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FOREWORD

Some Thoughts on Scientific Literacy: Motives, Meanings and Curriculum Implications

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Introduction

The shifting emphases of science education debate over the past 30-40 years is clearly reflected in the numerous slogans and rallying calls that have gained prominence, including "Being a Scientist for a Day" (from the early Nuffield science projects in the United Kingdom), "Learning by Doing", "Process, not Product", "Science for All" and "Children Making Sense of the World". From the mid-1990s onwards, much of the debate concerned another slogan - "Scientific Literacy", and how to achieve it. This particular debate shows little sign of slowing down or reaching resolution.

While scientific literacy has been almost universally welcomed as a desirable goal, there is still little clarity about its meaning (Jenkins, 1990; Eisenhart et al., 1996; Galbraith et al., 1997) and little agreement about precisely what it means in terms of curriculum provision. In one early attempt at clarification, Pella et al. (1966) suggested that scientific literacy comprises an understanding of the basic concepts of science, the nature of science, the ethics that control the scientist in his [sic] work, the interrelationships of science and society, the interrelationships of science and the humanities, and the differences between science and technology. A quarter century later, *Science for All Americans* (AAAS 1989, p.4) defined a scientifically literate person as "one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes." Many other definitions, some very similar to these, others strikingly different, can be located in curriculum documents originating in Canada, the United Kingdom, Australia, New Zealand and elsewhere. This brief essay is an attempt to untangle some of the strands of argument and to identify some of the curriculum imperatives if we are to achieve the goal of universal scientific literacy.

Professional Expertise or Civic Responsibility

The opening paragraph of Shahn's (1988) article is typical of much of the rhetoric surrounding the notion of scientific literacy, and is worth quoting at length:

> Science illiteracy is a serious problem. At one level it affects nations; because large parts of their populations are not adequately prepared, they cannot train enough technically proficient people to satisfy their economic and defense needs. More basically it affects people; those who are science illiterate are often deprived of the ability to understand the increasingly technological world, to make informed decisions regarding their health and their environment, to choose careers in remunerative technological fields and, in many ways, to think clearly.

This passage serves to illustrate the key distinction between an education that prepares students for a career as a professional scientist or engineer and an education focused on wider citizenship goals. In doing so, it raises important questions about the kind of science and technology knowledge the curriculum should include and about the level of attainment we should be seeking.

In many ways, the long-standing confusion with terms such as 'literacy', 'illiteracy' and 'literate', where some writers refer to a mere functional competence, while others imply a sensitive awareness of the complexities of language, is mirrored in the use of the term 'scientific literacy' and in the question of attainment levels. Some see 'being scientifically literate' as the capacity to read, with reasonable understanding, lay articles about scientific and technological matters published in newspapers and magazines; others regard it as being in possession of the knowledge, skills and attitudes deemed necessary for a professional scientist. Is scientific literacy more akin to what a 'literate person' would know and be able to do, or is it more akin to a basic or functional literacy - that is, being able to read at a reasonable level of comprehension? About ten years ago, Atkin and Helms (1992) asked two questions. First, does a person need to know science in the same sense that they need to know their mother tongue? Second, is the ability to use scientific knowledge in the way one uses language essential for adequate functioning and responsible citizenship? To both questions, their answer was "No".

An alternative question is: "Does one need to be literate in order to achieve scientific literacy?" Now, the answer is clearly: "Yes", regardless of whether the argument for scientific literacy is the preparation of future scientists or the education of responsible citizens. Engagement in science would not be possible without text and without literacy. As Anderson (1999, p.973) states: "reading and writing are the mechanisms through which scientists accomplish [their] task. Scientists create, share, and negotiate the meanings of inscriptions - notes, reports, tables, graphs, drawings, diagrams". Scientific knowledge cannot be articulated and communicated except through text, and its associated symbols, diagrams, graphs and equations. Moreover, because of the dependence of science on text, access to science also depends on basic literacy, and someone unable to read and write is unlikely to achieve even a rudimentary level of scientific literacy. Hewson (2002) has examined the nature of literacy in its prototypical form - reading and writing - in order to consider what similarities and differences between literacy and science might say about scientific literacy. His conclusions make fascinating reading:

> An analysis of literacy leads to several propositions, from which the analogy with scientific literacy can be drawn. First, achieving literacy involves the acquisition of literacy tools, viz., reading and writing, that facilitate a conversation between objects and events and our records of them. By analogy, we can consider explaining and predicting as the tools of a basic scientific literacy that together become a conversation between the natural world and our theories of it. Second, there are prerequisites for achieving literacy - the ability to communicate with others, that is, to possess language. This is also the case for scientific literacy. Third, the availability of literacy tools provides a means of storing and sharing human knowledge and understanding that is independent of human memory. In this case, there is no need for a direct counterpart in scientific literacy, since literacy itself, broadened to include mathematics as a language, provides the means of storing scientific knowledge and understanding. Fourth, literacy tools can be, and are, used in a wide variety of contexts. While this is also the case

> for scientific literacy, the applicability of its tools can never approach the universal applicability of the literacy tools of reading and writing. Fifth, when literacy functions effectively, it is transparent, taken-for-granted, invisible. In this regard, scientific literacy and literacy parallel each other. Finally, we don't have to be linguistic experts to acquire and use literacy tools. In this case, too, scientific literacy and literacy parallel each other, since of those who are scientifically literate, there can be no question that a large proportion are not experts in one or other scientific discipline.
>
> Literacy in its prototypical form focuses on the tools of reading and writing. The striking parallels between the two forms of literacy provide strong support for considering scientific literacy in relation to its tools, i.e., explaining and predicting, rather than to a body of knowledge. While this may seem to be a limited view of scientific literacy, the case of literacy is instructive. Over time, the influence of reading and writing has been quite remarkable. In the same way, focusing on two basic tools of scientific literacy, an achievable goal for all students, can have similarly revolutionary consequences (Hewson, 2002, p.207, original English text).

Clearly, effective reading of science text is more than recognizing all the words and being able to locate specific information, it also involves the ability to infer meaning from the text - in particular, the meaning intended by the author. Thus, it involves analysis, interpretation and evaluation. In consequence, it depends on what the reader brings to the task in terms of conceptual understanding and text interpretation strategies. Despite the often considerable substantive content, the abilities required to extract meaning from scientific text are largely those required to extract meaning from *any* text, and while content knowledge is important, it is by no means sufficient for a proper understanding of scientific text. Indeed, Norris and Phillips (1994) have shown that high school students who score highly on traditional measures of science attainment sometimes perform very poorly when asked to interpret media reports of scientific matters. To paraphrase the words of Norris and Phillips (in press), understanding of science text resides in the capacity to determine when something is an inference, a conclusion or an assumption, to distinguish between an explanation and the evidence for it, and to recognize when the author is asserting a claim to 'scientific truth', expressing doubt or engaging in speculation. Without this level of interpretation, the reader will fail to grasp the essential scientific meaning.

If it is correct that most people obtain their knowledge of contemporary science and technology from television and newspapers (National Science Board, 1998; Select Committee, 2000), then the capacity for active critical engagement with text is not only a crucial element of scientific literacy for citizenship, it is perhaps the *fundamental* element. In that sense, education for scientific literacy has striking parallels with education in the language arts. But what else should be regarded as crucial? Understanding the nature of science? Knowledge of the major theoretical frameworks of biology, chemistry and physics, and their historical development? Awareness of the applications of science? Ability to use science in everyday problem solving? In his seminal work, *The Myth of Scientific Literacy*, Shamos (1995) argued that the pursuit of universal scientific literacy is a futile goal because its elements are so wide ranging that they cannot be achieved. Moreover, he declared, scientific literacy in any of the senses relating to science content isn't necessary anyway - most people can get along perfectly well without it! In similar vein, Layton et al. (1993) describe a very different kind of scientific literacy, what they call "practical knowledge in action". The science needed for everyday life, they argue, is very different in form from that presented via the school curriculum. This strand of argument has prompted Peter Fensham (2002) to state that it is "time to change drivers for scientific literacy" and to abandon the traditional ways of identifying science content knowledge for the school curriculum. More in line with Fensham's recommendation would be a curriculum designed in accordance with the findings described by Law (2002) from a study in which she and her co-researchers asked leading scientists, health care professionals, managers and personnel officers in manufacturing industry, local government representatives, and others, about the kind of science and the kind of personal attributes and skills that would be of most value in persons employed in their field of expertise. In one sense, this line of thought leads directly to my next consideration: the social, cultural and environmental 'fallout' from the current concern to link business interests, economic growth and scientific literacy.

Corporatism Versus Democracy

In recent years, the economic argument for scientific literacy has become the predominant one in North America. It is a powerful and persuasive one, as illustrated by the government of Canada's (1991) attempt to establish a link between school science education and a culture of lifelong learning as the key to the country's prosperity.

> Our future prosperity will depend on our ability to respond creatively to the opportunities and challenges posed by rapid change in fields such as information technologies, new materials, biotechnologies and telecommunications... To meet the challenges of a technologically driven economy, we must not only upgrade the skills of our work force, we must also foster a lifelong learning culture to encourage the continuous learning needed in an environment of constant change. (Government of Canada, 1991b, pp. 12 & 14)

All forms of discourse are essentially concerned with creating a particular view of the world and particular 'kinds of people': "Ways of talking, listening, reading, writing, acting, interacting, believing, valuing, and using tools and objects, in particular settings and at specific times, so as to display or to recognize a particular social identity" (Lankshear et al., 1996, p. 10). While learning to use a particular discourse is an effective means of enculturation into a community of practice, it can also be an instrumental form of indoctrination. The power of a particular discourse is located in the ways in which it determines how we think about society and our relations with others, and in its impact on how we act in the world. Thus, it can be deployed as a means of creating an alternative social reality. Lankshear et al. (1996) use the term *fast capitalist texts* to describe the business and management books, company policy documents and media pronouncements which have now become mainstream popular cultural interpretations of the proper nature of work and commerce in newspapers, magazines, radio and television. Language has been transformed by industry and corporate business leaders into a sociotechnical device capable of creating and sustaining new social relationships between managers and workers, and imposing particular capitalist values on workers. In other words, transnational businesses have created and sustained a discourse that serves their immediate and future needs, and have extended this discourse to schools and the education system. In order to design, develop, optimize, produce and market goods and services for the global marketplace, industry needs a flexible, 'just-in-time' and compliant workforce, and it is the education system's job to provide it. Seemingly, at least in Ontario, industry has been successful in exerting its will on the school curriculum, as witness this statement from the Ontario Ministry of Education (2000, p.3):

> The new Ontario curriculum establishes high, internationally competitive standards of education for secondary school students across the province. The curriculum has been designed with the goal of ensuring that graduates from Ontario secondary schools are prepared to lead satisfying and productive lives as both citizens and individuals, and to compete successfully in a global economy and a rapidly changing world.

The pressures exerted by business and industry on schools to provide more 'job ready' people can be seen as part of an overt sociotechnical engineering practice in which new capitalism is creating "new kinds of people by changing not just their overt viewpoints but their actual practices" (Lankshear et al., 1996, p. 22). It is reengineering people in its own image! Indeed, there are many who view these developments as symptomatic of a dangerous trend, both for individuals and for society as a whole, part of what Bencze (2001, p.350) calls "an *apprenticeship for consumership* - that is, creation of a large mass of… citizens who simultaneously serve as loyal workers and voracious, unquestioning consumers". In similar vein, Apple (1993) states that in this new economy-driven educational climate, students are no longer seen as people who will participate in the struggle to build and rebuild the social, educational, political and economic future, but as consumers; freedom is "no longer defined as participating in building the common good, but as living in an unfettered commercial market, with the education system… integrated into the mechanisms of such a market" (p.116). When school presents students, almost daily, with a language that promotes economic globalization, increasing production and unlimited expansion, identifies technology with unfettered 'progress', work with money and excellence with competition and 'winning at any cost', it is implicated in the manufacture and maintenance of what Bowers calls the *myths of modernity*: "that the plenitude of consumer goods and technological innovation is limited only be people's ability to spend, that the individual is the basic social unit… and that science and technology are continually expanding humankind's ability to predict and control their own destiny" (Bowers, 1996, p. 5, emphasis added). At risk here are the freedoms of individuals, the spiritual well-being of particular societies, and the very future of the planet. In Edmund O'Sullivan's (1999, p.27) words:

> Our present educational institutions which are in line with and feeding into industrialism, nationalism, competitive transnationalism, individualism, and patriarchy must be fundamentally put into question. All of these elements together coalesce into a world view that exacerbates the crisis we are now facing.

Much of the world's poverty, injustice, terrorism and war can not be eradicated, nor can the litany of environmental crises (ozone depletion; global warming; land, air and water pollution; deforestation; desertification; and so on) be solved, without a major shift in the values that underpin western industrialized society. Interestingly, the key to ameliorating the current situation may lie in increased levels of scientific literacy among the world's citizens. As the authors of *Benchmarks for Scientific Literacy* (AAAS, 1993) suggest, "People who are literate in science... are able to *use* the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and make sense of many of the ideas, claims, and events that they encounter in everyday life" (p. 322, emphasis added). More recently, the OECD's programme for International Student Achievement (PISA) proposed that a scientifically literate person is "able to combine science knowledge with the ability to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD/PISA, 1998, p.5). There are strong echoes here of Arons' (1983) emphasis on the ability to "discriminate, on the one hand, between acceptance of asserted and unverified end results, models, or conclusions, and on the other, understand their basis and origin; that is, to recognize when questions such as "How do we know?" "Why do we believe it?" "What is the evidence for it?" have been addressed, answered, and understood, and when something is being taken on faith" (p.93). Similar capabilities have sometimes been included in the notion of *intellectual independence* (Munby 1980; Aikenhead 1990; Norris 1997). Without such capabilities, citizens are "easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems" (AAAS 1989, p.13) - including, one might add, some otherwise respectable scientists, politicians and commentators, who intimidate through their facility in a mode of discourse unfamiliar to many citizens.

The authors of *Science For All Americans* (AAAS 1989, p.12) also direct attention towards scientific literacy for a more socially compassionate and environmentally responsible democracy when they state that science can provide knowledge "to develop effective solutions to its global and local problems" and can foster "the kind of intelligent respect for nature that should inform decisions on the uses of technology" and without which, they say, "we are in danger of recklessly destroying our life-support system". Regrettably, they don't go on to suggest that scientific literacy also includes the capacity and willingness to act in environmentally responsible and socially just ways. This component is also absent from the definition proposed by the Council of Ministers of Education (1997, p.4) to guide curriculum construction throughout Canada: "scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them".

Because, they say, "it conveys more clearly a flavour of science education for action as well as for personal enlightenment and satisfaction", the Scottish Consultative Council on the Curriculum (SCCC, 1996, p.15) has adopted the term *scientific capability* instead of scientific literacy. Scientific capability is described in terms of five distinct, but clearly interrelated, aspects: *scientific curiosity* - an enquiring habit of mind; scientific *competence* - ability to investigate scientifically; scientific *understanding* - understanding of scientific ideas and the way science works; scientific *creativity* - ability to think and act creatively; and scientific *sensitivity* - critical awareness of the role of science in society, combined with a caring and responsible disposition. Hence, becoming scientifically capable involves considerably more than the acquisition of scientific skills, knowledge and understanding. It also involves the development of personal qualities and attitudes, the formulation of one's own views on a wide range of issues that have a scientific and/or technological dimension, and the establishment of an underlying value position. In the words of the SCCC (1996, p.15), "a person who is scientifically capable is not only knowledgeable and skilled but is also able to draw together and apply her/his resources of knowledge and skill, creatively and with sensitivity, in response to an issue, problem or phenomenon". It is interesting and extremely disappointing that a document purporting to be action-oriented, does not include preparation for sociopolitical action by students in its definition. If we are to tackle the crisis (crises) that O'Sullivan identifies, we need a much more overtly politicized form of science education, a central goal of which is to equip students with the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern.

Politicizing the Curriculum

One of the absurdities of some current curriculum initiatives is that they attempt to teach that science is a value-laden activity (the nature of science element in the STS emphasis, for example), but try to do so in a value-free way. Many teachers studiously avoid confronting the political interests and social values underlying the scientific and technological practices they teach about, and seek to avoid making judgements about them or influencing students in particular directions. This makes little or no sense. First, it asks teachers to attempt the impossible. Values are embedded in every aspect of the curriculum: content, teaching and learning methods, assessment and evaluation strategies are selected using criteria that reflect and embody particular value positions, whether we recognize it or not. Second, it mistakes the very purpose of education in science, which, in my view, is to ensure *critical* scientific and technological literacy for everyone as a means to social reconstruction. Its purpose is to enable future citizens to look critically at the society we have, and the values that sustain it, and to ask what can and should be changed in order to achieve a more socially just democracy and to ensure more environmentally sustainable lifestyles. Hence my view of science education is overtly and unashamedly political. Politicization of science education can be achieved by giving students the opportunity to confront real world issues that have a scientific, technological or environmental dimension. By grounding content in socially and personally relevant contexts, an issues-based approach can provide the motivation that is absent from current abstract, de-contextualized approaches and can form a base for students to construct understanding that is personally relevant, meaningful and important. My inclination is to provide a mix of local, regional/national and global issues focusing on: health; food and agriculture; land, water and mineral resources; energy resources and consumption; industry and technology (including biotechnology); information transfer and transportation; freedom and control in science and technology (ethics and social responsibility). As argued elsewhere (Hodson 1994), this kind of issues-based approach can be regarded as comprising four levels of sophistication.

- *Level 1*: Appreciating the societal impact of scientific and technological change, and recognizing that science and technology are, to some extent, culturally determined.

- *Level 2*: Recognizing that decisions about scientific and technological development are taken in pursuit of particular interests, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and technological development is inextricably linked with the distribution of wealth and power.

- *Level 3*: Developing one's own views and establishing one's own underlying value positions.

- *Level 4*: Preparing for and taking action.

The principal goal of such a curriculum is to equip students with the capacity and commitment to take appropriate, responsible and effective action on matters of social, economic, environmental and moral-ethical concern. However, socially and environmentally responsible behaviour will no more follow directly from knowledge of key concepts than ability to conduct scientific investigations will follow directly from experience of carrying out exercises based on the sub-skills of science. The keys to the translation of knowledge into action are *ownership* and *empowerment*. Those who act are those who have a deep personal understanding of the issues (and their human implications) and feel a personal investment in addressing and solving the problems. Those who act are those who feel personally empowered to effect change, who feel that they can make a difference. At level 1, students are encouraged to recognize the societal and environmental impact of science and technology. At level 2, they are sensitized to the sociopolitical nature of scientific and technological practice. At level 3, they are encouraged to become committed to the fight to establish more socially just and environmentally sustainable practices. But only by proceeding to level 4 can we ensure that students acquire the knowledge and skills to intervene effectively in the decision-making processes and ensure that alternative voices, and their underlying interests and values, are brought to bear on policy decisions.

As Curtin (1991) says, it is important to distinguish caring *about* and caring *for*. It is almost always much easier to proclaim that one cares about an issue than to do something about it! A politicized ethic of care (caring *for*) entails becoming actively involved in a local manifestation of a particular problem, exploring the complex sociopolitical contexts in which the problem is located and attempting to resolve conflicts of interest. Preparing students for action necessarily means ensuring that they gain a clear understanding of how decisions are made within local, regional and national government, and within industry and commerce. Without knowledge of where and with whom power of decision-making is located, and awareness of the mechanisms by which decisions are reached, intervention is not possible. Furthermore, the likelihood of students becoming active citizens is increased substantially by encouraging them to take action *now* (in school), and by providing opportunities for them to do so. Suitable action might include conducting surveys, making public statements and writing letters, organizing petitions and consumer boycotts of environmentally unsafe products, publishing newsletters, working on environmental clean-up projects, assuming responsibility for environmental enhancement of the school grounds, and so on. It is not enough for students to learn that science and technology are influenced by social, political and economic forces; they need to learn how to participate, and they need to experience participation. It is not enough for students to be armchair critics! A fundamental part of my argument is that education for critical scientific literacy is inextricably linked with education for *political literacy* and with the ideology of education as social reconstruction. As Kyle (1996, p.1) puts it:

> Education must be transformed from the passive, technical, and apolitical orientation that is reflective of most students' school-based experiences to an active, critical, and politicized life-long endeavour that transcends the boundaries of classrooms and schools.

The kind of social reconstruction I envisage includes the confrontation and elimination of racism, sexism, classism, and other forms of discrimination, scapegoating and injustice; it includes a substantial shift away from unthinking and unlimited consumerism, towards a more environmentally sustainable lifestyle that promotes the adoption of appropriate technology. Adopting appropriate technology entails the rejection of any technology that violates our moral-ethical principles, exploits or disadvantages minority groups, or has adverse environmental impact. The curriculum proposals outlined here are unashamedly intended to produce activists: people who will fight for what is right, good and just; people who will work to re-fashion society along more socially-just lines; people who will work vigorously in the best interests of the biosphere.

Unfortunately, there are many students who feel disempowered by their experiences in school and are increasingly alienated from science. There are many who feel no sense of ownership and certainly no feelings of empowerment, and who continue to regard science as a body of fixed, authoritative knowledge located in textbooks and technology as something beyond their control. It is to these matters that I now turn.

Problem of Access

For me, a major element of my current dissatisfaction with science education concerns restricted access. In some countries, access to significant science education is limited to the academically elite, and if selection is early this usually means the socially and economically advantaged. While the most recent Ontario curriculum document dispenses with the traditional curriculum differentiation into three secondary school science courses - basic, general and advanced - it now specifies four levels of anticipated achievement, identifies achievement at level 3 as "the provincial standard", and states that some students will not reach it. This is simply not good enough! If critical scientific literacy is a crucial aspect of responsible citizenship and sound environmental behaviour, it is essential for everyone - here in Ontario and elsewhere around the world. Those who leave school scientifically illiterate are essentially disempowered. Worse, they are predisposed to succumb to the blandishments of advertizers to act in ever more consumptive and polluting ways in pursuit of essentially trivial consumer goods.

Some students already believe that school is a waste of time: it confines them against their will in physically unattractive surroundings, imposes on them a code of conduct that is unfamiliar and unwelcome, and often denies them any measure of choice and self-determination about what and how they study. To compound matters, these already disenchanted students are presented with a science curriculum that they regard as remote from real life. Even if they make the effort to learn science, they are presented almost daily with unappealing messages about the nature of science and scientific practice. Science is presented as complex and difficult, and so only accessible to 'experts' who have subjected themselves to a long and arduous training. Scientists are often portrayed as dispassionate and disinterested experimenters, who painstakingly reveal the truth about the world. Frequently, scientific knowledge is characterized as established and proven knowledge that is not to be challenged or doubted by mere students. Moreover, it is often presented in an unfamiliar and depersonalized language. For many students, all this constitutes such a formidable barrier that they are unable to make satisfactory progress. Many are dissuaded from further study and merely 'mark time' until they can give up science altogether. It is particularly disturbing that girls and members of ethnic minority groups are over-represented among those who consistently under-achieve in science or terminate their science education at the earliest opportunity - yet another example of the injustices in our education system.

It is a matter of some urgency that ways are found to make science more accessible. Developing a more inclusive science curriculum requires that we look closely at what we teach (and why), at how we teach, and at how we assess and evaluate learning. To enable *all* students to achieve critical scientific and technological literacy, we must pay much closer attention to the transitions from everyday understanding to scientific ways of understanding and from everyday ways of communicating to scientific ways of talking and arguing. Increasing access and participation levels also entails paying much more attention to the specific barriers and obstacles experienced by individuals, many of them related to ethnicity, gender and social class. This requires us to address the inherent biases of science and science education, create a more authentic, culturally sensitive and inclusive image of science, scientists and scientific practice, illustrate the ways in which science is used and developed by diverse people in diverse situations, and establish and maintain a school science environment in which all students feel a sense of comfort and belonging. At present, many students in science lessons are bored by content they consider irrelevant to their needs, interests and aspirations. They are uninvolved by the kinds of teaching/learning methods we employ and they find the social and emotional climate of the science classroom uninviting, or even alienating. Some of those who do engage in effective science learning do so at considerable social and emotional cost, sometimes resulting in disaffection, exclusion or ostracization from peers and family (Costa, 1995).

In my view, critical scientific literacy for an increasingly diverse student population can only be achieved by the *personalization* of learning, by developing an education that looks not only to the students' cognitive development but also to their emotional, aesthetic, moral and spiritual needs, an idea that is developed at length by Hodson (1998). Personalization of learning means ensuring that the curriculum takes account of the knowledge, beliefs, values, attitudes, aspirations and personal experiences of individual students. In my view, it also means that every student has the opportunity to conduct authentic scientific investigations and to engage in technological problem-solving tasks of their own choosing and their own design. But that is an issue well beyond the scope of this essay.

References

Aikenhead, G.S. (1990) Scientific/technological literacy, critical reasoning, and classroompractice. In S.P.Norris & L.M. Phillips (Eds), *Foundations of Literacy Policy in Canada*. Calgary, AB: Detselig.

American Association for the Advancement of Science (1989) *Science For All Americans*. A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology. Washington, DC: AAAS.

American Association for the Advancement of Science AAAS (1993) *Benchmarks for Scientific Literacy*. Oxford: Oxford University Press.

Anderson, C.W. (199) Inscriptions and science learning. *Journal of Research in Science Teaching*, 36, 973-974.

Apple, M.W. (1993) *Official Knowledge: Democratic Education in a Conservative Age*. New York: Routledge.

Arons, A.B. (1983) Achieving wider scientific literacy. *Daedalus*, 112, 91-122.

Atkin, J.M. & Helms, J. (1993) *Testing in Mathematics and Science - For Everyone*. TIMSS document reference ICC413/NPC061. Vancouver: TIMSS International Coordinating Centre.

Bencze, J.L. (2001) Subverting corporatism in school science. *Canadian Journal of Science, Mathematics and Technology Education*, 1(3), 349-355.

Bowers, C.A. (1996) The cultural dimensions of ecological literacy. *Journal* *of Environmental Education*, 27(2), 5-11.

Council of Ministers of Education, Canada (1997) *Common Framework of Science Learning Outcomes*. Toronto: CMEC Secretariat.

Costa, V.B. (1995) When science is 'another world': relationships between worlds of family, friends, school, and science. *Science Education*, 79, 313-333.

Curtin, D. (1991) Toward an ecological ethic of care. *Hypatia*, 6, 60-74.

Eisenhart, M., Finkel, E. & Marion, S.F. (1996) Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal*, 33: 261-95.

Fensham, P.J. (2002) Time to change drivers for scientific literacy. *Canadian Journal of Science, Mathematics and Technology Education*, 2(1), 9-24.

Galbraith, P.L., Carss, M.C., Grice, R.D., Endean, L. & Warry, M. (1997) Towards scientific literacy for the third millennium: A view from Australia. *International Journal of Science Education*, 19, 447-67.

Government of Canada (1991) *Prosperity through Competitiveness*. Ottawa: Minister of Supply and Services Canada.

Hewson, P.W. (2002) Literacy and scientific literacy: A response to Fensham. *Canadian Journal of Science, Mathematics and Technology Education*, 2(2), 207-213.

Hodson, D. (1994) Seeking directions for change: The personalisation and politicisation of science education. *Curriculum Studies*, 2, 71-98.

Hodson, D. (1998) *Teaching and Learning Science: Towards a Personalized Approach*. Buckingham: Open University Press.

Jenkins, E. (1990) Scientific literacy and school science education. *School*

Science Review, 71 (256), 43-51.

Kyle, W.C. (1996) Editorial: The importance of investing in human resources. *Journal of Research in Science Teaching*, 33, 1-4.

Lankshear, C., Gee, J.P. & Hull, G. (1996) *The New Work Order: Behind the Language of the New Capitalism*. Boulder, CO: Westview Press.

Law, N. (2002) Scientific literacy: Charting the terrains of a multifaceted enterprise. *Canadian Journal of Science, Mathematics and Technology Education*, 2(2), 151-176.

Ministry of Education and Training (2000) *Ontario Curriculum,, Grades 9 to 12: Program Planning and Assessment*. Toronto: Queen's Printer for Ontario.

Munby, H. (1980) Analyzing teaching for intellectual independence. In H. Munby, G. Orpwood & T. Russell (Eds), *Seeing Curriculum in a New Light: Essays from Science Education*. Toronto: OISE Press.

National Science Board (1998) *Science and Engineering Indicators - 1998*. Arlington, VA: National Science Foundation.

Norris, S.P. (1997) Intellectual independence for nonscientists and other content-transcendent goals of science education. *Science Education*, 81, 239-258.

Norris, S.P. & Phillips, L.M. (1994) Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching*, 31, 947-967.

Norris, S.P. & Phillips, L.M. (in press) How literacy in its fundamental sense is central to scientific literacy. *Science Education*.

Organization for Economic Cooperation and Development (OECD) (1998) *Instrument Design: A Framework for Assessing Scientific Literacy*. Report of Project Managers Meeting. Arnhem, Netherlands: Programme for

International Student Assessment (PISA).

O'Sullivan, E. (1999) *Transformative Learning: Educational Vision for the 21st Century*. London: Zed Books.

Pella, M.O., O'Hearn, G.T. & Gale, C.W. (1966) referents to scientific literacy. *Journal of Research in Science Teaching*, 4, 199-208.

Scottish Consultative Council on the Curriculum (1996) *Science Education in Scottish Schools: Looking to the Future*. Broughty Ferry: Author.

Select Committee on Science and Technology, House of Lords (2000) *Science and Society*. 3rd Report, Session 1999-2000. London: HMSO.

Shahn, E. (1988) On science literacy. *Educational Philosophy and Theory*, 20, 42-52.

Shamos, M. (1995) *The Myth of Scientific Literacy*. New Brunswick, NJ: Rutgers University Press.

Educational implications of humanistic education.Â The humanistic approach, as Stevick (1990) expresses, has also some implications for teacher education.Â Indeed, through social interaction and negotiating of meaning among peers, cooperative language learning can facilitate and support most of their affective factors: reducing anxiety, increasing motivation, fostering the development of positive attitudes toward language learning, promoting self-esteem, as well as supporting different learning styles and encouraging perseverance in the difficult and confusing process of learning another language (Arnold, 1999, p. 227). The notion of spiral curriculum states that a curriculum should revisit basic ideas, building on them until the student grasps the full formal concept. Although extrinsic motivation may work in the short run, intrinsic motivation has more value. Implications on the learning process. Brunerâ€™s learning theory has direct implications on the teaching practices. Here are some of these implications: Instruction must be appropriate to the level of the learners. For example, being aware of the learnersâ€™ learning modes (enactive, iconic, symbolic) will help you plan and prepare appropriate materials fo Most literate women learnt to read in primary school, and the fact that a woman has had an education may simply indicate her family's wealth or that it values its children more highly. Now a long-term study carried out in Nicaragua has eliminated these factors by showing that teaching reading to poor adult women, who would otherwise have remained illiterate, has a direct effect on their children's health and survival.Â Why are the children of literate mothers better off? According to Peter Sandiford of the Liverpool School of Tropical Medicine, no one knows for certain. Child health was not on the curriculum during the women's lessons, so he and his colleagues are looking at other factors.