Scientific Literacy: A Conceptual Overview

RÜDIGER C. LAUGKSCH
School of Education, University of Cape Town, Private Bag, 7701 Rondebosch, South Africa

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ABSTRACT: In this review of the published literature in English on the concept of scientific literacy, the net is cast wider than just the professional science education community, and the diverse works on scientific literacy are brought together in an interpretative synthesis of this literature. Scientific literacy is first placed in an historical context, and a number of different factors that influence interpretations of this concept are discussed thereafter. These factors include the number of different interest groups that are concerned with scientific literacy, different conceptual definitions of the term, the relative or absolute nature of scientific literacy as a concept, different purposes for advocating scientific literacy, and different ways of measuring it. The overview yields a fuller understanding of the various factors that contribute to the concept of scientific literacy, and makes clear the relationships between these factors. © 2000 John Wiley & Sons, Inc. *Sci. Ed* **84:**71–94, 2000.

INTRODUCTION

Scientific literacy has become an internationally well-recognized educational slogan, buzzword, catchphrase, and contemporary educational goal. Scientific literacy "stands for what the general public ought to know about science" (Durant, 1993, p. 129), and "commonly implies an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas" (Jenkins, 1994, p. 5345). The term is usually regarded as being synonymous with "public understanding of science," and while "scientific literacy" is used in the United States, the former phrase is more commonly used in Britain, with "la culture scientifique" being used in France (Durant, 1993).

It is, however, generally accepted that the deceptively simple conceptualization of scientific literacy just described masks different meanings and interpretations associated with the concept of scientific literacy because of, for example, different views of what the public ought to know about science and who "the public" is (see later). Differences in meanings and interpretations may, as a result, be considered to have given rise to a view that scientific literacy is an ill-defined and diffuse concept (e.g., Champagne & Lovitts, 1989). In order

Correspondence to (present address): R. C. Laugksch, Department of Mathematics, Science, and Technology Education, University of the North, Private Bag X1106, Sovenga 0727, South Africa. Email: laugkschr@unin.unorth.ac.za
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to obtain a fuller understanding of this important contemporary educational goal, a number of factors that influence interpretations and perceptions of scientific literacy as a concept are described. In the following review of the published literature in English, the net is cast wider than just the professional science education community, and the diverse works on the concept of scientific literacy are brought together in an overview and interpretative synthesis of this literature. Scientific literacy is first placed in an historical context, and a number of different factors that influence interpretations of this concept are discussed thereafter.

THE HISTORICAL CONTEXT

The term "scientific literacy" was coined in the late 1950s, and most probably appeared in print for the first time when Paul Hurd (Hurd, 1958) used it in a publication entitled *Science Literacy: Its Meaning for American Schools* (DeBoer, 1991; Roberts, 1983). Nevertheless, interest in and concern about elements of the concept of scientific literacy (i.e., the idea that the public should have some knowledge of science) go back at least to the beginning of this century (Shamos, 1995). Because the emphasis of this review is scientific literacy in a contemporary context, the focus here is only on the years following the late 1950s. A brief historical overview of this period is helpful in placing the discussion of scientific literacy as a concept in context. For a fuller historical account of the scientific literacy movement the reader is referred to Shamos (1995).

The impetus for interest in scientific literacy during the late 1950s is likely to have been the concern of the American science community about public support for science in order to respond to the Soviet launch of Sputnik. Waterman (1960) wrote in a review of the first 10 years of the U.S. National Science Foundation of the recognition that "progress in science depends to a considerable extent on public understanding and support of a sustained program of science education and research" (p. 1349). At about the same time, Americans—again sparked by the space race—became concerned about whether their children were receiving the kind of education that would enable them to cope with a society of increasing scientific and technological sophistication (Hurd, 1958). Increasing the level of scientific literacy among Americans was seen as a strategy for effectively addressing both of the above concerns (Hurd, 1958; Waterman, 1960). Roberts (1983) reviewed the period from the 1950s to the late 1970s, and the conclusions reached about scientific literacy as a concept in those years, which are presented in what follows, are based on this review.

Given the important dual context of support for science and science education, numerous authors began to promote various aspects associated with scientific literacy (e.g., references cited in DeBoer [1991] and Roberts [1983]). Roberts (1983) characterized the years from about 1957 to 1963 as the "period of legitimation" (p. 25) of the concept. The individuals advocating scientific literacy, however, did not always provide a clear definition of what they meant by this concept. The initial period was thus followed by a "period of serious interpretation" (Roberts, 1983, p. 26) in which multiple and diverse meanings of scientific literacy became apparent (DeBoer, 1991; Roberts, 1983; see also, e.g., references cited in Pella, O'Hearn, & Gale [1966]). A number of attempts at consolidating scientific literacy as a concept were made (e.g., Agin, 1974; Pella, 1976), after which a period of further interpretation ensued (Roberts, 1983). However, Gabel (1976), cited in Roberts (1983), showed in his work on a theoretical model of scientific literacy, based on a large dataset of interpretations of the meaning of scientific literacy, to what extent this concept "has had so many interpretations that it now means virtually everything to do with science education" (Roberts, 1983, p. 22). The interpretations of scientific literacy as a concept had "come to be an umbrella concept to signify comprehensiveness in the purposes of science teaching in the schools" (Roberts, 1983, p. 29).

The period of the late 1970s and early 1980s was characterized by a multitude of varied definitions and interpretations of scientific literacy (Roberts, 1983), and a persistent lack of consensus diminished the usefulness of this concept (Graubard, 1983). At about the same time, the United States was facing two important challenges. The first was related to the emergence of the economic power of Japan and other Pacific rim countries (i.e., South Korea, Singapore, Taiwan, etc.) and a general belief that America's international economic competitiveness—and thus its industrial leadership—was on the wane (e.g., Bloch, 1986). Science and technology were seen as the fundamental basis for economic progress (e.g., Bloch, 1986; Lewis, 1982), and it was therefore inevitable for America's science policy to come under the spotlight. The second challenge was related to the declining research base in science and engineering in the U.S. (e.g., Bloch, 1986), and to America's poor standing in international comparisons of science achievement (see, for example, references cited in Appendix B of American Association for the Advancement of Science [1989]; Wirszup [1983/84]). At this time a widely held belief about the existence of a crisis in science education prevailed (e.g., Champagne & Klopfer, 1982; Yager, 1984; but, for a contrary view, see Shamos [1988]), particularly after the National Commission on Excellence in Education (1984) report, *A Nation at Risk.*

Due to perceived threats to the economic competitiveness of the United States and the crisis that American science education was seen to be in, a reawakened interest in scientific literacy developed in the early 1980s (Prewitt, 1983; Graubard, 1983). Since this period, the scientific literacy of adults has received regular attention in the United States and elsewhere (e.g., Miller, 1992). The social and cultural relevance of science in a scientific and technological society (Chen & Novik, 1984; Shymansky & Kyle, 1992)—with its resultant "socio-civic" (Hlebowitsh & Hudson, 1991) or social responsibility (Ramsey, 1993) focus on science education reform—has also increasingly received attention through the concept of scientific literacy. In recent years, policy statements related to science education have thus been replete with references to scientific literacy as a goal (Atkin & Helms, 1993; Jenkins, 1992).

In many ways, therefore, scientific literacy is an old educational slogan (Roberts, 1983), and the concept has generated much interest over the last four decades. Consequently, there exists a substantial and diverse literature related to this concept (e.g., Baker, 1991; DeBoer, 1991; Garfield, 1988; Layton, Jenkins, & Donnelly, 1994; Roberts, 1983). For example, based on an ERIC search, over 330 journal articles, conference papers, project descriptions, project reports, and editorials related to scientific literacy were found to have appeared in the literature between 1974 and 1990 (an arbitrary period), with the vast majority being published after 1980. In order to obtain a better understanding of the concept of scientific literacy and its associated difficulties, a conceptual overview is described next.

CONCEPTUAL OVERVIEW

Despite (or maybe because of) the attention that scientific literacy has received over the years, this concept is frequently recognized as being controversial (Jenkins, 1990, 1994). Why should this be so? The fact that the term scientific literacy can be thought of as belonging to a class of terms like *liberty, justice,* and *happiness,* that we assume to contain simple and desirable qualities but that under closer examination become vastly more complex and often elusive (cf. Venezky, 1990), will have undoubtedly contributed to its controversial nature. Inspection of the extensive literature on scientific literacy suggests, however, that there are a number of different factors that can influence interpretations of scientific literacy. These factors include the number of different interest groups that are concerned with scientific literacy, different conceptual definitions of the term, the relative or absolute nature of scientific literacy as a concept, different purposes for advocating scientific literacy, and different ways of measuring it (Fig. 1). Each factor consists of different positions or facets, and it is postulated here that combinations of different facets of each of the five individual factors result in permutations of varying interpretations and perceptions of scientific literacy. These different interpretations result in scientific literacy appearing to be an ill-defined and diffuse—and thus controversial—concept.

Described in what follows are some of the different positions and perceptions available under each of the factors identified previously. The four broad categories of interest groups concerned with scientific literacy are sketched first, and thereafter the different conceptual definitions of scientific literacy that have been proposed are reviewed. The relative or absolute nature of the concept is described next, and the benefits alleged to accrue from scientific literacy are discussed thereafter. Finally, a brief overview of the different research frameworks employed to measure scientific literacy is given.

Interest Groups

Although scientific literacy is widely regarded as being of general educational importance, at least four broad categories of workers involved in scientific literacy are discernible. These categories or "interest groups" are characterized by a shared core theme of

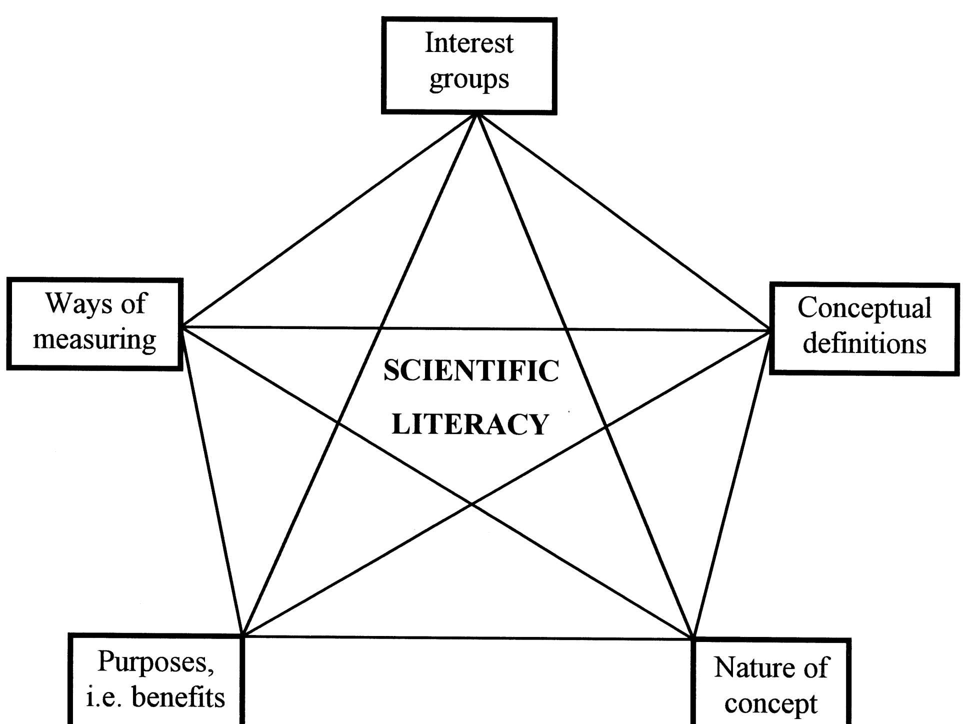

Figure 1. A conceptual overview of scientific literacy.

interest in the promotion of scientific literacy in the whole or in a particular section of the wider community.

The first interest group that can be identified is the science education community, which is concerned with the nature (i.e., purpose), performance, and reform of existing educational systems (see, e.g., Champagne & Newell, 1992; Jenkins, 1992; Kyle, 1995a, 1995b). 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.

The second interest group includes social scientists and public opinion researchers concerned with science and technology policy issues (see, e.g., Miller, 1992). This interest group is essentially concerned about the extent of the general public's support for science and technology, as well as the public's participation in science and technology policy activities. Pertinent fields of inquiry for this category of researchers are thus related to the identification of the individual's sources of scientific and technical information; measuring the public's scientific knowledge base and perceptions of the limitations of science; as well as measuring the public's attitude toward science and technology in general and toward selected current policy issues in particular (see, e.g., National Science Board [NSB], 1991, 1993, 1996).

The third interest group includes sociologists of science and science educators employing a sociological approach to scientific literacy. These researchers are concerned with the construction of authority with respect to science (i.e., organizational forms of ownership and control of science), or "knowledges in context" as Wynne (1991) has put it. Fields of inquiry for this category of researchers are related to how individuals in everyday life interpret and negotiate scientific knowledge; how social access, trust, and motivation are linked to public uptake of and support for science; and how ". . . members of the public . . . monitor sources of scientific information, judge between them, keep up with shifting scientific understandings, distinguish consensus from isolated scientific opinion, and decide how expert knowledge needs qualifying for use in *their* particular situation" (Wynne, 1991, p. 117).

The fourth interest group that can be identified is the informal and nonformal (cf. Lucas, 1991; Maarschalk, 1988) science education community, and those involved in general science communication. The combined group thus consists of those professionals that provide educational and interpretative opportunities for the general public to better familiarize itself with science (see, e.g., Durant, 1992; Quin, 1993), in addition to those who report science as "news" (see, e.g., Nelkin, 1995) and write about science in general (see, e.g., Lewenstein, 1989; McRae, 1993). These professionals include relevant personnel involved in science museums and science centers, botanical gardens and zoos, as well as members of creative teams involved in science exhibitions and science displays. Science journalists and writers, and relevant personnel involved in science radio programs and television shows complete this interest group.

The preceding interest groups also differ with respect to the "audiences" that form the focus of the groups' attention. The science education group focuses largely on the scientific literacy of children (i.e., at primary school) and adolescents (i.e., at secondary school), whereas the social scientist and sociologist of the science interest group focuses on the scientific literacy of out-of-school individuals (i.e., adults). The fourth interest group, however, focuses on promoting the scientific literacy of a combination of the three audiences just identified; that is, children, adolescents, as well as adults. As a result, the approaches that this fourth group takes with respect to its conceptualization of scientific literacy are believed to be necessarily informed by the approaches of the first three groups that cover these audiences primarily. The fourth interest group will therefore not be considered further here.

Conceptions of Scientific Literacy

During the course of the development of the concept, a number of different positions on, as well as interpretations and definitions of, scientific literacy have been proposed. Some of these interpretations were based on research, and others were based on personal perceptions about the characteristics of a scientifically literate individual and what such an individual should be able to do. In what follows, commonly cited definitions and interpretations of scientific literacy are described in more or less chronological order of publication.

In the Rede Lecture at Cambridge University in 1959, C. P. Snow suggested that there was a sharp division between literary intellectuals on the one hand, and scientists on the other (Snow, 1962). This division, in his view, represented a gulf of mutual incomprehension, hostility, and dislike, and, most importantly, resulted in a lack of understanding between "the two cultures." He saw the development of these two separate cultures as counterproductive, especially in a democratic society, and suggested that individuals in a rapidly changing scientific and technological world cannot be regarded as "learned" unless they have some grounding in both cultures.

The work by Pella et al. (1966) represents one of the earliest attempts to provide an empirical basis for the definition of scientific literacy. Pella and colleagues determined the frequency of occurrence of "referents", that is, themes that were assumed in advance to be related to scientific literacy, in 100 carefully and systematically selected papers published between 1946 and 1964. They concluded that the scientifically literate individual was characterized as one with an understanding of the (a) interrelationships of science and society; (b) ethics that control the scientist in his work; (c) nature of science; (e) difference between science and technology; (d) basic concepts in science; and (f) interrelationships of science and the humanities (Pella et al., 1966). The frequency of occurrence of these "referents" in the literature revealed that the first three characteristics were more important than the latter three (Pella et al., 1966).

Pella's work on the delineation of scientific literacy as a concept was elaborated on by Showalter (1974) (cited in Rubba & Anderson, 1978), who integrated 15 years of relevant literature into a definition of scientific literacy consisting of seven dimensions:

I. The scientifically literate person understands the nature of scientific knowledge.
II. The scientifically literate person accurately applies appropriate science concepts, principles, laws, and theories in interacting with his universe.
III. The scientifically literate person uses processes of science in solving problems, making decisions, and furthering his own understanding of the universe.
IV. The scientifically literate person interacts with the various aspects of his universe in a way that is consistent with the values that underlie science.

V. The scientifically literate person understands and appreciates the joint enterprises of science and technology and the interrelationship of these with each and with other aspects of society.

VI. The scientifically literate person has developed a richer, more satisfying, more exciting view of the universe as a result of his science education and continues to extend this education throughout his life.

VII. The scientifically literate person has developed numerous manipulative skills associated with science and technology. (p. 450)

The feature of this particular work was that it defined scientific literacy "with a degree of specifity not found in other definitions of this concept" at that time (Rubba & Anderson, 1978, p. 450).

Shen (1975a) suggested three categories of scientific literacy, namely practical, civic, and cultural scientific literacy. These categories were acknowledged to be not mutually exclusive, but were nevertheless distinct with respect to objective, audience, contents, format, and means of delivery. By practical scientific literacy, Shen (1975a, p. 46) meant the "possession of the kind of scientific knowledge that can be used to help solve practical problems"; that is, knowledge that addresses the most basic human needs related to food, health, and shelter (Shen, 1975a, 1975b). This category of scientific literacy was seen as being of particular importance in, but by no means confined to, developing countries, where "a few pieces of essential scientific information can mean the difference between health and disease, life and death" (Shen, 1975a, pp. 46–47). (See Kalra [1990] for a recent attempt to translate such practical scientific literacy into an appropriate curriculum for the rural youth with limited schooling in India.) In industrialized countries, on the other hand, practical scientific literacy could well be useful in consumer protection efforts (Shen, 1975b). Shen (1975a) believed civic scientific literacy to be the cornerstone of informed public policy. He suggested that the aim of this category of scientific literacy was to enable citizens to become sufficiently aware of science and science-related public issues in order for the average citizen to become involved in the decisionmaking process related to such issues as, for example, health, energy, natural resources, food, the environment, and so forth. Like Snow (1962) and others (see later), Shen (1975a) believed such an involvement to be necessary for democratic processes to operate in a technological society. "Cultural scientific literacy is motivated by a desire to know something about science as a major human achievement" (Shen 1975a, p. 49). Although he saw this category of scientific literacy to be achieved by only a comparatively small number of individuals because its reach would not extend much beyond the intellectual community (Shen, 1975b), he believed this category to be important and influential because it would preferentially reach current and future opinion-leaders and decisionmakers (Shen, 1975a). The kinds of categorizations of scientific literacy provided by Shen's interpretation of the concept can be expanded to accommodate a range of functional scientific literacies related to different contexts (Jenkins, 1994).

An example of such an expansion is Branscomb's (1981) proposed conceptualization of scientific literacy. She examined the Latin root of "science" and "literacy" and defined the concept as "the ability to read, write, and understand systematized human knowledge" (p. 5). She identified eight different categories of scientific literacy: (a) methodological science literacy; (b) professional science literacy; (c) universal science literacy; (d) technological science literacy; (e) amateur science literacy; (f) journalistic science literacy; (g) science policy literacy; and (h) public science policy literacy (Branscomb, 1981). Each of these scientific literacies is related to a particular context, such as, for example, that of the professional scientists going about his or her work (professional science literacy); the average citizen understanding and coping with natural phenomena of daily life (universal science literacy); and that of the political representative making public decisions requiring an understanding of scientific data or predictions of probable consequences (science policy literacy).

As was mentioned earlier in the discussion of the historical context of scientific literacy, issues related to science and technology, science policy, and the role of science in society were of concern in the United States in the early 1980s. In a 1983 special issue of *Daedalus,* the journal of the American Academy of Arts and Sciences, a number of authors gave their opinion on scientific literacy and the challenges facing America. Jon Miller's article on a conceptual and empirical review of scientific literacy was influential, as he not only proposed a multidimensional definition of scientific literacy, but also suggested ways of measuring scientific literacy (Miller, 1983). In addition, he presented data of adult levels of scientific literacy in the United States based on his framework. Miller (1983) contended that "in a democratic society, the level of scientific literacy in the population has important implications for science policy decisions" (p. 29). He examined how the meaning of the term had changed in the United States since the latter part of the last century, and reviewed the various attempts to measure individual components of scientific literacy since the 1930s. On the basis of these considerations, Miller (1983) defined scientific literacy in the "contemporary situation" (p. 31) (i.e., in today's scientific and technological society) as consisting of three dimensions: (a) an understanding of the norms and methods of science (i.e., the nature of science); (b) an understanding of key scientific terms and concepts (i.e., science content knowledge); and (c) an awareness and understanding of the impact of science and technology on society. Coming after Gabel's (1976) findings of the late 1970s that scientific literacy was too loose a term and with too many interpretations to be of any use, Miller's (1983) article proposing a particular, bounded, and multidimensional model of scientific literacy comprised an important consolidation of this concept.

Arons (1983) enumerated 12 attributes of a scientifically literate individual that he considered important. He included Miller's (1983) three dimensions in the list of attributes, but emphasized the intellectual abilities required of scientifically literate persons. For example, Arons (1983, pp. 92–93) contended that such individuals will possess the ability: (a) to recognize that "scientific concepts are invented or created by acts of human intelligence and imagination . . ."; (b) to "comprehend the distinction between observation and inference . . ."; (c) to comprehend ". . . the deliberate strategy of forming and testing hypotheses"; and (d) to ". . . recognize when questions such as 'How do we know . . . ? Why do we believe . . . ? What is the evidence for . . . ?' have been addressed, answered, and understood, and when something is taken on faith." (Linked to Arons's [1983] emphasis is a portrayal of scientific literacy in which scientifically literate individuals are able to correctly apply scientific knowledge and reasoning skills to solving problems and making decisions in their personal, civic, and professional lives [e.g., Brickhouse, Ebert-May, & Wier, 1989; cf. Laetsch, 1987]. These issues are related to the benefits or purpose for promoting scientific literacy, and will be discussed in a later section.)

A more recent development is the establishment of Project 2061—a long-term, three-phase undertaking of the American Association for the Advancement of Science designed to contribute to the reform of education in science, mathematics, and technology in the United States with respect to improving scientific literacy (American Association for the Advancement of Science [AAAS], 1989). The product of Phase I and II of this endeavor is represented by *Science for All Americans* (SFAA) (AAAS, 1989) and *Benchmarks for Science Literacy* (AAAS, 1993), respectively. The former publication consists of a set of recommendations "spelling out the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience" (AAAS, 1989, p. 3) in order to be regarded as scientifically literate. In the latter publication, the goals for scientific literacy of each SFAA chapter were reformulated into intermediate levels of understanding for various grade spans; that is, what students should be able to do at the end of grades 2, 5, 8, and 12 (AAAS, 1993). Allied to these reform initiatives in science education is the development of the *National Science Education Standards* (NSES) under the auspices of the National Research Council of the United States (Bybee & Champagne, 1995). Although the NSES go beyond specifying content standards to be mastered at the end of particular grades and include *inter alia* also standards for teaching, professional development, and assessment (National Research Council, 1996), a comparative analysis "reveals that *Benchmarks* and *NSES* are very similar in philosophies, language, difficulty and grade placement of their learning goals . . ." (AAAS, 1997, p. 76). In other words, there is a high degree of congruency in the conceptualizations of scientific literacy between the efforts of the National Research Council and Project 2061 (Anonymous, 1995; AAAS, 1997). The concept of scientific literacy contained in SFAA is therefore very influential in the major current science education reform efforts in the United States, and deserves to be scrutinized more closely. Two arguments for promoting scientific literacy dominate SFAA: one is centered on personal self-fulfilment, that is, to prepare individuals to lead, among other things, personally fulfilling and responsible lives; the other argument is based on the belief that America's future depends on the quality of science education received by individuals, that is, the argument is based on national socioeconomic needs (Fourez, 1989). As these are expansive goals, it is not surprising that the recommendations contained in SFAA reflect a very broad and comprehensive definition of scientific literacy. First, the scope of the content to be mastered in order to be regarded as scientifically literate is not limited to traditional key concepts and principles in physics, chemistry, biology, and so forth, but also includes those in mathematics, technology, and the social sciences (AAAS, 1989). The inclusion of particularly the social sciences in a conceptual model of scientific literacy is novel, and SFAA contains chapters on what scientifically individuals should know "about themselves as a species" (AAAS, 1989, p. 67), as well as what such persons should know about "human society in terms of individual and group behavior, social organizations, and the processes of social change" (p. 77). Second, part of the SFAA conceptualization of a scientifically literate person is such an individual's understanding of the scientific endeavor. According to SFAA, it is the union of science, mathematics and technology that makes this mode of knowing so successful (AAAS, 1989). The focus is consequently on the scientific world view, scientific methods of inquiry, the nature of the scientific enterprise, features of mathematics and mathematical processes, the connection between science and technology, the principles of technology itself, and the connection between technology and society (AAAS, 1989). Furthermore the report includes recommendations on common themes that pervade mathematics, technology, and the sciences and that, according to SFAA, transcend disciplinary boundaries (e.g., systems, models, stability, patterns of change, evolution, and scale) (AAAS, 1989). (For a related point on how interconnected portrayals of science, technology, society, and history are presented in SFAA, see Fourez [1989].) Recommendations on "some episodes in the history of the scientific endeavor [that] are of surpassing significance to our cultural heritage" (AAAS, 1989, p. 111) (e.g., displacing the earth from the center of the universe, uniting matter and energy, time and space, etc.) complete the knowledge base to be mastered by scientifically literate individuals. The third way in which the recommendations contained in SFAA reflect a very broad and comprehensive definition of scientific literacy is related to the values, attitudes, and skills scientifically literate individuals should possess and exhibit. These "habits of mind" are clearly spelled out and include values "inherent in science, mathematics, and technology; the social value of science and technology; the reinforcement of general social values; and people's attitudes toward their own ability to understand science and mathematics" (p. 133), as well as particular skills (i.e., computational skills, manipulative and observation skills, communication skills, and critical-response skills) (AAAS, 1989). This shared outlook on knowledge and learning, as well as on ways of thinking and acting, then enables scientifically literate individuals to "deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty" (p. 13), not only with respect to decisions involving their own lives but also with respect to issues that affect societies in general (e.g., assessing the use of new technologies and their implications for the environment and culture) (AAAS, 1989).

Hazen and Trefil (1991) believe that there is a clear distinction between *doing* and *using* science. In the case of the former, the average citizen will be able to do what scientists do, such as, for example, "sequence a section of DNA" (Hazen & Trefil, 1991, p. xii). In their view, however, scientific literacy only concerns the latter case. Here the average citizen will, for example, have enough background knowledge in molecular biology to be able to understand how new advances in this field occur, and what the consequences of these advances are likely to be for the citizen's family (Hazen & Trefil, 1991). They thus define scientific literacy as "the knowledge you need to understand public issues. It is a mix of facts, vocabulary, concepts, history, and philosophy" (p. xii). Such a conceptual definition of scientific literacy is linked to Hirsch's (1987) concept of "cultural literacy," which he described as the "oxygen of social intercourse" (p. 19). Hirsch's premise is that effective communication between two parties (whether between individuals or groups) requires an estimate of how much relevant information can be taken for granted in the other party, as this assumed background knowledge reflects a necessary familiarity of the current mainstream culture, whether in language, history, or science. A store of shared knowledge—"cultural literacy"—is therefore important in national communication, such as, for example, reading newspapers and magazines, communicating with elected representatives, or following debates about public issues. Hirsch, together with two colleagues, identified about 5000 terms and phrases that in their view, as well as being validated by reviewers, constitute the contents of cultural literacy in the social and natural sciences (Hirsch, Kett, & Trefil, 1988).

Hazen and Trefil (1990) furthermore believe that scientifically literate individuals should be able to place news of the day about science in a meaningful context. They describe 18 general principles of science that cover a range of topics from absolute zero to X-rays (Hazen & Trefil, 1990). (Brennan's [1992] list of definitions of about 650 science terms and topics represents a similar attempt to provide the necessary vocabulary to follow public debates involving science- and technology-related issues.) The distinguishing feature of the preceding conceptions of scientific literacy is the emphasis on the required content knowledge in science; that is, Miller's second dimension of scientific literacy.

Shamos (1995) proposed a conception of scientific literacy consisting of three forms, ". . . which build upon one another in degree of sophistication as well as in the chronological development of the science-orientated mind" (p. 87). The first form, "cultural scientific literacy," is that proposed by Hirsch (1987), which was described previously. It is the simplest of the three forms of scientific literacy, and in Shamos's view represents the level of scientific literacy held by most educated adults who believe they are reasonably literate in science (Shamos, 1995). The second form, "functional scientific literacy," requires that the individual not only has a command of a scientific vocabulary—a "science lexicon" (p. 88)—but also that the individual be able to converse, read, and write coherently in a nontechnical but meaningful context (Shamos, 1995). An important difference between these forms of scientific literacy is that the first form is passive (e.g., recognition of science-based terms used by the media), whereas the second is more active. A functionally scientifically literate individual would thus not only be able to read and comprehend a science-based newspaper article, but would also be able to communicate the substance of that account to a third party (Shamos, 1989). The third form and level of scientific literacy, "true scientific literacy," is the most difficult to attain, as it involves, in addition to the previous forms, also knowing something about the scientific enterprise. Such an individual:

> . . . is aware of some of the major conceptual schemes (the theories) that form the foundations of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of experimentation in science. This individual also appreciates the elements of scientific investigation, the importance of proper questioning, of analytical and deductive reasoning, of logical thought processes, and of reliance upon objective evidence. (Shamos, 1995, p. 89)

Shamos (1989, 1995) conceded that this is a difficult and demanding level to obtain, and that true scientific literacy is likely to be out of reach for most members of society— as in the case of most highly specialized knowledge. (For a related point on the knowledge gap between specialists and nonspecialists in academic fields due to the level of specialization in science, see Lévy-Leblond [1992].)

A perspective of scientific literacy different from the ones encountered thus far is aptly described as "science for specific social purposes" (e.g., Layton, Davey, & Jenkins, 1986; Layton, Jenkins, Macgill, & Davey, 1993). It represents a functional view of scientific literacy in which the meanings and social uses which science has for members of the adult public are explored (Layton et al., 1986). This interpretation of scientific literacy contends that members of the public are not passive "consumers" of science but that "usable" scientific knowledge usually needs to be reworked and put into context (Layton et al., 1993). "Scientific knowledge is not received impersonally, as the product of disembodied expertise, but comes as part of life, among real people, with real interests, in a real world" (Ziman, 1991, p. 104). How the public perceives and uses scientific knowledge is therefore not only related to the public's understanding of the formal content of scientific knowledge and the methods and processes of science, but also with "the forms of institutional embedding, patronage, organisation and control of scientific knowledge" (Wynne, 1992, p. 42).

Issues raised by this particular interpretation of scientific literacy, as well as those raised by the other definitions of scientific literacy just described, are related to the nature of the concept, the purpose of scientific literacy, and how scientific literacy should be measured. Each of these issues will now be discussed separately.

The Nature of the Concept

In order to describe and analyze how the various definitions and interpretations of scientific literacy impact on the general notion of scientific literacy, an attempted summary scheme follows. This scheme provides a framework that highlights common and implied features of previously suggested definitions of scientific literacy. The framework is based on different interpretations of the word "literate," as well as on the nature of knowledge implied by each definition. This approach to classifying different definitions of scientific literacy borrows from Venezky's (1990) work in general literacy.

The term "literacy" is usually interpreted as the ability to read and write. However, extensions of this term to, for example, computer literacy, cultural literacy, political literacy, and, of course, scientific literacy, suggest that semantic aspects of this term are very important in such extensions (Kintgen, 1988). Although authors generally use the term "literacy" in its descriptive sense, it is the evaluative sense of the term—the mastery of a

TABLE 1
Classification of Various Interpretations of the Concept of Scientific Literacy According to Three Implied Interpretations of the Word "Literate"

Author	"Learned"	"Competent"	"Able to function Min. as Consumers and Citizens"
Snow (1962)	X		
Shen (1975a, 1975b)			
Practical scientific literacy			X
Civic scientific literacy			X
Cultural scientific literacy	X		
Branscomb's (1981) categories	X		X
Miller (1983)			X
Arons (1983)	X		
Hirsch (1987)		X	
Science for All Americans (AAAS, 1989)		X	X
Hazen and Trefil (1991)		X	
Shamos (1995)			
Cultural scientific literacy		X	
Functional scientific literacy		X	
True scientific literacy	X		
Layton et al. (1986, 1993)			X

body of knowledge—that provides an understanding of the intended meaning (Kintgen, 1988). Three different interpretations and uses of "literate" are considered here: literate as learned; literate as competent; and literate as able to function minimally in society.

The word *literate* derives from the Latin term *litteratus* (Clanchy, 1979), and, as Kintgen (1988) and Venezky (1990) have pointed out, the ability level of a *litteratus* has changed over the centuries. The initial, classical meaning of the word at the time of Cicero did not describe a person who could read Latin, but one who was learned (Clanchy, 1979). The *Oxford English Dictionary* (1989, Vol. 3, p. 604) defines "competent" as "adequate or sufficient in quality or degree," and this term thus describes an intermediate level of ability between mastery and nonmastery. The third use of literate is taken from Miller (1989) who, in discussing the relative nature of literacy, defined it as "the minimal acceptable level of knowledge or skills required to function in some set of roles in a specific society" (p. 4). The roles he selected to be important in the context of scientific literacy in a contemporary society were those of a consumer and citizen (Miller, 1989).

Ten of the 12 definitions and interpretations of scientific literacy described in the previous section have been classified using the three interpretations of the word "literate" (Table 1). The two definitions of the concept based on criteria of scientifically literate individuals compiled from the literature (i.e., those of Pella et al. [1966] and Showalter [1974]) were excluded, as these definitions did not convey the context in which the original authors had identified the criteria.

In order to be able to place the various interpretations of scientific literacy in one or another literate category, an additional classification criterion was required so that more meaningful distinctions between the definitions could be made. This criterion was related to how the proposed scientific literacy attributes were to be used. When moving across the literate categories from "learned" to "function in society," an increasingly greater emphasis is placed on being able to carry out a task with the acquired scientific literacy attributes, and on being able to use these attributes to cope in everyday life.

Definitions which include demanding and intellectual abilities as being part of scientific literacy but do not require an explicitly stated purpose for acquiring those abilities (e.g., Shamos's functional and true forms of scientific literacy, Shen's cultural scientific literacy, Arons's intellectual abilities) were thus placed in the learned category. Such interpretations appeared to be proposed only for the intellectual value of being scientifically literate. On the other hand, when a context was suggested in which a scientifically literate individual needed to operate (e.g., Hirsch's "oxygen of social intercourse"), or if a particular activity was required to be performed (e.g., reading science-related newspaper articles [works by Shamos, Hirsch, Hazen, and Trefil], solving practical problems related to food, health, and shelter [Shen], or thinking critically and independently in order to deal sensibly with problems involving evidence, quantitative considerations, logical arguments, etc. [SFAA]), then the concept was placed in the competent category. Competent relates in this instance to the extent of the ability to carry out such tasks.

Whereas Branscomb's (1981) professional science literacy fits in the learned category, the other proposed scientific literacies (e.g., universal science literacy, technological literacy, etc.) fit in the third category. This latter category was used if the suggested definition required the scientifically literate individual to play a particular role in society, such as, for example, that of a consumer (e.g., Shen's practical scientific literacy) or citizen (e.g., Shen's civic scientific literacy). The concept of scientific literacy used in SFAA clearly falls in this category, as scientific literacy is advocated in order for the "life-enhancing potential for science and technology" (p. 13) to be utilized for better decisionmaking at the level of the individuals (e.g., preventing citizens from becoming easy prey to "dogmatists . . . [and] flimflam artists" [p. 13]), as well as at the level of society and nations in general (e.g., developing effective solutions to global and local problems; intelligent respect for nature, without which there is the danger of recklessly destroying the earth's life-support system) (AAAS, 1989). The kind of scientific literacy espoused by proponents of science for specific social purposes is also accommodated in the third category. Scientifically literate individuals in this interpretation of scientific literacy fulfill a particular role in society, namely that of citizens and consumers, and it is taken for granted that such citizens and consumers have a need for, and *use,* scientific knowledge in a wide variety of social contexts that affect their personal or economic well-being (e.g., nutrition, health, energy usage) (Jenkins, 1994). It is noteworthy that a "fundamental difference between medieval and modern approaches to literacy is that medieval assessments concentrate on cases of maximum ability, . . . whereas modern assessors measure the diffusion of minimal skills among the masses" (Clanchy, 1979, p. 183). The different implied uses of literate in the various definitions of scientific literacy reflect this shift in emphasis.

In general, two features of the summary scheme of different definitions of scientific literacy can be identified. The first is related to the relative or absolute nature of the scientific literacy concept. The aforementioned three literate categories differ with respect to how the proposed body of knowledge to be mastered is defined. In the learned category, the required science content and intellectual abilities are defined with reference to the existing body of knowledge and way of thinking in the natural sciences (e.g., Arons, 1983; Snow, 1962), and is therefore defined in an absolute sense. The competent category is similarly defined in an absolute sense, as definitions of scientific literacy in this category (e.g., Hazen & Trefil, 1990; Hirsch, 1987) rely on a shared store of particular science content knowledge. In the function-in-society category, on the other hand, the required scientific literacy abilities are defined with reference to functioning effectively in society (e.g., Branscomb, 1981; Miller, 1983); that is, in a manner relative to society.

In order to further clarify the notion of scientific literacy, it is useful to elaborate briefly on the general relative–absolute distinction. At face value, an absolute definition of scientific literacy is perhaps appealing in that it implies a set of science content knowledge, skills, and attitudes toward science that would hopefully be common to all individuals. Although it is conceivable that such a set exists, it would be very difficult to identify, given the variety of social and economic systems that exist in the world. The notion of an absolute definition of scientific literacy is thus an impractical idea. For all intents and purposes, scientific literacy depends on the context in which is it intended to operate, and "is inherently relative to the society in which it is used" (Miller, 1989, p. 4). If it is accepted that scientific literacy is essentially a socially defined concept, it follows that the concept differs for different eras in time (e.g., pre- and postnuclear age), geographical regions (e.g., heavy industry- and agriculture-based local economy), and communities or social conditions (e.g., suburban and informal or high-density housing).

The second feature of the summary scheme is the extent of involvement in and with society. Conceptions of scientific literacy in the learned category specify no involvement and appear to operate in a social vacuum, whereas definitions in the competent category require at least some form of interaction (e.g., the ability to communicate about scientific matters). Definitions with respect to the third meaning of literate require the scientifically literate individual to use science in performing a function in society. The purpose for which scientific literacy is advocated is thus important, and the suggested reasons for promoting scientific literacy are discussed in the following subsection.

Why Is Scientific Literacy Important?

There seems to be widespread agreement that scientific literacy is "a good thing," yet there often exists only a tacit understanding of the reasons for advocating scientific literacy (Thomas & Durant, 1987). In this section, a number of common arguments that have been suggested in favor of scientific literacy are listed. These arguments for promoting scientific literacy, which are based on Thomas and Durant (1987) and Shortland (1988) unless indicated otherwise, can essentially be grouped into a macro and micro view. The former relates to the alleged benefits that accrue to the nation, science, or society, whereas the latter relates to the enhancement to the lives of the individual. Each group of arguments is now described in turn.

Macro View. The first common reason for advocating scientific literacy has to do with the connection between scientific literacy and the economic well-being of a nation. It is argued that national wealth depends on competing successfully in international markets. International competitiveness in turn relies *inter alia* upon a vigorous national research and development program in order, first, to maintain or capture ground in the worldwide race for new high-technology products in the case of developed countries and, second, to exploit smaller niche markets in the case of developing countries. Underpinning such a research and development program is a steady supply of scientists, engineers, and technically trained personnel. Only nations whose citizens possess an appropriate level of scientific literacy will be able to sustain this supply. In addition to this argument, there is the view that scientific literacy will enable individuals to participate more intelligently in the productive sector of the economy (Walberg, 1983). Scientific literacy should therefore be seen as a form of human capital that influences the economic well-being of a nation in a number of different ways.

The second argument, allied to the economic perspectives, suggests that higher levels of scientific literacy among the populace translate into greater support for science itself. This would occur because a greater number of new recruits would be attracted to science, and because "it is often suggested that public support for science depends upon at least a minimal level of general knowledge about what scientists do" (Shortland, 1988, p. 307). Unless the general public values what scientists are attempting to achieve, science is unlikely to be financially supported from public funds. Hence, Couderc (1971) (cited in Shortland, 1988, p. 307) advocated knowledge itself as an "'antidote to anti-science.'"

A third way in which science itself may benefit from the promotion of greater scientific literacy is related to the public's expectations of science. The more the public understands about the objectives, processes, and capabilities of science, the less likely the public will be to acquire unrealistic and unrealizable expectations of science. While unrealistic expectations may lead to loss of confidence in, and eventually withdrawal of support for, science, increased levels of scientific literacy may counteract this potential disenchantment with science.

Related to public support for science is of course the public's right to influence the science policymaking process. The report of the Royal Society of London on *The Public Understanding of Science* states that a scientifically literate public would ". . . significantly improve the quality of public decision-making, *not* because the 'right' decisions would then be made, but because decisions made in the light of an adequate understanding of the issues are likely to be better than decisions made in the absence of such understanding" (Royal Society, 1985, p. 9). Citizens also have a legitimate interest in science, as a great deal of science is funded from public funds and as the products of scientific and technological research will inevitably have an influence on many aspects of public and private life (Thomas & Durant, 1987). Increased scientific literacy of citizens:

> . . . may be thought to promote more democratic decision-making (by encouraging people to exercise their democratic rights), which may be regarded as good in and of itself; but in addition, it may be thought to promote more effective decision-making (by encouraging people to exercise their democratic right *wisely* [emphasis added]). (Thomas & Durant, 1987, pp. 5–6)

Prewitt (1983) supported this argument and makes a strong case for the fact that scientifically "savvy" citizens help to underpin the democratic practice in societies with a scientific–technical base through meaningful involvement in and engagement with political processes, public policymaking, and social change.

The last argument, operating at the level of relationships within society, is concerned with the relationship between science and culture. Thomas and Durant (1987) asserted that the general health of a nation in which science is practiced depends on the effective integration of science in the wider culture. Science is generally seen by the public as the epitome of specialization and technicality, and may therefore cut itself from the common cultural weal because of such a fragmentation process. The isolation of science from the wider culture may result in the general public failing to understand science properly, and as a consequence citizens respond to science with a mixture of adulation and fear. Increased scientific literacy of the public would thus counteract such a perceived "cult" image of science.

The macro view of the arguments in favor of promoting scientific literacy thus includes benefits to national economies, science itself, science policymaking, and democratic practices, as well as to society as a whole.

Micro View. Turning to the direct benefits of scientific literacy to individuals, it has been suggested that improved understanding of science and technology is advantageous to anyone living in a science- and technology-dominated society (Thomas & Durant, 1987). More knowledgeable citizens, the argument goes, are able to negotiate their way more effectively through the society in which they live:

> Personal decisions, for example about diet, smoking, vaccination, screening programmers or safety in the home and at work, should all be helped by some understanding of the underlying science. Greater familiarity with the nature and the findings of science will also help the individual to resist pseudo-scientific information. An uninformed public is very vulnerable to misleading ideas on, for example, diet or alternative medicine. (Royal Society, 1985, p. 10)

Widespread scientific literacy among the populace, the argument goes, would therefore result in citizens feeling more confident and competent to deal with science- and technology-related matters as they arise in the course of daily life.

Related to this very important area of benefits to individual citizens is the issue of employment. As economies are becoming more "knowledge-based," the quality of human resources is increasingly seen as the most important economic asset of modern science- and technology-based societies (Brooks, 1991). Scientifically literate individuals may therefore be in a favorable position to exploit new job opportunities and be able to take full advantage of technical developments in their place of work (Thomas & Durant, 1987).

The next set of arguments are closely related and are concerned with the intellectual, aesthetic, and moral benefits of scientific literacy to individuals. It is commonly accepted that knowledge of science is an important element of what it means to be an educated person in the 20th century, and that ". . . science is an intellectual enabling and ennobling enterprise" (Shortland, 1988, p. 310). Snow (1962, p. 14) expressed this very poignantly when he wrote that ". . . the scientific edifice of the physical world . . . in its intellectual depth, complexity and articulation, [is] the most beautiful and wonderful collective work of the mind of man." Promotion of scientific literacy therefore contributes to the promotion of the intellectual culture itself. Allied to the preceding argument is the aesthetic argument that suggests that "science is the distinctively creative activity of the modern mind" (Shortland, 1988, p. 310). Science has been eloquently described as "this century's cathedral building . . . [and] this century's art" (Shortland, 1988, p. 310), and the aesthetic argument affirms that science is as central to a truly cultivated mind as literature, music, and the performing arts (Shortland, 1988). This argument therefore suggests that we should advocate scientific literacy for the "same sorts of reasons that we preserve beautiful buildings and paintings. Without knowledge of science, . . . life would be that much less worth living" (Shortland, 1988, p. 310). Last, there is the ethical argument that suggests that ". . . the internal norms or values of science are so far above those of everyday life that their transfer into a wider culture would signal a major advance in human civilisation" (Shortland, 1988, p. 311). What is being suggested is that widespread scientific literacy would result in a better and more profound understanding of the norms and values of science, which "would make people not merely wiser but better" (Shortland, 1988, p. 311).

In summary, there are thus a number of reasons for promoting scientific literacy for both the common and the individual good. The list of general arguments just expressed, however, may paint a somewhat overly neat and simplistic picture of a complex concept, for overlap between the various arguments can and does exist. For example, the interests of science and the effective integration of science in the wider culture are connected. Similarly, as Thomas and Durant (1987) have pointed out, the interests of individuals and those of national economies may overlap to a significant degree. The nature of such overlap is, in the opinion of Garrison and Lawwill (1992), problematic, and leads them to express strong reservations against making economic competitiveness *the* end of science education on moral grounds. The purpose for promoting scientific literacy is therefore not only dependent on the benefits envisaged to result from such literacy, but is also influenced by ideological and philosophical considerations (Champagne & Lovitts, 1989), such as, for example, "differing visions of what kind of a society we are and what kind of society we aspire to be" (Kaestle, 1990, p. 66).

Ways of Measuring Scientific Literacy

Given the different interpretations of scientific literacy with respect to the concept's definition, nature, and purpose for promoting it (see earlier), it is not surprising that there exist also differences in the manner in which scientific literacy is measured. Earlier a distinction was made between the target groups and interests of at least three different groups involved in scientific literacy, namely those of (a) sociologists of science or science educators with a sociological approach to scientific literacy; (b) social scientists and public opinion researchers; and (c) science educators. Differences in the manner of measuring scientific literacy are evident from the methodologies used by these interest groups.

Sociological Approach. The sociological approach to investigating scientific literacy has been variously termed "science for specific social purposes" (Layton et al., 1986), the "context model" (Ziman, 1992), or the "interactive model" (Layton et al., 1993). Within this measurement context it has been argued that it matters considerably whether the design of instruments is based upon whether individuals share the scientist's view of the natural world (i.e., the viewpoint of "insiders" [Ziman, 1984, p. 184]), or whether the instrument used to measure scientific literacy is based on what a citizen needs to know (i.e., the viewpoint of "outsiders" [Ziman, 1984, p. 184]) in order to cope effectively in a science- and technology-based society (Layton et al., 1986). As the purpose of the sociological approach to scientific literacy is to identify and describe the range of possible interactions between people's existing understandings of situations involving science and those understandings that emanate from science itself (Wynne, 1991), this approach necessarily employs contextual, small-scale, and interpretative studies to describe the scientific literacy of adults. The main methods of obtaining data for this qualitative approach are case studies using participant observation, longitudinal panel interviews, structured in-depth interviews, and local questionnaires on specific issues (Wynne, 1991).

Public Opinion Researchers. The approach taken by social scientists and public opinion researchers in measuring scientific literacy differs substantially from the approach just noted and has been termed the "deficit model" by proponents of the sociological approach (Ziman, 1991). Social scientists are essentially interested in describing and comparing trends with respect to, for example, acquisition of specific science content knowledge, attitudes toward science, and support for science among a representative sample of a population (e.g., Miller, 1992; NSB, 1991, 1993, 1996). These researchers therefore use large-scale samples, standardized questions, and survey techniques to obtain their data.

The work of Jon Miller has been particularly influential in this particular research framework (see Laugksch & Spargo, 1996a, 1996b).

Miller's (1983) article proposing a particular multidimensional character for scientific literacy marked an important consolidation of this concept at the time (see earlier). Moreover, Miller's "three constitutive dimensions" model of scientific literacy provided a sufficiently specific and bounded definition of scientific literacy in order for this concept to be measured in a composite manner. Although "the empirical study of the public understanding of science [in the United States] began with a 1957 national survey of Americans adults" (Miller, 1992, p. 23), the 1979 U.S. *Science & Engineering Indicators* survey, at Miller's suggestion, included for the first time items from all three dimensions of scientific literacy, and thus allowed the first construction of a measure of this concept (Miller, 1983, 1992). Measures of all three dimensions of scientific literacy have been included in all subsequent biennial surveys of this nature in the United States (Miller, 1987, 1992). Moreover, Miller's "three constitutive dimensions model" of scientific literacy has formed the basis of almost all national and cross-national studies of the scientific literacy of adults conducted in the last decade or so (Laugksch & Spargo, 1996a, 1996b).

In summarizing the results of a major program of research into scientific literacy conducted in response to the report on *The Public Understanding of Science* (Royal Society, 1985), Ziman (1991) claimed that the deficit model, which attempts to interpret the knowledge of science held by individuals simply in terms of what they do *not* know, was not "an adequate analytical framework for many of the results of our research" (p. 101). Durant, Evans, and Thomas (1992) identified three principle objections to the deficit model. The critics claim that this model: (a) "misrepresents science itself by portraying it as an unproblematic body of knowledge" (p. 162); (b) "overlooks the fact that a great deal of scientific knowledge is both remote from and largely irrelevant to everyday life" (p. 162); and (c) is either explicitly or implicitly normative, that is, "the model embodies the specific value judgement that scientific understanding is inherently good" (p. 163) (Durant et al., 1992). In rebutting these claims, Durant et al. (1992) argued that, whereas a great deal of scientific knowledge is problematic and contested, a great deal is also not. And while they conceded that many individuals are ignorant about matters outside their immediate spheres of professional and personal interest, they argued that "this does not mean that it is either unrealistic or unwise to aspire to a level of universal education in which everybody possesses at least some elementary knowledge of a whole series of subjects . . ." (p. 163), including science (Durant et al., 1992). Finally, they ask, is everybody with a low or bad score automatically branded as inferior? In citing from Gould (1981), they answered:

> Not at all. It is worth remembering that the French psychologist Alfred Binet developed the IQ test in order to identify those pupils who were most in need of educational assistance. Later, IQ scores were widely used to identify the specially gifted. To be sure, psychometry may be used to target resources in many different ways; but the example of Binet himself demonstrates that there is nothing necessarily prejudicial about the wish to find out how well individuals are doing in any particular areas of educational or scientific attainment. (Durant et al., 1992, p. 164)

But they concede that the deficit model is not suited to handling all aspects of the relationship between science and the public (Durant et al., 1992). This, then, is the essential point: approaches to measuring scientific literacy should be appropriate to the aims and objectives of the study. It is not simply a question of which approach is better or worse, but it is a question of which approach is more suited to uncovering what one wishes to find out! (In this respect, one is reminded of the general debate about the greater suitability of either quantitative or qualitative research methods in the social sciences.) A further point is that the context and deficit approaches to measuring scientific literacy have different limitations, and a choice of one or the other research framework represents a trade-off in information such as, for example, between the depth of understanding of science probed for in individuals and the coverage of the desired target population. Given a particular set of circumstances, it may be preferable to obtain one or the other kind of information. Other factors that need to be weighed will almost certainly include research costs, available personnel, the time-frame of the study, and the breadth of science knowledge to be investigated.

Science Educators. Although the composite sense (i.e., multidimensional nature) of scientific literacy has been widely recognized (see the various definitions of scientific literacy just described), science education researchers have essentially not measured the concept in a composite manner (Laugksch & Spargo, 1996a). Measures of individual dimensions (e.g., the nature of science, science content knowledge, attitudes toward science, the impact of science and technology on society, etc.) were thus also used and referred to as measures of scientific literacy. Much work has clearly been carried out by the science education community in ascertaining *separately* students' views and knowledge in each of the dimensions of scientific literacy, and reference is made here to only a small number of important overviews of these research foci.

As may be expected, the dimension of scientific literacy regarding science content knowledge has been of particularly keen interest to science educators, as the assessment of students' conceptions of various important concepts in science is vital to much of teaching and learning in the sciences. Particularly in the identification and assessment of misconceptions or alternative frameworks, the research literature is now considerable (see, e.g., Anonymous, 1989; Carmichael, Driver, Holding, Twigger, & Watts, 1990; Pfundt & Duit, 1994). However, a review of the techniques used to investigate the understanding of concepts in science is beyond the scope of this study.

Individuals' conceptions of the nature of science, Miller's (1983) second dimension of scientific literacy, has been comprehensively reviewed by Lederman (1992) and Meichtry (1993). Assessment of students' perceptions in this area did not commence until the 1950s, but since then a large body of literature has been established in this field (Lederman, 1992). A number of instruments have been developed to investigate particular aspects of students' understanding of the nature of science (Lederman, 1992; Meichtry, 1993), of which the most widely known are probably Cooley and Klopfer's (1961) *Test on Understanding Science* (TOUS), Kimball's (1967/68) *Nature of Science Scale* (NOSS), and Rubba and Anderson's (1978) *Nature of Scientific Knowledge Scale* (NSSK). All three tests employed a large number of test items either based on surveys of the then current literature both in science and the history and philosophy of science (e.g., TOUS and NOSS), or on the early works on scientific literacy (e.g., NSSK) (Cooley & Klopfer, 1961; Kimball, 1967/68; Rubba & Anderson, 1978).

The nature of science is associated with Miller's third dimension of scientific literacy (i.e., the impact of science and technology on society) through content such as, for example, the epistemology of science and its social context (Aikenhead & Ryan, 1992). This third dimension is closely allied to the science–technology–society (STS) movement, which emphasizes a holistic, problem-solving approach to science teaching and attempts to deal with current social and technological issues impacting on society (Yager, 1993). In this research field, Aikenhead and Ryan (1992) developed a sophisticated instrument, *Views* *on Science–Technology–Society* (VOSTS), that monitors students' views on a broad range of STS topics: science and technology, the reciprocal influence of science on society and technology, the influence of school science on society, characteristics of scientists, social construction of scientific knowledge and technology, and the nature of scientific knowledge.

Thus, despite the considerable body of research focusing on separate assessment of the dimensions of scientific literacy, few *composite* measures of all three have, to the best of my knowledge, been developed and published in the last decade. Exceptions are, first, Lord and Rauscher (1991), who based their short scientific literacy questionnaire on information contained in upper primary and middle school life science textbooks; second, Cannon and Jinks (1992), who used a "cultural literacy" approach (see Hirsch, 1987) to assess scientific literacy; and, third, Laugksch and Spargo (1996a, 1996b), who constructed a 110-item *Test of Basic Scientific Literacy* based on selected chapters of *Science for All Americans* (AAAS, 1989). This test instrument was specifically designed for students leaving high school and entering tertiary education (Laugksch & Spargo, 1996b). (Results of a South African scientific literacy survey, in which this test was used, are reported in Laugksch and Spargo, 1999.)

CONCLUSION

This review of the concept of scientific literacy was not only carried out from the perspective of the professional science education community, but also included the viewpoints of the wider research community concerned with this important concept. The diverse positions, descriptions, and interpretations were integrated into a useful conceptual overview of scientific literacy that highlights important features of this concept. This overview therefore yields a fuller understanding of the various factors that contribute to the concept of scientific literacy and makes clear the relationships between these factors, thus giving rise to a more refined and focused conceptualization of scientific literacy.

Furthermore, the review clearly shows that underlying the deceptively simple term *scientific literacy* are a number of different—often tacit—assumptions, interpretations, conceptions, and perspectives of what the term means, what introducing the concept should achieve, and how it is constituted. It is therefore not surprising that the concept of scientific literacy is often regarded as diffuse, ill-defined, and difficult to measure (e.g., Champagne & Lovitts, 1989). It would therefore seem prudent for members of the research community to spell out their position(s) with respect to relevant factors of scientific literacy when discussing this concept. Such a measure may not necessarily result in arguments about scientific literacy that are more fruitful and less heated, but they will certainly be less frustrating (cf. Ahlgren & Boyer, 1981, cited in Champagne & Lovitts, 1989). At least in theory, apples can then be compared with apples and not with a whole melange of other fruit. Such a consequence can only be of benefit to the concept of scientific literacy and thus to science education in general.

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