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SCIENCE, TECHNOLOGY AND LIFE-LONG LEARNING IN THE 21ST CENTURY

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INTRODUCTION

In 1981, Claude Fortier, then Chairman of the Science Council of Canada, wrote in the journal Science:

> "At no time in our history have we been confronted with so many problems needing science-based solutions. It is not possible to exaggerate the importance of decisions which confront Canada in such areas as resource management, energy options, health care, food supply, pollution, transportation, and so on. Furthermore, the wisdom of the choices that we, as a nation, make in these areas will be dependent on the maturity, knowledge, versatility and stature of Canadian science and engineering."

On February 4th, 1993, Canada's Globe and Mail newspaper reported the following part of a speech by British chemist George Porter: "Should we force science down the throats of those who have no taste for it? Is it our duty to drag them kicking and screaming into the 21st century? I am afraid that it is!"

The theme of this International Symposium, "When Science Becomes Culture", implies that 21st-century society should aim for a merger between our scientific and cultural mindsets. In her recent book "Planet Under Stress", Emeritus Professor Ursula Franklin of the University of Toronto expressed this related view:

> "The task of the future is to build knowledge and understanding among and between citizens and scientists, so that the distinction

> between the two groups vanishes – so that both become citizen scientists, potentially able to solve our problems together."

Environmentalists have coined the 1990s as "the decisive decade". In the April 1993 issue of "Intersect/Japan and the World" magazine, Canadian science communicator Dr. David Suzuki remarked:

> "If the inhabitants of the industrialised world do not make a radical change in how they live and what they expect, and at the same time convince the less developed countries that the western model of economic progress has proved unworkable, then the outlook is bleak beyond belief."

It is the scale, urgency and potential Earth-threatening nature of our problems which drives the need to lessen the distinction between citizen and scientist. The human population is expected to double by 2050 A.D., yet last year alone at least 22,000 other species became extinct and 25 billion tonnes of agricultural topsoil were lost to urbanisation or erosion. In the USA alone, almost 80 million people live within 70 km of ocean coastlines. Under global warming, polar ice-caps and mountain glaciers recede, sea-level rises, and coastal cities become inundated. Also, in a very real worldwide sense, the availability of water, food, shelter and medicine to our exponentially-increasing population is a massive challenge which needs the achievement of Professor Franklin's "citizen scientist" more than ever before.

As a societal goal, and using the language of this Symposium, "when science becomes culture" requires proactive strategies by the "practitioners of scientific and technological culture". Who are these practitioners? As the Symposium Program suggests, major players include the scientific community, communications industry, private sector, and public-at-large. Our collective task ought to proceed on a large, coordinated scale with conviction, urgency and optimism. Although the challenge is immense, the human spirit cannot despair that the task on a global scale is, as a colleague recently speculated, akin to shifting deck-chairs on the Titanic!

My own view is that through public awareness of science strategies that the general public must develop a much increased level of life-long learning. It is further my view that public educational institutions known generally as "science centres" are one of society's most effective vehicles for tackling the goal of "when science becomes culture". Hence the title of my presentation, "Science, Technology and Life-Long Learning in the 21st Century".

This year's newborn will enter school in 2001 A.D. Their education cannot afford to stop at graduation. If the 20th century is about to enter history as the period when we created problems, potentially affecting our very survival, then the 21st century must be when we learn to find and implement solutions together.

From these angles, this presentation is one person's perspective on the public awareness of science. It is a commentary, using personal anecdotes, which explores why awareness is necessary, delves into major terminology, examines how the public acquires information, assesses socio-economic barriers to awareness, examines the responsibilities of the scientific community, and concludes with the emerging major role of science centres.

WHY GREATER PUBLIC AWARENESS OF SCIENCE IS NECESSARY

This is an immensely important issue, one that must be repeatedly raised with public audiences to advance their interest in the value of a scientific and technological culture. In my view, five of the more pressing categories are as follows.

Basic necessities

Here I refer to nutrition, shelter, energy and medicine. While we all readily understand their necessity, none are problem-free or guaranteed to be available, as the following few examples remind us: possible extinction of the Grand Banks cod fishery; uncertain adverse effects of agricultural pesticides and food additives; controversy over health consequences of prolonged exposure to electricity power lines; unknown cause of multiple sclerosis; untested blood supplies; suspected toxic emissions from dry-cleaning of clothes and some household flooring

materials; the finite supply of fossil fuels; and the temporary storage of nuclear energy waste while research continues on a permanent solution.

In particular, we must be spurred to more effective action by the large "have-not" regions of the globe where inhabitants already suffer dismal situations with respect to nutrition, medical attention and shelter. For them, science and technology have so far failed.

Natural hazards

As the world population grows, our encounter with the planet's natural hazards will increase concomitantly. News reaches us with alarming regularity of devastating storms, floods, volcanic eruptions, earthquakes, bush fires, landslides, avalanches, etc. Hazards strike suddenly causing death and destruction. The predictive ability of meteorologists and geologists will likely always be imperfect because of the extreme complexity of natural phenomena.

The news also brings stories of re-constructing homes on the barrier-island after the hurricane, on the river floodplain after inundation, and along the fault-line after a major earthquake. Even if this is inevitable, the aftermath of natural hazards is an opportune time for public education about natural forces and the establishment of "state-of-emergency" contingency budgeting by governments. Hazards could also bring about more stringent construction codes and improved plans for disaster preparedness.

Politics and government

Many of society's science and technology issues are matters of policy arising from decisions in the political arena. At the large end of the scale is the introduction to world leaders of the "sustainable development" concept and massive international summit meetings on the health of the whole planet, the best known one being in Rio de Janeiro. Within the jurisdiction of local, regional and national governments are policy issues such as: land-use zoning, logging, crop rotation, fishing quotas, standards for industrial emissions, laws for transport of hazardous materials, and sewerage.

The public would benefit from a much greater awareness of these science and technology issues so as to empower their probing questions during elections and their following of political debates. The fact that governments commonly plan their actions in timeframes only spanning half a decade has given rise, in part, to a large variety of community-based and international activist groups.

The environment and global change

Pondering the legacy of this generation for our children and grandchildren obliges another agenda of priorities, as earlier suggested.

Evidence abounds that each of the planet's concentric shells which enclose the biosphere – that is, the layers of rock, soil, water, air, space – are in a deteriorating state. Reports of toxic effluent from old landfills, acid rain and ozone holes are examples. Most disturbing of all is the loss of other life-forms around the planet, which we seldom share under ecological principles. Destruction of habitats, disruption of food chains, extinction of species, pollution of the environment, and the effect of toxic spills are current events demanding public concern. If society does not understand and raise these longer-term issues, then our politicians are less likely to reduce or prevent their occurrence.

Lessons from our heritage

It is one of life's fundamental axioms that we learn from experience. Today, progressive organisations refer to themselves as "learning institutions" dedicated to "continuous improvement". Society, as a whole, should have the same practices. As much as our consumption with the present timeframe often precludes our adequate attention to the future, so does it seem to hinder us looking back critically to learn. Our heritage is the sum total of all of society's successes and failures. It is our best reservoir of knowledge, combined with new research, upon which to determine a sustainable course of decisions and actions for the future.

One example of positive action in the wake of a disaster is the Challenger Center for Space Science Education, based in the Washington D.C. region. This was founded by the family members of the ill-fated Challenger shuttle crew on NASA's first mission in 1986 with a teacher aboard. Everyone recalls the tragedy of its

explosion shortly after blast-off. Today, more than twenty Challenger Learning Centers across the USA and Canada "continue the mission" by involving school students in learning experiences within simulated mission control and space station environments, in turn involving computer communications, teamwork, and the important pathways to risk and success. As the network grows, more and more scientists and technical experts are finding themselves drawn to assist with this laudable cause.

"PUBLIC AWARENESS OF SCIENCE" – EXPLORING TERMS

Among scientists concerned about their gap with mainstream society, and as delegates to this conference well know, the umbrella term "public awareness of science" and acronym "PAS" have rapidly become popular. "Awareness" meaning alert, informed, observant, etc. is superior to earlier choices of terminology, such as "public understanding of science" and "public interest in science". "Understand" tends to imply a thorough grasp which is unrealistic. "Interest" tends to imply appeal or curiosity which is insufficient.

Dr. Brian Wynne of the University of Lancaster in England studied sheep farmers in the British Lake District after the Chernobyl nuclear catastrophe. He found that public awareness of science is invisible until the moment when people are required to cope with a serious life experience. Chernobyl led to closure of the sheep farms. Dr. Wynne discovered that the farmers were rather well-informed about the science of raising sheep and nuclear physics. As international museum consultants Drew-Ann Wake and James Bradbourne have commented, Dr. Wynne's study suggests that it may be simplistic to apply a pass-fail verdict to societies asked a standard list of scientific literacy questions.

Other examples of this phenomenon readily come to mind – namely, the decision to quit smoking after cancer strikes, to wear a seat-belt after witnessing an accident, or to enforce building occupancy limits after a major fire.

A few other basic definitions are in order. "Science" refers to the field of systematically acquired knowledge from observable phenomena and demonstrable truths. There are the natural sciences, physical sciences, social sciences and, according to modern philosophy, we also have political science. "Technology"

refers broadly to applications of scientific knowledge to society. The aims of technological development may be beneficial (e.g. solar energy receptors, birth control), destructive (e.g., the atomic bomb, nerve gas), initially of uncertain consequence (e.g., robots, space travel), or frivolous (e.g., gadgets without public appeal).

Increasingly, the public is seeking a greater, more direct involvement with ethical decisions surrounding scientific research and technological developments. Current Canadian examples are human reproductive technologies; doctor-assisted suicide; logging versus mining in British Columbia's temperate rainforests; new landfill sites for Metro Toronto; and dumping of raw sewerage into Atlantic and Pacific harbours.

The word "culture" conjures up a host of impressions, mostly in association with the arts, performing arts and human history museums. Natural history museums and interactive science centres tend not be so readily perceived as being part of "culture". Yet they are commonly also affiliated with the culture ministries of governments. Generally, culture refers to self-defining and enlightening experiences of a society which, in turn, amount to its cultural identity and heritage. Defined this way, science and technology deserve to share the stage with the arts, performing arts and human history.

In Canada, "cultural tourism" enjoys greater understanding than "science culture", presumably because people have more direct encounters with the tourism industry than with science.

HOW THE PUBLIC ACQUIRES INFORMATION

The foundation of our knowledge and attitudes about science originates with the curriculum and instructional approach at the schools we attended. As well, the attitude and outlook of our parents are generally considered to be powerful forces. This is a huge area of study by itself, well beyond the scope of this contribution.

However, three recent developments in North America are worthy of mention as examples of the many fresh attempts to transform the school curriculum and approach to the changing needs of society. Firstly, the Conference Board of Canada

has launched a national dialogue involving representative industry/education leaders and parents on a new vision and strategy for education which includes life-long learning. Secondly, an effort in California to study new ways in which science museums and science centres can actively support reforms of school education is in the planning stage. Thirdly, The Royal Canadian Geographical Society has just formed the Canadian Council for Geographic Education with an impressive array of prize-winning competitions aimed at increased awareness of Canada's land, science and technology.

In adulthood, the foundation of formal education may be built upon by various life-long learning opportunities. Brief comments on several areas follow. The role of science centres will be profiled at the end of this paper.

Cultural tourism and ecotourism

The tourism industry – traditionally accented on relaxation at seaside resorts, entertainment complexes, sporting vacations, cruises, and spas – has lately undergone some pronounced shifts. An opinion poll in the late 1980s on travel preferences in the United States revealed that while 17% prefer beach vacations, 68% prefer to tour regions and visit cultural attractions.

At its 1986 Congress in Madrid, the World Tourism Organisation declared cultural tourism as the industry's fastest growing segment. In countries like France, government investment in science culture and regional interpretative facilities is responded to with a large cultural tourism industry.

Ecotourism relates to wilderness areas and involves lower tourist numbers because of the ecologically fragile nature of the area being visited. Ecotourism "packages" commonly enrich participants with an understanding of natural history, resource development questions, biodiversity and ecology.

Of course, it need not only be during vacations that one becomes actively interested in the world. Life-long learning aims for increased awareness and enlightenment to be a part of everyday life. Every neighbourhood has its share of science and technology issues which need attention. In this regard, the growing popularity of cottager associations around lakes north of Toronto with the

objective of ensuring safe and sustainable recreation, such as swimming and catch-and-release fishing, is most encouraging. These were among the many exhibitors at a recent exposition of the Environmental Youth Corps at the Ontario Science Centre.

Career opportunities and further education

Some types of job, by their very nature, expose people to high ongoing awareness about certain science and technology fields. Examples are architects, engineers, meteorologists, doctors, biochemists, geologists, and environmental consultants. In turn, people in these kinds of careers are, at least in principle, well-positioned to advance their knowledge about other science and technology areas. In this general regard, studies have shown that museum – goers are traditionally younger, better educated – and better paid than the whole population.

A few of us choose to continue our education by registering as a "mature student". The University of Toronto recently announced evening courses on the subject of Great Lakes pollution. Across North America, the growth of the Elderhostel movement is most encouraging. This club is active in organising cultural excursions for its large membership.

Literary and electronic media

Science columns in newspapers and magazines, and science/technology magazines themselves, are a valuable source of information to society to increase public awareness. Some scientific associations, such as the Canadian Society of Petroleum Geologists, recognise outstanding science journalism with annual awards. I have been interested to see the recent dialogue in Canada's Globe and Mail newspaper where scientists have written letters to the Editor responding to research reports not stemming from previously peer-reviewed articles in scholarly journals. This raises questions about ways in which science enters the public arena via the media.

Television, and to a lesser extent radio, are other major vehicles for the spread of information to the public about science and technology. With rare exceptions, science documentaries are not prime-time viewing against the higher ratings of re-

run films, series of many kinds, and sports. As an example, I remember when an episode of CBC-TV's "The Nature of Things" on dinosaur-collecting aired in 1984, one in which I had a minor role, this science program was reported as being behind the weekly ratings of "Dallas" and "Hockey Night in Canada"!

Highlight coverage of science by news broadcasts is typically limited to dramatic items such as medical breakthroughs, space exploration, environmental damage, and significant fossil finds. Expansion of speciality cable channels and "information highway" developments into homes likely signify revolutionary, positive developments vis-à-vis science culture.

SOCIO-ECONOMIC BARRIERS

Identification of barriers to greater public awareness of science is an important step in formulating strategies towards the merger of science and culture. Table 1 in "Science Culture in Canada", one of the pre-published papers under the first theme of this International Symposium, explores the issue of barriers. Here, I wanted to add the view that these barriers are mostly of a socio-economic nature. That is, without social equity and financial self-sufficiency, there cannot be, as others have noted, an expectation that citizens will care about science-and-society matters, such as environmental degradation.

Specific barriers of a socio-economic nature, collectively affecting large regions and large sections of the global population, include famine, war, being in the aftermath of a natural disaster, a lack of cultural identity, and consuming racial tensions. At the 1992 International Council of Museums (ICOM) Conference in Quebec City, I vividly recall the appeal by museum delegates from former Yugoslavia for an international collaborative effort to save their material culture which war was fast destroying.

Other barriers to increased public awareness of science are the seemingly relentless pressures on our time to achieve much more than basic subsistence activities around the home and workplace. When we do have spare time, there is a great variety of leisure activities at our disposal, inside and outside the home. In the home, a high volume of TV game shows and soap operas can easily transform our lives into an imaginary world. However, when I see young video game enthusiasts

designing a city on the Nintendo System – complete with land-use zoning, transportation corridors, residential areas of various densities, siting of emergency facilities, etc. – I am reminded that home entertainment systems can indeed provide valuable experiences.

The growth of "creation science" associated with fundamentalist religions is another challenge to increasing public awareness of science.

RESPONSIBILITIES OF THE SCIENTIFIC COMMUNITY

Dr. Bruno Latour, a professor of philosophy at the Centre de Sociologie de l'Innovation à l'École des Mines in Paris, was at the University of Toronto last year for a conference on the contributions of Dr. Louis Pasteur. Coverage of Dr. Latour's lecture by Mary Gooderham in Canada's Globe and Mail newspaper spoke of his views that successful science is a closed institution operating apart from society. Dr. Latour was quoted as saying:

> "We need to bridge the gap between the general culture and the kinds of things scientists do."

This Globe and Mail columnist went on to comment:

> "Though massively financed by public money, science escapes the public scrutiny that all other institutions – notably the political system – must bear. Thus, it is a members-only club, where risk-taking and free thinking are not encouraged. Entry into a discipline such as physics is barred to those who question its laws and traditions… With our massive scientific and technological institutions becoming more complex, a contemplative public and critical media are essential… The day when people are prepared to think deeply about the meaning and expectations of scientific discoveries will be the day that science ceases to be detached from society and becomes part of it."

Louis Pasteur was highly skilled at public presentations on his research. His famous lecture on spontaneous generation on bacterial life at the Sorbonne in April 1864 included demonstrations with beakers, slides and microbes. Modern science

is endowed with many Pasteur-like personalities who can communicate with equal brilliance to scientific and public groups. In the Earth science field, familiar examples are Dr. Stephen Jay Gould and the late Dr. J. Tuzo Wilson. Each field has its share and scientific associations owe it to their profession to recognise and support the dual talents of such people. In this regard, the Academy of Sciences of the Royal Society of Canada has introduced the McNeill Medal for outstanding contributions to the public understanding of science.

Recently at the Ontario Science Centre, as part of our annual week-long program on Earth sciences and society, the Geological Association of Canada brought to our public auditorium and adjacent hall the oral and poster sessions of a divisional conference on urban environments. It appears that this was the first time in the 47-year history of this Association that the process of scientist presenting his/her science at a conference took place with complete openness in a public setting. I will long remember the sight of a group of high school students listening in on a controversial point of intense discussion between scientists in front of a poster presentation.

There is a small but growing number of scientists who volunteer their time in local schools to share personal experiences, answer questions and be role models. There are those, too, who eagerly judge science fairs, answer media inquiries, work with science museums and science centres, work with the electronic media, and write books for children and the general public. All these are wonderful trends and are also deserving of greater peer recognition.

In his 1988 autobiography entitled "Metamorphosis – Stages in a Life", Dr. David Suziki, a long-time presenter of the previously-mentioned "The Nature of Things" recalls:

> "My growing involvement in television was resented by my fellow professors. I can't second-guess all of the reasons, and there were undoubtedly many. I heard some of them: I was on an ego trip, my science was not good enough so I shifted areas, I was wasting my time. I felt the disapproval by my colleagues came mostly from their view that popularizing science through broad-casting was beneath the dignity of a university professor."

I contend that variations on this unfortunate theme are quite common.

Another caution is necessary. Like many of you I am sure, I have seen my fair share of public science lectures which, because of their lack of background explanation, excessive use of jargon, complicated slides, etc., quickly became failed attempts to enlighten their audience. As a result, members of the audience may choose to stay away from all future opportunities. At the grand opening of a new geology department at a major North American university in the mid-1980s, I observed many guests slipping away from the graduate student's explanation of the origin of the attractive building stone in the foyer. Jargon belonging in a doctoral thesis was strung through his words, such that the audience instantly turned off.

Whether or not a particular practising scientist is adept at increasing public awareness in his/her field, I submit that every scientist ought to take an active interest in the "citizen scientist" goal. It would be helpful for scientists to follow the field of public science education to a level where they can knowledgeably support the PAS attempts of scientific associations and encourage the development of PAS-relevant skills in their graduating students. When visiting public science institutions and community action groups in Paris last Fall, I was struck by the very encouraging high level of science culture there. In France, it seems that all scientific research institutions are required to allocate some of their operating budgets to public open-house events.

ROLE OF SCIENCE CENTRES

Traditional collection-based museums are characterised by conservation work, curatorial research and galleries of static displays where visitors can appreciate the intrinsic value of, and learn from, specimens and artifacts. Science centres, on the other hand, feature visitor participation in dynamic exhibits and working demonstrations. In terms of core activities, museums showcase their collection to visitors whereas science centres invent their visitor experience. Of late, conventional differences in educational methodology have been lessening as the first- and second-generation types of museums recognise the value of their varied approaches.

Initially described as "hands-on", nowadays the exhibits within science centres often require total body participation and engage all the senses. By literally involving the visitor with a scientific principle or an example of technology, the experience tends to be highly effective at exciting curiosity, inspiring insights and motivating learning. Many studies are under-way to understand the balance of cognitive versus affective learning from interactive exhibits and to conduct longitudinal evaluations on visitors.

Science centres were a North American invention in the late 1960s with the Exploratorium in San Francisco and the Ontario Science Centre in Toronto as concurrent pioneers of new second-generation museums, both opening in 1969. The science centre concept grew rapidly in North America, and then in western Europe, Australia, New Zealand, Mexico, several countries in the Far East, etc. Both the Ontario Science Centre and Exploratorium have international marketing activities which have spread the science centre concept to these and other continents. Across Canada, there are now science centres in Vancouver, Edmonton, Calgary, Regina, Winnipeg, Sudbury, Toronto, Ottawa, and Halifax. Their total annual attendance exceeds 3.5 million.

The essence of science centre mission statements is, to borrow a phrase from the one for the Ontario Science Centre, "to open minds to science and technology". Because of the use of technology in the visitor experience, they have always had a particular appeal to the younger generation. Their appeal to schools is therefore very strong with a large variety of curriculum-related workshops offered by advance reservation. Science centres have also long been popular attractions for local residents of all ages, as well as tourists. Of late, in the context of life-long learning, new marketing strategies are reaching out to all demographic sectors and persons with disabilities under government barrier-free policies.

The advent of the interactive science centre has been one of several influences on broadening of the "museum" definition. For the purposes of defining membership and representation, the Canadian Museums Association, for example, is open to collection-based museums and science centres as well as aquariums, botanical gardens, park interpretive centres, and several other diverse kinds of cultural institutions.

ICOM, the International Council of Museums, at its 1972 meeting in Santiago declared:

> "The emergence of the central role of museums as both an expression of cultural identity and as a powerful force for human development and education at both the individual and community level".

At the 1974 ICOM meeting, museums were spoken of as:

> "…in the service of society and its development…"

Then at its 1989 meeting in The Hague, ICOM spoke of museums as:

> "…generators of culture, and as places where we can look for the meaning of the world around us".

These powerful statements point to science museums and science centres as leading practitioners for our scientific and technological culture.

Science centres are attractive to sponsorship by progressive private sector companies and to private citizen memberships. They also play a major role as ambassadors for the importance which their funding governments attach to quality-of-life, equity policies, tourism, economic development, and international trade. Furthermore, science centres are well-positioned to be a public forum for debates on controversial science and technology issues and to tackle their ethical aspects.

I am of the view that the challenge of creating a scientific and technological culture in society is one which, due to the large scale and high urgency of problems we have created, is especially well-suited to the mission of science centres. I reach this conclusion after being an engineering geology consultant, a faculty member at two universities, a researcher for the national government and one provincial government, carrying out geological fieldwork on three continents and other travel worldwide, and latterly leading the efforts of a natural history museum and now an established science centre. The public educational expertise and drawing power of museum-type establishments must be fully utilised. At the same time, the many exemplary individual efforts must be encouraged to continue because personal

contact between scientist and citizen is highly effective in stimulating life-long learning.

POSTSCRIPT

I end this paper by citing an example of new educational efforts in south-east Asia. The Ontario Science Centre recently received a report entitled "The Philippine Plan of Action on Education for All". In this document, one finds the following phrases:

> "A blueprint for national survival … for meaningful human existence … realities of poverty and under-development manifested in widespread child malnutrition … forced labour of school-aged minors, poor health of both parents and offspring… make it difficult for the school-going population to maximise the benefits of the school system".

In the 21st century, more effective formal education and life-long learning cannot be considered options. They are necessities to ensuring attainment of a minimum state of ecological balance with Planet Earth and, perhaps, the very existence of the human species. Surely there can be no greater compelling motivation for harmonious, effective action by scientists and citizens.

Science and technology can be a threat or an opportunity. The choice lies with us – all of us, together.