress towards the goal of scientific literacy for all is being made. If true, there are probably lots of reasons for this lack of progress, including social issues such as poverty and school crime. However, I have developed a suspicion that at least part of the blame falls to science educators. My readings of science education literature lead me to the conclusion that a lot of science education research and practice is redundant, and goes in cycles based on popularity rather than "results." As

Bybee (1997, p. 25) says, "The last fifty years of science education reveal a pattern of cycles of reform. ... [Yet] reform had little effect on teaching and learning in classrooms. We offer a seemingly limitless supply of activities, techniques, and materials, but the cumulative effect is only marginal. We have to ask why this is so." One of my personal aims is to help improve the discipline of science education by addressing this question.

And finally, the reader will no doubt wonder if I favor or oppose the goal of scientific literacy. My reply is that I am somewhat ambivalent towards it: in some ways, I believe it is a very worthy pursuit, but in other ways I think our efforts may be fruitless or even misdirected. The research being reported here is as much an attempt to clarify my own feelings on the goal as it is to explicate the rationales for scientific literacy for others.

Purpose of the Study

The interpretive research study being reported here is part of a more extensive investigation that aims to elicit and compare past and present perceptions of the goal of scientific literacy for all, as well as science educators' responses to criticisms of the goal. This paper is primarily concerned with three questions:

1. What are some broad categories of the rationales (motives, purposes) for the goal of scientific literacy as currently espoused by science educators?
2. What are the bases for their rationales?
3. What are the educational implications of these rationales?

Methods

In this section, I describe the study's qualitative research design and the methods I am using in order to discover the participants' views of the goal of scientific literacy for all. I also discuss some of the limitations of the study.

Design of the Study

The design of this study is based on the interpretive research tradition in science education (Gallagher, 1991). I have used a grounded theory design (Strauss and Corbin, 1990), a type of interpretive research with the intent to generate or discover a theory about a phenomenon that relates to a particular situation. The situation is one in which people act, react, and interact with the phenomenon. In this case, the phenomenon is the goal of scientific literacy for all, and the "people" involved are science educators or related professionals. To obtain science educators' personal perspectives on the goal of scientific literacy, I gathered data in the form of face-to-face, semi-structured interviews (Patton, 1990). I analyzed the transcripts in a series of coding cycles in an attempt to inductively derive themes, hypotheses, models, and (hopefully) a substantive-level theory about the phenomenon (Strauss and Corbin, 1990). Although this paper primarily reports findings from these interviews, the study discussed here is part of a more comprehensive effort that also examines nearly 50 years of documents pertaining to the goal of scientific literacy (books, articles and conference papers). My ultimate objective is to build theoretical statements about science educators' beliefs concerning scientific literacy as a goal; however, at this point I have derived tentative categories or themes that will need further investigation before a theory can be formed.

Participants

To begin a grounded theory study the researcher can *purposefully* choose sites, persons, and documents that promise to provide data for the study (Strauss and Corbin, 1990). The basic idea is that the initial gathering of data "is open to those persons, places, [and] situations that will provide the **greatest opportunity** to gather the **most relevant data** about the phenomenon under investigation" (Strauss and Corbin, 1990, p. 181; emphases in the original). Laugksch (2000, pp. 74-76) subdivides the many "workers involved in scientific literacy" into 4 "interest groups":

- the science education community
- social scientists and public opinion researchers concerned with science and technology policy issues
- Sociologists of science and science educators employing a sociological approach to scientific literacy
- informal and nonformal science education community

For both methodological and practical reasons, I have purposely chosen to limit participants to one of these "interest groups," namely, the science education community. Laugksch (2000, pp. 75) describes this group as being

> concerned with the nature (i.e., purpose), performance, and reform of existing educational systems... This group's involvement in scientific literacy is motivated by issues related to (a) the goals of science education (i.e., why teach science and what form should the science content take); (b) how personal skills, attitudes, and values implied by the goals are successfully incorporated into the science curriculum, and effectively taught by teachers; (c) the quality and nature of resources required to achieve these goals efficiently (e.g., textbooks); and (d) appropriate measures of assessment to ascertain to what extent the goals for science education have been met. Associated with this interest group would also be science curriculum development groups, as well as professional science education associations. This first interest group is therefore mainly concerned about the relationship between formal education and scientific literacy, and the group has a specific focus on secondary, but increasingly also on primary and tertiary, education.

I was most interested in interviewing U.S. science educators (first) in this exploratory study because "theoretically" they are the ones most directly responsible for promoting and working towards (or against) the goal of scientific literacy in this country. As my main selection criterion, I proposed to interview individuals who are considered (or who consider themselves) "experts" of scientific literacy. By "expert," I had in mind people who are now or formally were engaged in research, programs, or policy generation directly related to (and with potentially widespread impact on) the goal of scientific literacy. There are a number of other stakeholders that one might investigate concerning the goal of scientific literacy (e.g., students, parents, teachers, legislators, business people, etc.), however, a second more "practical" consideration is that it is necessary to limit the scope of this exploratory study to manageable proportions.

In this study I have interviewed 9 college and university science educators, i.e., professors whose primary teaching and research responsibilities relate to the study of teaching and learning in science. I have also interviewed 2 other professionals (both former college professors) who have published papers about scientific literacy in science education professional journals. It is important to note that as with any study involving a small sample size, I do not intend for the results here to be construed as fully representative of the science education community as a whole (see the later section on "External validity"). Any hypotheses I put forth here should be viewed as untested and very tentative.

Some of the participants have given permission for their real names to be used. Others have asked that their names be withheld. While it would perhaps make some of the findings more credible if I revealed the names of the participants (because most are fairly well known among science educators), for consistency's sake all names given for participants in this paper are pseudonyms that I assigned (Table 1). To protect their anonymity and confidentiality, I am somewhat restricted in what I can reveal about the participants. I interviewed people from 8 states, and no two work at the same university or site. Eight participants are male and 3 are female. The first 7 participants interviewed were purposefully selected because they all met the following criteria: (a) 15 or more years of experience in the fields of science or science education; (b) participation in projects and/or publications that explicitly concern scientific literacy in the U.S.; (c) although most of their work is focused on the U.S., they are all internationally recognized for promoting the goal of scientific literacy; and (d) they volunteered and were accessible to me in person. The idea was to interview participants who were likely to be well informed about and to hold strong opinions about the goal of scientific literacy (not all favorable opinions, I might add).

Three of the last 4 participants interviewed are individuals recommended by one or more of the other participants as someone who "I should speak to" concerning scientific literacy. The remaining participant was a science education professor I met at a conference who heard about my study and volunteered. Since I knew he had done work with regard to at least one particular aspect of scientific literacy, I readily accepted his offer. All four of these participants met at least 3 of the criteria (a - d) above. I had met some of the 11 participants prior to the study, but I only knew one of them well prior to the study.

Interviews

One of the hallmarks of the grounded theory design is the researcher must set aside, to the extent possible, his or her preconceptions and theoretical notions so that the analytic, substantive theory can "emerge" from the data. Therefore, I did not begin with preset variables, conditions, or control situations in my design. I interviewed each participant separately, and following transcription of the audio-tape I began to code the data (open-coding). The first interviews were face to face and very nearly open-ended. The interviews took place between April 1998 and June 1999. As interviewing and data analysis proceeded, the interview questions became more focused. I re-interviewed 3 of the early participants, 1 in person and 2 via mail, using the more focused questions. The final interview questions most pertinent to the findings being reported here include the following:

- Scientific literacy for all has been characterized as the fundamental goal of science education. Do you agree or disagree? Please explain your response.

- Why is scientific literacy necessary or beneficial for an individual in the United States? (Or for society?)
- Is scientific literacy for all an appropriate goal for science educators in less developed (third world) countries? Please explain your response.
- We often hear that scientific literacy is a necessity for everyone. But do you know of any studies that have shown how scientific literacy benefits particular individuals or groups? Please tell me something about these studies.
- Morris Shamos (1995) says that members of the general public do not believe becoming scientifically literate is necessary. Please respond.
- Shamos says that arguments used to promote the need for scientific literacy are actually better arguments for technologic literacy. How do you respond?
- Shamos says that the goal of scientific literacy for all is a front for science educators' true goal of perpetuating their own careers and keeping the science pipeline flowing. The cry of scientific illiteracy is used as a slogan to get more funds for curriculum programs and research. How do you respond?

Not all participants were asked each of these questions, but most of them were asked the majority of these questions or similarly worded ones, assuming they did not bring up these issues on their own during the interview. Note that at the request of the participants, most redundancies (the, the ...), false starts, and fillers (um, ah, ...) are omitted in the interview quotes.

Data Analysis

The interview transcripts and documents were analyzed in a series of coding cycles in an attempt to inductively derive themes about science educators' views on the goal of science literacy for all. As soon as possible following an interview, I transcribed it and begin to code or label the data. "Coding" means identifying bits of data that seem relevant to the study, and giving them names. This procedure is a way of "conceptualizing" the data, i.e., "taking apart an observation, a sentence, a paragraph, and giving each discrete incident, idea, or event, a name, something that stands for or represents a phenomenon" (Strauss and Corbin, 1990, p. 63). I also coded documents in a similar manner.

Strauss and Corbin (1990) refer to the development of categories in this initial coding cycle as "open coding." Categories are simply conceptual constructions that capture recurring patterns in the data (Merriam, 1998). Categories span different sources of data, and are not the data themselves (Merriam, 1998). The categories describe the data and to some extent interpret it (Merriam, 1998). The characteristics or attributes of a category, called its *properties*, are also developed and described to represent multiple perspectives about each of the main categories (Creswell, 1998; Strauss and Corbin, 1990). These properties are then "dimensionalized," i.e., they are located along one or more continua (Strauss and Corbin, 1990). For example, suppose the category is "watching." Properties of watching might include the "frequency" and "duration" of watching. The dimensional range of frequency might be from "never to often," while a dimension of duration might be from "short to long" (Strauss and Corbin, 1990). Identifying the properties and dimensions of categories not only helps the researcher to understand the category, but to identify the relationships between categories, too (Strauss and Corbin, 1990).

In open coding, the data are taken apart, in a reductionist manner, and analyzed in detail to identify categories. Following, or proceeding nearly simultaneously along with open coding, the researcher also engages in the process of "axial coding" (Strauss and Corbin, 1990). In axial coding, the data are put back together in new ways to make connections between a category and its subcategories (Strauss and Corbin, 1990). In axial coding, a single category is identified as the central phenomenon of interest. The researcher then engages in the following steps (Creswell, 1998; Strauss and Corbin, 1990):

a) exploring the antecedent or *causal conditions* that influence and give rise to the phenomenon
b) identifying the *context* (specific set of properties) in which the phenomenon is embedded, e.g., time, location, number, etc.
c) specifying actions and interactions, or *strategies*, that address the central phenomenon, and the intervening conditions that bear upon these strategies (e.g., culture, economic status, history, etc.), and
d) delineating the outcomes or *consequences* of undertaking the strategies for this phenomenon.

The causal conditions, context, strategies, and consequences of the phenomenon are referred to as the subcategories of the category (Strauss and Corbin, 1990). Like the categories they refer to, subcategories have properties and dimensions that must be identified (Strauss and Corbin, 1990). Strauss and Corbin (1990, p. 99) link the subcategories to a category in a set of relationships they call the "paradigm model," which highly simplified looks like this:

CAUSAL CONDITIONS → PHENOMENON → CONTEXT → INTERVENING CONDITIONS → ACTION/INTERACTION STRATEGIES → CONSEQUENCES.

To further explore the relationship of the category and its subcategories, the researcher must verify hypothetical relationships in the data; search for additional properties and dimensions of the category and subcategories; and look for variation in the phenomenon (Strauss and Corbin, 1990). There is a constant interplay between proposing hypotheses and checking them.

If the goal is to build theory, then the researcher must begin a third level of analysis at some point (Strauss and Corbin, 1990; Merriam, 1998). This third cycle of coding is called "selective coding" (Strauss and Corbin, 1990). I have not yet engaged in this stage of coding. In essence, open coding provides the (developing) categories, axial coding identifies interconnections between the subcategories and categories, and selective coding builds the story that connects the major categories (Creswell, 1998). The desired product is "a discursive set of theoretical propositions" about the phenomenon under study (Creswell, 1998, p. 150).

Selective coding involves moving back and forth in a nonlinear fashion among five steps (Strauss and Corbin, 1990):

a) explicating the *story line*
b) relating *subsidiary categories* around the *core category*
c) relating categories at the dimensional level
d) validating those relationships against data, and
e) filling in categories that need further refinement or development.

The researcher must first commit to a single descriptive story about the central phenomenon of the study, then summarize this story in an analytical *story line*. The central phenomenon (what the story is about) is identified and named, becoming the *core category*. The properties and dimensions of this core category are developed, and the other categories are related to it as *subsidiary categories*. The subsidiary categories are arranged and rearranged "**in terms of the paradigm** [model] **until they seem to fit the story, and to provide an analytic version of the story**" (Strauss and Corbin, 1990, p. 127; emphases in the original). One or more hypotheses may now be derived regarding the relationships among the categories (Strauss and Corbin, 1990). These hypotheses are checked against new or old data to validate them. By grouping categories and relating them at the property and dimensions levels, the researcher derives the rudiments of a theory. The theory is laid out diagrammatically or narratively, and each statement "regarding the category relationships under varying contextual conditions are developed and ... validated against the data" (Strauss and Corbin, 1990, pp. 133-134). Finally, conceptual density and specificity are added to the theory by filling in any missing details.

Validity and Reliability

A number of different strategies can be used to enhance the "believability" or "truthfulness" of findings in research. The strategies I am employing to assure that the findings are trustworthy are discussed below under three headings.

Internal validity. Internal validity deals with the issue of whether the findings fit reality, i.e., it addresses the question, "Are you studying what you think you are?" Internal validity is being enhanced in my study through the following procedures (Merriam, 1998):

- Triangulation of data sources--I used data from both interviews and documents as sources of data, rather than relying on a single type of information.
- Member checks--Once findings began to emerge, I asked some participants whether my tentative interpretations of data seemed plausible.
- Peer examination--I have been asking other science educators to comment on the findings as they emerge.
- Statement of researcher's biases--I clarify my experiences, assumptions, and biases at the outset of the study (see the section on Researcher Perspectives and Assumptions), and have continually watched for biases throughout the study.

Reliability. Reliability in the traditional, physical science sense means replicability, i.e., if the phenomena were studied again would the same results emerge. Reliability in this sense is not achievable in qualitative studies of human beings "because human behavior is never static" (Merriam, 1998, p. 205). Qualitative researchers believe reality is multifaceted and highly contextual. Studying the same situation or people for a second time, a researcher may reach different conclusions. Even if two researchers study the same phenomena simultaneously, they are likely to have different interpretations and findings. Thus, Lincoln and Guba (1985, p. 288) suggest thinking of reliability in qualitative research as "dependability" or "consistency." In other words, "rather than demanding that outsiders get the same results, a researcher wishes outsiders to concur that, given the data collected, the results make sense--they are consistent and dependable"

(Merriam, 1998, p. 206). In this sense, reliability of this study is being enhanced by the following methods (Merriam, 1998):

- The investigator's position--I explain the assumptions and theories behind the study, my position in regards to the participants (e.g., I am a science educator studying other science educators), the basis for selecting participants, and the social context from which data are collected.
- Triangulation--using multiple methods of data collection strengthens reliability as well as internal validity.
- Audit Trail--I describe how data were collected, how I derived categories, and how I made decisions throughout the inquiry so the reader can decide if my methods and reasoning are sound.

External validity. External validity pertains to the generalizability of the findings. Can the findings of this study be applied to other situations? Because qualitative studies are so context and researcher specific, generalizing findings is always problematic, i.e., qualitative research is low in external validity in the traditional sense. As with reliability, qualitative researchers propose viewing external validity in new ways. For example, Patton (1990, p. 491) argues that qualitative methods should "provide perspective rather than truth, empirical assessment of local decision makers' theories of action rather than generation and verification of universal theories, and context-bound extrapolations rather than generalizations." Merriam (1998, pp. 211-212) suggests that generalizability in this qualitative study can be enhanced as follows:

- Rich, thick description--I provide enough description so that readers will be able to determine how closely their situations match the research situation, and hence, whether findings can be transferred. I provide thick description through numerous quotations from interviews or documents.
- Typicality or modal category--I describe how typical the participants and their views are compared with other science educators at the same level, so that users can make comparisons with their own situations.
- Multisite design--Although not a true multisite design, the participants come from many different universities and agencies. I feel that by purposefully choosing participants from many different settings the potential for generalizability, not to mention richness of data, is being enhanced. The findings will certainly not be generalizable outside of science education, however.

Study Limitations

One limitation of my study is that only professional science educators were interviewed. Other voices (e.g., teachers, administrators, politicians, representatives from businesses, students) are not heard. I believe that for the time being this limitation is justifiable because this is an exploratory study, and I started with those people I thought were most responsible for developing and promoting the concept of science literacy. It also allowed me to limit the scope of the study to manageable proportions.

Another limitation is that I have interviewed all US based educators, thus the study is US centered.

Access to participants was a limitation of this study; potential participants are located throughout the country and world. I had limited funds for this project, and participants had limited time to be interviewed.

Because I have only met some of the participants once or twice, it is possible they told me what they thought I wanted to hear, though I did not perceive any intentional deception during the interviews or afterwards.

Findings

A question that students often ask is, "Why do we have to learn this?" They are usually inquiring about a particular subject about to be discussed in a class, but the question can also be applied more broadly. Why do students have to learn science in the schools? What is it about scientific literacy that makes it a desirable goal for all students or for adults? To attempt to answer these questions, it helps to first have some idea of what scientific literacy is. There are a number of definitions of scientific literacy (Kemp, 2000), so it would be impossible to communicate with absolute certainty what scientific literacy is, but for the purposes of this discussion the definition given by the *National Science Education Standards* will serve (Figure 1).

Tentative Categories

The *Standards* are also an appropriate place to begin in the search for categories of rationales supporting the goal of scientific literacy, because several of the participants in this study helped to shape that document often referred to it during their interviews. In the *Standards'* shorter definition of scientific literacy (Figure 1), one sees some rationales, including that it somehow is "required for personal decision making, participation in civic and cultural affairs, and economic productivity," and it helps "a person … ask, find, or determine answers to questions derived from curiosity about everyday experiences." The *Standards* (NRC, 1996, pp. 1-2) address the purposes for scientific literacy more explicitly from the very first sentences of the first chapter of the document:

> In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and personal fulfillment that can come from understanding and learning about the natural world.
>
> Scientific literacy also is of increasing importance in the workplace. More and more jobs demand advanced skills, requiring that people be able to learn, reason, think creatively, make decisions and solve problems. An understanding of science and the processes of science contributes in an essential way to these skills. Other countries are investing heavily to create scientifically literate work forces. To keep pace in global markets, the United States needs to have an equally capable citizenry.

Combining these statements with the purposes of scientific literacy outlined in the definition given by the *Standards*, one may derive the following tentative list of categories for rationales for the desirability or necessity of scientific literacy for US citizens:

Participation in civic and cultural affairs (hereafter, "Participation")

- People need "to be able to engage intelligently in public discourse and debate about important issues that involve science and technology."

Economic productivity (hereafter, "Productivity")

- Understandings of science and the processes of science contribute to "advanced skills" necessary for work, including the abilities "to learn, reason, think creatively, make decisions and solve problems."
- A scientifically literate public will help the United States "to keep pace in global markets."

Personal decision making

- People use "scientific information to make choices that arise every day."

Curiosity about everyday experiences (hereafter, "Curiosity")

- "Understanding and learning about the natural world" is exciting and leads to "personal fulfillment."

The *Standards* were derived from the input of hundreds of individuals, including teachers, professors, administrators, policy-makers, scientists, and others. Thus, as a "consensus" document, one might suspect that it includes the full range of rationales for scientific literacy. But does it? Many of the participants did, indeed, refer to the same set of rationales during my interviews with them. For example, Dr. Infeld said, "If you look at goals of science education over the past hundred years, one of the things that you see is that the goals don't much change. That what changes is the order in which the goals are presented." Note that she is using the term 'goals' in the sense that I am using the term 'rationales,' because her next statement was, "And basically there's the one that sort of at the top of the list now is productivity. And the productivity goal is the one that I think fueled the current reform. ...We were scared to death that Japan and Germany were outdistancing us in the world economic market." A little later, she explained further:

> So to get back to the goals, I think the one that's on top at the moment and has been on top for a while is the sort of view of being a productive citizen. Then there's the ... engaging in civic responsibilities is a second one. A third one is sort of personal life. Not mixing Clorox and Drano in the toilet kind of thing. Making reasonable decisions about [whether to take] hormone replacement therapy or not kind of things are the personal kind of stuff. And the one that's sort of at the bottom of the list in terms of the goals for school science is preparation for life in science. Sort of the 'little scientist' thing. Now I think all of the first three combine in what I think of as science literacy. It's sort of a definition of the kind of science that ordinary people need to be productive, good citizens and take care of the science-related parts of their daily lives.

Thus, Dr. Infeld's statements reflect the first three types of rationales described above (Participation, Productivity, and Personal decision-making). She makes an important point that it is possible to think of the rationales in a hierarchical arrangement, but the hierarchy is subject to change. There may be a dominant rationale for science education as a whole, such as the Productivity rationale. But it is also possible that individual science educators have their own hierarchies.

Several participants referred to scientific literacy as necessary for "democracy" and "society", or what I have tentatively labeled "Participation":

- "everybody votes. And … if we're going to make a democracy work, then we have to have an educated population." (Dr. Andrews, citing John Dewey)
- "in a democratic society, individuals should be able to participate in the conversation about their world that they live in, part of which is a scientific world. … As a fully participating member of society, they have to share at some level--and each of us is going to participate at a different level--in the conversation about the world that they live in." (Dr. Benjamin, second interview)

Others spoke of the Personal decision making group of rationales:

- "if people could attack, interface with, approach problems with an understanding in problem-solving, with an understanding of reasoning, with a reliance on evidence, … they would ultimately make wiser decisions." (Dr. Kellogg)
- "In our society we get a lot of information passed onto us regarding health issues in the print medium, and on television. To some extent orally, by doctors and the medical profession. And from tradition. … Our own health and well-being are certainly important issues for us to be involved with." (Dr. Benjamin, second interview)

And still others spoke of science as a way of appreciating the world and as something that is interesting in and of itself.

- "[Science is] important from a philosophical, and in some ways, even a recreational view, an appreciation view. An appreciation of the world around us." (Dr. Andrews)
- "science is and of itself intrinsically interesting" (Dr. Kellogg, referring to one rationale given by the *Standards*.)
- "scientific literacy benefits people "in terms of understanding the natural world. Kind of the aesthetic, the enjoyment of it. Being able to understand how certain things work." (Dr. Howard)
- "[One] reason for science literacy is just to know science. … In other words, it's one thing to be practical and know about science because it can help you in your own life. It's another thing to know something just because it's nice to know it." (Dr. Johnson)

For now, I have lumped these latter statements into the "Curiosity" tentative category.

Significantly, there is often some overlap in the tentative categories I have thus far derived. For example, participants spoke of rationales falling under the tentative "Participation" category and the tentative "Productivity" category in the same breadth. Some representative comments include:

- "science has been and will continue to be an important aspect of society, i.e., economy, politics, etc." (Dr. Euler)
- "science is a very important part of our culture. … it's not only is it important for voters, but it's important economically." (Dr. Andrews)
- "[scientific literacy is needed] to be contributing citizens, [and] to be economically self-sufficient" (Dr. Howard)

Because civics (politics, democracy), culture (society), and economy (especially on a national level) are so often linked in participants' statements, it is perhaps not advisable to think of the "Participation" and the "Productivity" tentative categories separately.

The "Personal decision-making" and "Curiosity" tentative categories share a similar fate. For example, the following remarks by Dr. Johnson seems to say that being curious about personal encounters with science helps one make practical personal decisions:

> There's a whole bunch of reasons why we want people to be scientifically literate in the context of knowing, using, and lifelong desire to want to learn more about it. One is just the simple practical aspect knowing how people are able to do things. It's important in your life. It's nice to know how the computer works when you're using it, so ... if something goes wrong, you can fix it. So it's just kind of practical. It's practical for your health. You should know about side effects of things. And what drugs [are able to do]. What disease is like. ...The practicality of science literacy is obvious. If somebody knows about diseases, it's useful. That's number one, I think. It's good to be scientifically literate because people that know science will be able to deal with the everyday world in a scientific way.

These reasons for scientific literacy also add a new dimension to the "Curiosity" category, namely, someone may not only be curious about "the natural world," but also the human constructed world, or technology.

Rethinking the Categories

It seems prudent at this point, due to the overlaps discussed above, to collapse the 4 tentative categories into just 2 categories. In order to name these new categories, we must first examine the dimensions of the categories closer. The first one includes national, political, societal and economic concerns. Some additional dimensions might be allied with these elements. For example, several of the participants mentioned the launching of the first artificial satellite, *Sputnik*, in 1957 by the USSR as a stimulus for the curriculum reforms of the 1960s and the beginning of the movement towards scientific literacy. One aspect of that era was the "Cold War" and a fear that satellites and other Soviet technology threatened the United States sovereignty. Thus, a national military concern could also be added to the list of dimensions for this category.

One participant, Dr. Curtis, added another dimension to the first of our new categories that was not originally derived from the *Standards*. Specifically, he said, "it's become a goal to a certain extent to be competitive in international science competitions," i.e., tests of science achievement such as the Third International Math and Science Study. In the 1950s and 60s, such competition might have been seen as important in economic or militaristic terms, but it seems to me that more than anything else, it is currently a matter of national pride.

Dr. Curtis also discussed another rationale not originally derived from those in the *Standards* that I think could be added to this expanded category. He says that one theme in science education today, which is certainly embodied in the goal of scientific literacy, is "countering the drift towards non-scientific ways of thinking in the culture," including such things as "creationism, astrology, [and] all of the non-scientific trends that seem to have been amplified by both [a] lack of education and by the media." What is implicit in a statement like this is the notion that we educate children in science because we already have a scientific society, but just as important, we also *want* a scientific society and we want it to keep changing and advancing. In this sense, then, the goal of scientific literacy is sought after in order to support the popular view that the US has greater scientific/technological power than other countries, and that those within US society who possess (scientific) literacy are more well off than those who are illiterate. At the same time, the goal of scientific literacy recognizes science and technology can not stand still or the US will lose its preeminence.

The widespread beliefs that science leads to technology and the country/society with the best technology will have the strongest economy, military, industrial capacity, etc. are at the heart of this category. Science is valued as a major pillar of US society—a way of life, even—because it significantly influences the country's standing in the world and its chances for peace and prosperity. Therefore, I call this category **Social Benefits of Science** (or perhaps more formally, the "Socio-national Benefits Perceived from the Public Support of Science" category).

If "Personal decision-making" is combined with "Curiosity," then the resulting new category includes:

- problem-solving and reasoning skills so that one can make decisions involving science, such as one's health;
- understanding science-related experiences in the natural and human-made worlds so that one might survive or thrive;
- curiosity about the way things work or are;
- appreciation and personal fulfillment or satisfaction that comes from knowing and understanding things about the world.

At first glance, it might seem unlikely that this diverse array of purposes could be lumped into the same category. However, in the words of Dr. Benjamin, this category can be viewed as pertaining to "those kinds of things [that] are interesting and useful for people." Or in other words, the focus of this category is not on supporting science for advancing the purposes of the nation-state or society; rather, the focus is on personally taking advantage of science in order to survive, succeed, or just for enjoyment. I have labeled this category **Personal Benefits of Science**.

Science encounters in everyday life can take place fortuitously, for example, one might find an article concerning science in the newspaper one morning. Or science might be encountered intentionally, e.g., a person might visit a science museum for enjoyment. Responses to encounters (after one becomes aware that an encounter is taking place) can range from avoidance to passive coping to active acceptance (or rejection) and action. [Note that a person does not have to accept the science as desirable, and may take action against the science, e.g., some people actively protest the use of fetal tissue in research. See the next category.] The goal of science education is to move people from "avoidance-coping" end to the "action" of the continuum of this category.

<u>Other Categories</u>

The two preceding categories roughly correspond to categories derived by Laugksch (2000), which he called a "Macro View" (Social Benefits) and "Micro View" (Personal Encounters). However, at least two of the dimensions he includes in his categories deserves their own category status in my view. First, there is the belief that scientific literacy leads to rational thinking, and rationality is the penultimate goal for humanity. Dr. Benjamin described science education as part of an overall education: "I think the primary goal of education is to understand the world. ... And if you're taking a

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humanistic approach to education then it's to understand our experience of the world as human beings. ... That is why we're studying anything in the first place, because it's important to us as human beings." Dr. Kellogg said: "I have a fundamental belief ...that humans are a rational animal, the procedural [part of scientific literacy] captures the rationality of who we are." The "procedural part" of scientific literacy, in her view, includes "problem-solving, ... reasoning and argument." Therefore, another category of purposes for scientific literacy could be called **Promoting Humanity**.

Participants saw Promoting Humanity as a particularly important rationale for scientific literacy because it applies to all people, no matter where they live and regardless of what science knowledge or technological applications are available to them. Or, as Dr. Benjamin put it, each society or culture has to "define scientific literacy for them[selves] somewhat differently" depending on their needs and the extent of science-related issues in their lives. Dr. Euler said the goal of scientific literacy should "be part of the general goal of increasing the educational level of all citizens--regardless of the country." In a written interview response, Dr. Dobson said that even people in less developed nations need scientific literacy because its "features ... are human traits." Dr. Kellogg said that from her point of view scientific literacy was beneficial for "everyone on Earth," regardless of where someone lives, because "being human is being human."

It is important to recall that these categories reflect participant responses (and the perhaps the *National Standards*), but this study includes a small sample of participants. The point is not to conclude these categories actually exist but to hypothesize they might be found if looked for in a more diverse or inclusive study.

Laugksch (2000) says, "Related to public support for science is of course the public's right to influence the science policymaking process." Although the participants in my study did not discuss this idea directly, Dr. Gilbert did emphasize that she believes scientifically literate people should not only have the knowledge and skills needed to apply science in their lives, but they should also be aware of science issues in society and be inclined "to action." However, she went on to describe how many people in the US do not participate in public debate about science issues, either because they do not understand or do not care about what they read or hear in the public media. For example, she knows of one proposed agricultural biotechnology project being carried out by a large US-based corporation that is being virtually ignored by the public here in the United States. She says she wonders what

> "the farmer who leaves 30 miles away [from the company] really thinks about in terms of science and how this [project] is possibly going to affect what's going on here?' Why is there no longer a national dialogue on these kinds of issues? Or a local dialogue? Why is the assumption in the US made by a lot of people, 'well, science and technology are great. We don't have to think about it'?"

In Europe, by way of contrast, some people have a much greater awareness and they are also "burning fields that have [the company's] plants in them, because they're protesting this whole notion of genetic engineering and biotechnology." Thus, she describes a scientifically literate person as one who acts on science-related issues in their "daily lives," as well as being concerned about "what goes on a local, state, national, regional, [and] global level" related to science and technology.

I refer to this "right" or "inclination" to "influence the science policymaking process" as a fourth category called **Control of Science**. Control of Science can be internally imposed or externally applied. In the former sense, science has its own values that help to set limits for itself. For example, the values that experiments must be repeatable and that results should always be seen as tentative help to keep scientists "honest," so to speak. But more importantly, for our present discussion, is the fact that science can be influenced by values arising from outside its own realm. For example, the public might object to any particular science project/pursuit because it costs too much (e.g., the Superconductor Supercollider), has undesirable ethical implications (e.g., fetal tissue research), or perhaps just does not seem to be necessary. On the other hand, the public might support a science project because it does accord with external values, such as the "race for the moon" research in the 1960s or AIDs research today. This category can therefore be viewed as sort of a bridge between Social Benefits of Science and Personal Benefits of Science. If a project is viewed by the majority of interested people as in accord with their own values, it will be supported. If not, then it will be resisted.

Discussion

Thus far, I have derived four categories that seem to encompass the range of rationales given for the goal of scientific literacy: Social Benefits of Science, Personal Benefits of Science, Promoting Humanity, and Control of Science. There is perhaps some overlap in these categories, e.g., it might be argued that what is good for the nation is good for the individual, and *vice versa*. But there are important distinctions between the categories, and these differences create tensions in science education because they have different implications for policy, programs, and practices.

The tension between Social Benefits of Science and Control of Science is fairly obvious; one cannot "control" science if any and all science is to be supported. The first category implies that we should teach "science appreciation" in the schools, whereas the second implies "science skepticism" or even a "watch-dog" mentality. What might be less obvious is the tension between Social Benefits of Science and Personal Benefits of Science (and perhaps with Promoting Humanity). The thrust of Social Benefits of Science is the nation-state and/or society, whereas Personal Benefits concerns individuals. The former supports national standards, benchmarks, tests, etc., and perhaps even national curricula; the view of the latter endorses individual choice in what is taught and what is learned in the schools. It hardly seems realistic that one can have both a set of learning objectives that apply to all students, and yet allows individual teachers to decide what to teach and individual students the choice of what to learn.

Individual science educators might emphasize one of the categories over the other, and these may differ from the views expressed in the *Standards*. For example, Dr. Euler said that directly developing a public that is appreciative of science (Public Social Benefits of Science) may not be a necessary part of the goal of scientific literacy for all: "I'm not too convinced that our whole purpose is to develop levels of literacy because people won't continue supporting science. I think it's like a secondary benefit. You just get that."

Can these different groups of rationales really support the same goal? It has already been pointed out that the rationales sometimes have conflicting implications. But it might also be said that these conflicts actually arise because there are different goals involved. For example, Tippins et al. (1999) pointed out the goal of "scientific literacy for all" may actually be two separate and potentially contradictory goals: "scientific literacy" and "science for all":

> The goal of scientific literacy seems to be based on the notion that there is a single (though dynamic) set of knowledge, understandings, skills, and dispositions that all students should possess. The essential characteristics of the scientifically literate student have been codified in the form of benchmarks (AAAS, 1993) and standards (NRC, 1996). On the other hand, the phrase "science for all" evokes images of school science being accessible, relevant, and interesting to students.

Whereas the former implies "the same science for all students", the latter implies "different science for different students" (Tippins, et al., 1999, p. 6). In this view, the goal of scientific literacy is based mainly on the Social Benefits of Science rationale, whereas the goal of science for all is based primarily on Personal Benefits of Science. They might be able to peacefully co-exist in theory, or they might not, that is yet to be decided.

Basis for rationales

A question yet to be addressed is one concerning the foundations for these rationales. The *Standards* open with the recognition of science as a necessity for all. Similarly, *SFAA* begins with these statements: "This book is about scientific literacy. *Science for All Americans* consists of a set of recommendations on what understandings and ways of thinking are essential for all citizens in a world shaped by science and technology" (Rutherford & Ahlgren, 1990, p. v). Thus scientific literacy is claimed to be "essential" or "a necessity" for everyone by two of the leading policy documents of the current US science education reform movement. However, neither the *Standards* nor *SFAA* cite direct evidence or empirical studies to back up the claim that scientific literacy is essential for everyone. In fact, such studies seem to few and far between according to Shamos, 1995.

Perhaps empirical evidence for the benefits of scientific literacy are not needed. My participants certainly did not consider such evidence to be important. In a written response to one question, Dr. Euler said that there can be other foundations for the goal of scientific literacy. He says, "The goal of scientific literacy is, at least in part, philosophical." Dr. Infeld said the idea that scientific literacy benefits the public is "an assumption that's made by most people who like science and who are lobbying for lots of science education in schools. Is there an empirical basis? No." She also pointed out that there is little empirical evidence for learning science "through inquiry" or by "working in groups," yet these are practices widely advocated today. Dr. Infeld says that particularly when the 'for all' is added to 'scientific literacy,' that it becomes "a philosophical, not an empirical statement. And there's a big push that unless we believe every mother's child can become science literate somehow, they won't. So, that's a philosophical statement."

When I asked him if there are any studies that show people benefit from scientific literacy, Dr. Benjamin replied: "I would see it as a basic value, and not something that's really testable. I don't see ... how you could do empirical research to determine whether it's a good thing or not." He continued:

> So, it's not a question of whether scientific literacy is a good thing or not. ...That's the value. The question is whether or not the methods that are used in school lead to an outcome that is a scientifically literate person. That is, somebody who can participate in discussions about scientific issues as adults. So, what you could do empirical studies on is the effectiveness of the educational approach. You can't do studies on the effectiveness of the outcome, because I think the outcome is simply a statement of what you value.

Some participants compared the goal of scientific literacy to other basic values in American society. For example, Dr. Benjamin remarked, that the goal of scientific literacy for all is "pretty hard to argue with. It's just like arguing for motherhood or ... good food in good restaurants." Dr. Andrews said he agrees with what Rodger Bybee (e.g., 1997) has had to say on the issue, namely that scientific literacy is comparable to such societal goals as "justice for all," and he says we should recognize that "it doesn't come easy. But we shouldn't give up on it." Dr. Howard said that while people might survive without scientific literacy, "you're dooming those people to a certain kind of existence that we shouldn't tolerate."

Thus, while the participants in this study provided some "anecdotal evidence" for the benefits of scientific literacy, most felt its pursuit is a moral obligation that does not need a research basis. Tippins, *et al.* (1999, p.7) point out in this regard scientific literacy is not atypical: "few, if any, educational goals are based on empirical data." However, they fear basing "the fundamental goal of science education" (Bybee, 1997, p. 46) on unconfirmed assumptions might leave it open to criticism, make it hard to defend on a rational basis, and qualify it as a cultural myth:

> we are attempting to make other science educators aware of the shaky foundation on which we stand, which leaves our discipline open to criticism, distrust and 'band-wagon' effects. We are calling for science educators to help shore up these foundations by examining them and reframing them in more sturdy arrangements. As currently articulated, scientific literacy as a necessity for all students may not be a defensible goal, but it does seem defensible to say that science educators are responsible for making the opportunity to become scientifically literate equally available to all students. All students may not need or want to learn the same things in science, but all deserve quality science education experiences. We suggest that science educators carefully re-examine the goals and assumptions of their discipline so that all students can equitably experience quality school science instruction that will provide them with the knowledge, skills, and dispositions they want or need for their lives. (Tippins, *et al.*, 1999, p.7)

A related issue that arises in the examination of the underlying bases the rationales is the question of the *necessity* versus *desirability* of scientific literacy. I believe that if scientific literacy is viewed as actually necessary for survival or in order to thrive in the US, empirical studies providing evidence of this need would not be hard to find. On the other hand, if scientific literacy is merely desirable (according to the academic elite), then no empirical evidence is needed to support this view. Since there are not many studies demonstrating the direct benefits of scientific literacy, perhaps science educators are unintentionally confusing necessity with desirability. However, Shamos' (1995) critical remarks imply that science educators intentionally "oversell" the necessity of scientific literacy in order to get more funds for curriculum programs and research and to perpetuate their own careers. This charge should not be left unexamined by science educators.

Conclusions

Science educators' comments in this study, and excerpts quoted from the *Standards* (NRC, 1996), support 4 categories of rationales for the goal of scientific literacy for all in the US. These categories have different implications and are potentially in conflict, possibly hindering the work toward scientific literacy for all. However, in the end it may not be the rationales promoted by science educators that make the difference in whether or not the goal of scientific literacy for all is achieved. Rather, it is the target of the goal, the public, who must decide whether or not the goal is worth pursuing. Whether or not scientific literacy really is "'a good thing'" (Laugksch, 2000, p. 84) may not matter if people do not *perceive* the benefits of scientific literacy to justify the efforts required to achieve it (Shamos, 1995). If scientific literacy for all really is a goal that science educators wish to continue to pursue, then they need to do a better job of "selling" the goal to the public. One way to do so would be to back up their rationales with convincing empirical evidence that the goal really does benefit individuals, the nation, and/or humanity, as well as help to control the scientific enterprise itself.

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Table 1. Participant Pseudonyms

The participants are listed in the order they entered the study. Note that pseudonyms were assigned by the researcher and have no particular significance. For the most part, they were taken from author's names on my office bookshelf.

First 7 participants

Pseudonym	**Gender**	**Primary Activities Related to Scientific Literacy**
Dr. Andrews	Male	Science education professor
Dr. Benjamin	Male	Science education professor
Dr. Curtis	Male	Science education professor
Dr. Dobson	Male	Science education professor
Dr. Euler	Male	Policy and program development; Former science education professor
Dr. Fowler	Male	Former scientist and science education program developer
Dr. Gilbert	Female	Science education professor

Last 4 participants

Pseudonym	**Gender**	**Primary Activities Related to Scientific Literacy**
Dr. Howard	Male	Science education professor
Dr. Infeld	Female	Science education professor
Dr. Johnson	Male	Science professor; science education professor; program developer
Dr. Kellogg	Female	Science education professor

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Figure 1. Definition of Scientific Literacy in the *National Science Education Standards* (NRC, 1996, p. 22).

> Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities. In the *National Science Education Standards*, the content standards define scientific literacy.*
>
> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.
>
> Individuals will display their scientific literacy in different ways, such as appropriately using technical terms, or applying scientific concepts and processes. And individuals often will have differences in literacy in different domains, such as more understanding of life-science concepts and words, and less understanding of physical-science concepts and words.
>
> Scientific literacy has different degrees and forms; it expands and deepens over a lifetime, not just during the years in school. But the attitudes and values established toward science in the early years will shape a person's development of scientific literacy as an adult.

* Emphasis added. Despite this lengthy definition, the *Standards* (1996, p. 22) imply the definition is much longer by saying "the content standards define scientific literacy" (as I underlined above). The science content standards include:

- Science as Inquiry
- Physical Science
- Life Science
- Earth and Space Science
- Science and Technology
- Science in Personal and Social Perspectives
- History and Nature of Science

Each of these standards are divided up between grades K-4, 5-8, and 9-12, and each are several pages long. Therefore, it would be impractical for me to go into any further depth about their details here.