MATH FOR THE MASSES
WHY QUANTITATIVE LITERACY MATTERS

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MATH FOR THE MASSES

Synopsis: The digital age both empowers and challenges the ability of everyone to cope with a mounting volume of quantitative information and with the logic that underlies it. Are we equipped for the task? How must education change to ensure we will be?

Let me begin by saying what an honour it is to be invited to participate in this distinguished lecture series. I commend the Department of Statistics and Mathematics here at Dalhousie for the initiative to bring their subject to a broad public audience. For me, personally, it is especially gratifying to have the opportunity to return to the city of my birth and, of course, to my *alma mater* … and in this case to talk to you about my lifelong passion for numbers and about the unique light with which they can illuminate our world and our lives.

In these remarks, I will argue the case for a sharper focus on "quantitative literacy" because I believe that a basic ability to apply quantitative concepts is *increasingly* a prerequisite for competence as a worker, a consumer, and as a citizen. I will try to enliven the topic with a number of examples that illustrate the substance of quantitative literacy. I hope these examples will entertain as they inform. In conclusion, I will offer some broad policy-oriented observations as to what I believe is needed to foster a more quantitatively literate citizenry.

In choosing a title for this talk – Math for the Millions – I owe a debt of acknowledgement to Professor Lancelot Hogben, a British zoologist and medical statistician who, in 1936, wrote a popular book entitled *Mathematics for the Million* which I devoured at the age of 13 during rainy summer days in 1955 at the home of my grandparents in Baddeck. Then I was hooked.

My next stop was *Mathematics and the Imagination* by Edward Kasner. What I remember most vividly from Kasner's book was a number he called a "googol" – one

followed by one hundred zeros or ten duotrigintillion according to a Wikipedia article I found via a quick search thanks to, what else, Google! (The company's name is a deliberate misspelling of the original.) A googol is a monumentally large number – much larger in fact than the number of atoms in the observable universe which has been very roughly estimated as one followed by a mere 80 zeros, give or take.

No one can really begin, even remotely, to comprehend numbers on this scale. But bringing things back to earth, we are daily confronted with quantities, the meaning of which is almost equally opaque, but the practical significance of which can be quite profound.

How fast is Lake Huron emptying?

The daily media are full of examples. An article in the Globe and Mail a couple of weeks ago caught my eye. It was headlined: "Natural causes cited for drop in Lake Huron's water level". I happened to be aware of the bitter controversy over declining levels in Lake Huron and the effect it was having on waterfront cottage property. A search for the cause is the subject of a major study currently underway by the International Joint Commission. The news story reported that the IJC's analysis was disputed by an environmental group and noted the group's claim that Lake Huron was "losing an extra 23 billion litres a day". No further context was provided in the article. What is one to make of this? Sounds like a gargantuan outflow, but, then again, Lake Huron is a pretty big bathtub.

So I went to Google, found the surface area of Lake Huron, and calculated that the claimed outflow would reduce the lake level by about 14 centimetres per year. At that rate – and the fact that Lake Huron has an average depth of 59 meters – the lake would be empty in about 422 years. Who knows if the 23 billion litre daily outflow is a correct number, or even if it is a net outflow, but at least it can be comprehended and evaluated if expressed as something like a 14 centimetre annual drop in the water level. With a calculator and Google this is a straightforward calculation – just multiplying and dividing

– but how many journalists, or Canadians, can do it? So let me turn to the theme I want to lay out this evening.

Quantitative literacy and why it matters

In simplest terms, quantitative literacy implies a comfort with numbers and other mathematical objects, together with the set of skills needed to handle effectively the quantitative situations arising in everyday life and work. The English usually call this "numeracy" by obvious analogy with prose literacy.

Quantitative literacy is most definitely not higher mathematics. Indeed, it bears the same relationship to what professional mathematicians do as prose literacy does to what Margaret Atwood does. Of course, we are expected to enjoy Ms. Atwood, whereas very few would ever think of spending an evening curled up with Newton or Euclid!

So while quantitative literacy requires mastery of basic math at the grade school level, it is the application to everyday life that will be the primary focus of my remarks. I will argue that quantitative literacy should be as routine a capability of an educated person as the capability to read and write. That is far from the case today.

For evidence, consider that the latest International Adult Literacy and Skills Survey (in 2003) showed that fully 55 per cent of Canadians between the ages of 16 and 65 did not possess the basic numeracy skills required to function really effectively in today's knowledge-based economy. Only in Saskatchewan, Alberta and BC was more than half the working-age population above the threshold of adequate numeracy. Manitoba, Ontario and Nova Scotia were next, with only about half the population above the adequacy threshold. The survey also assessed prose literacy, and while those results were troubling as well – 42 per cent of Canadian adults fell below the "Level 3" proficiency considered necessary to cope adequately with written material – a much larger deficit relates to quantitative literacy.

Quantitative literacy matters because we are confronted increasingly – for some fundamental reasons I will explain in a moment – with quantitative information and associated logical structures. That is why quantitative literacy is needed to meet the requirements of today's workplace, and even more so tomorrow's. And that is also why we need to be quantitatively literate to behave effectively as consumers, as savers and investors, as interpreters of risk data (especially related to the daily litany of health risks), and, quite simply, as informed and aware individuals.
In the words of Professor Lynn Arthur Steen, one of America's most articulate advocates of quantitative literacy: "An innumerate citizen today is as vulnerable as the illiterate peasant in Gutenberg's time."

Beyond the functional motivations to become quantitatively literate, I believe there are important *cultural* reasons as well. That is because an instinct for logic and the sense of number are as much a part of being human as the power of language. The capability of quantitative reasoning has underpinned the evolution of science and technology, and therefore of society itself. Though even a cursory discussion would be well beyond the scope of these remarks, let me open a very brief parenthesis here and mention just a few examples of the enormous philosophical and cultural contributions of mathematics through the ages.

In the 16th and early 17th centuries, Copernicus and Galileo settled, once and for all, the great theological question as to whether the sun orbited the earth, or vice versa. Then Isaac Newton, in one of the greatest conceptual achievements of all time, reasoned mathematically, from Johannes Kepler's observations, that a universal, invisible force called gravity could explain both why the apple fell from the tree and the planets described elliptical orbits around the sun. Newton's monumental *Principia Mathematica*, published in 1687, became the model for a mathematical analysis of natural phenomena, the broad philosophy of which persists to this day.

Fast forward to 1864 when the great Scottish scientist, James Clerk Maxwell, predicted, purely by mathematical reasoning, that electric and magnetic forces would combine to generate waves that propagated through space at a speed that turned out to be the speed of light – or an astonishing 300,000 km per second or almost eight circuits of our planet in one second. Thus was born a theory that has enabled human beings, through generations of ingenious radio and television engineering, to encode sound and pictures on electromagnetic waves.

One can multiply these examples almost endlessly.

- Einstein's famous "$E = mc^2$" described the wonderful and terrifying possibility of extracting prodigious energy from the atom – e.g., when one gram of uranium (235) undergoes fission, the energy released through the conversion of mass to energy is equivalent to the chemical energy released in burning about two and a half tons (or 2.3 million grams) of coal.
- The quantum theory of matter, developed in the first half of the 20^{th} century, has given us the ability to engineer lasers and microchips.
- The mathematics of the "bell curve" has enabled the measurement, and then the *management,* of uncertainty; although – as the global financial meltdown has emphatically shown – models of uncertainty in human affairs are often flawed and poorly understood by senior decision makers.

I believe that an amateur's acquaintance with the monuments of mathematical achievement should be no less a part of everyone's cultural education than history, literature and philosophy. In fact, an appreciation for the great historical achievements of mathematics illustrates our common humanity in a way that few subjects do. Great mathematical truths transcend all national, linguistic, religious and cultural divides. The square on the hypotenuse equals the sum of the squares on the other two sides of a plane right-angled triangle, everywhere and always. It is an enduring truth, the ancient discovery of which by Pythagoras embodies the essence of human reasoning.

I remember, at the age of sixteen, spending several evenings on the couch at home with my lawyer father reading together a book he had been given in 1946 entitled "Physics and Philosophy" by the celebrated British physicist, Sir James Jeans. Professor Jeans described how, according to Einstein's theory of relativity, a moving yardstick contracts in length; a moving clock runs slower than a clock at rest – and how, according to the quantum theory, what appears to be solid matter can only be understood at the sub-microscopic level as "waves of probability."

My mind was bent by this shocking picture of a reality so outlandishly at odds with my basic intuition. I decided, then and there, that I had to understand how Einstein's and Bohr's view of the world could be so out of synch with mine.

And so began a university career in physics and mathematics here at Dalhousie that had absolutely nothing to do with job prospects or learning how to evaluate personal investments, but had everything to do with a pure quest for understanding.

Of course, for most people, the cultural and philosophical side of mathematics is either of no intrinsic interest, or else is assumed – usually incorrectly I believe – to be completely beyond them. So while the cultural aspects of quantitative literacy are important, and deeply gratifying, they are the frosting, not the cake.

The motivation for most of us will be largely functional – What does quantitative literacy mean for me? How could more of it add value to my day?

To answer these questions requires some explanation of the increasing ubiquity and significance of quantitative information in the modern world, or in other words, *why quantitative literacy matters*.

The twin drivers of quantitative information

There are two factors primarily at play – one socioeconomic, and the other technological. The socioeconomic factor derives from the fact that society's *material* progress depends ultimately on the cumulative development of science and technology, the language of which is quantity, logic, and mathematics. Human beings have progressed materially because we have learned to exert increasing control over nature – for better or for worse.

And to control nature requires that we must be able to predict nature's behaviour, at least to a decent approximation. And prediction requires an understanding of natural processes that is developed painstakingly through *measurement* of cause and effect, or circumstance and behaviour. Quantitative forecasts can then be made, on the basis of which our understanding of the world is continuously and cumulatively refined via the cycle of hypothesis, prediction, experiment, and revised hypothesis – leading perhaps eventually to a "theory". This cycle is the essence of scientific method.

As the technology of measurement, and the means of analyzing data, have been continuously enhanced, more and more phenomena have fallen within the scope of this method.

The extraordinary success of the quantitative sciences of physics and chemistry has stimulated the extension of quantitative methods to biology, medicine, psychology, economics, political science, sociology, the management of business processes and even to aspects of the humanities.

So as technical progress unfolds, more and more numbers, together with their complex relationships, unfold with it. This then is the first source of the increasing quantification in our lives. It explains much of the growing vocational importance of quantitative literacy.

The second factor is purely technological – based primarily on the microchip and its miraculously expanding capacity to capture and process symbolic information.

The pervasive influence of the computer derives from the fact that it is a general purpose information processor that amplifies the capabilities of the human mind. More than a billion computers linked via the internet now amount to a global "cyber nervous system" – an analogue at planetary scale of the human central nervous system.

I would argue that the most transformative technologies throughout history have been those that amplify a key human capability. Thus machinery amplifies muscle; the radio amplifies our hearing; TV our vision; and the internal combustion engine our legs. Computer and communications technology, by amplifying the mind, and instantaneously connecting potentially every mind on earth, puts us into a different realm altogether.

The power of networked computer technology is nowhere near its limits. The capability of the technology, relative to its cost, has increased more than a *million-fold* since the 1970s. For roughly the past four decades, the amount of computer power you could buy for a dollar has doubled every eighteen to twenty-four months – a regularity that has been dubbed "Moore's Law" after Gordon Moore, the co-founder of Intel Corporation, who first predicted this regular doubling more than three decades ago. A million-fold improvement in anything is almost impossible to imagine. If, for example, an analogue of Moore's Law applied to automobiles, then a BMW that might have cost $20,000 in the 1970s could be purchased for a couple of pennies today!

So as the cost of gathering, processing and storing data continues to be driven down exponentially by successive waves of technological innovation, some basic principles of economics more or less guarantee that the amount of data being produced will inevitably continue to *increase* exponentially. The fruits of this digital data cornucopia, whether sweet or bitter, are all around us. The message is that a powerful combination of pervasive economic and technological forces will continue to drench us, directly or indirectly, in quantitative information. That is why basic competence in understanding

the quantification of our economic and socio-cultural environment is increasingly required for success both as individuals and as nations.

In particular, more and more of the good jobs will be going to the quantitatively literate, whether here in Canada or in other far off places like China and India where mathematical predilection has been part of the culture for centuries. It is this realization that has led President Obama to make grade school education and university-level science and math into centrepieces of his program to revitalize America's economy and sustain U.S. leadership.

Quantitative literacy in everyday life

There is another dimension of our life – quite apart from the vocational – where quantitative literacy is equally relevant. We are all consumers, savers and investors, and citizens of a self-governing democratic society. Quantitative literacy is increasingly important in all of these non-vocational roles.

The requirements range from the quasi-ridiculous, like converting currencies (do I multiply or divide?), to the relatively sublime tasks of making savings and investment decisions; or making sense of the latest media hype on medical risks and miracle cures.

Of course one can always turn to the pros for advice in handling the more arcane tasks like purchasing an investment product. But who are they working for? Never has that question seemed more relevant. Better to have some basic savvy yourself. Let me give you one simple example.

We've all seen the ads for the mutual fund manager that's beaten the market six or seven years in a row. Or at least we used to see those ads. They were of course designed to make us believe that that particular manager knew something the competitors didn't. Well maybe. But if you start with, let's say, 800 mutual funds to choose from, then on the basis of chance alone, about half of them would beat the market *average* in any given year and half would not. So after one year, about 400 funds will have outperformed the TSX. Of those 400, pure chance says that about half will beat the market average the

next year. So after two years, about 200 funds will have out-performed two years in a row. And so it goes, with the lucky ones being cut roughly in half each year. Even after seven years, chances are that about six of the original 800 will have beaten the market seven years in a row – not because of any special skill, but simply because of the laws of probability. And those, of course, are the funds that will be taking out the ads trumpeting their remarkable financial acumen.

Now I would not claim that there aren't some financial managers who have the skill to outperform the market, but legions of academic studies have shown that they are extremely rare. More often than not, chance alone explains a run of out-performance in the stock market. This is a valuable lesson to bear in mind.

A point I would emphasize repeatedly is that quantitative literacy does *not* require proficiency in higher mathematics. In terms of the mechanics, it's mostly just adding, subtracting, multiplying and dividing. Admittedly, analysis of medical information and investment decisions may be somewhat more involved than converting from dollars to euros, but still there's no higher math required. What is needed, though, is a sense of how numbers and logic fit together. A calculator or your laptop can do the rest.
But if you don't know whether you should multiply or divide, a calculator obviously does little good! So, quantitative literacy is really not about the *mechanics* of calculation – we now have tools for that. Quantitative literacy is about the skills needed to apply those tools to gain insight and solve practical problems in the *unstructured* circumstances of daily life.

Quantitative literacy and citizenship

I have already suggested that there is an important linkage between quantitative literacy and competent citizenship. Virtually every major public issue – from healthcare, to energy and the environment, to economic policy – depends on data, projections, inferences, and the kind of systematic thinking that defines quantitative literacy.

My earlier anecdote about the water level in Lake Huron is one case in point. Let me illustrate, with one more example, the linkage between quantitative literacy and democratic accountability. This linkage is not widely recognized, and the consequences for public policy can be quite serious. If issues are not understood by the public, or by journalists, we all become victims of the political or corporate spin doctors whose function is to sow confusion, not to convey insight.

A cautionary tale is provided, as you may recall, by the bitter and confusing debate a couple of years ago over the feasibility of meeting Canada's Kyoto Protocol commitments to reduce greenhouse gas (GHG) emissions by six percent below their 1990 level over the five-year period beginning in 2008.

The public debate over Kyoto was all about symbolism – are you green, or aren't you? – with scarcely any heed paid to the actual *numbers* and their implications. But the Kyoto Accord itself, and what would be needed to meet Canada's commitment, are actually very much about numbers. Yet how many Canadians are even remotely aware of the quantitative facts?

According to Environment Canada's website, Canada's GHG emissions were just under 750 million tons (megatons) in 2007, about two percent of the global total. Our Kyoto target was 563 megatons – a huge gap of almost 200 megatons. To meet the target, Canada would need to somehow achieve an absolute cut, *relative to trend*, averaging well over 200 megatons per year over the five-year period from 2008 through 2012. To put that in some perspective – all the cars in Canada (again, according to Environment Canada) generate roughly 41 megatons of GHG annually. Take them all off the road and you would make-up only about one-fifth of the Kyoto gap.

The message of this example is certainly *not* that political decisions should be reduced to a dry set of figures. It is clearly the case that beliefs, values and seasoned judgment should be the basis on which societies decide. But surely the formation of our beliefs and political convictions must pay heed to the constraints of reality, and increasingly, those

constraints reveal themselves in numbers. A society that is unwilling, or unable, to analyze its data will, ultimately, not be able to govern itself wisely.

Developing an intuition for magnitude

A big problem with numbers, large and small, is that most of us lack a real intuition for magnitude. The development of such an intuition is a key objective of quantitative literacy. For example, Canada's gross domestic product is currently about 1.6 trillion dollars. This number is simply unimaginable and therefore completely meaningless to most people. Unfortunately, because of that, too many of us have no benchmark to judge relevance when it comes to government budgets or statistics about the economy. That matters.

But look at the 1.6 trillion dollar GDP this way. Imagine Canada as a very thick wallet, stretching from Halifax to Vancouver – a really enormous wallet, just over 6,000 kilometers thick. Now imagine it filled with hundred dollar bills, stacked face-to-back, just like bills in your wallet. If fairly loosely packed, each one would take up, say, four-tenths of a millimeter of the wallet space, or a bit less. In other words, 2,500 of these bills, representing $250,000, would make a stack about one meter high. That wallet, stretching from Halifax to Vancouver, packed with hundred dollar bills on edge, is what 1.6 trillion dollars would look like. Still awfully hard to imagine, but you are beginning to get the picture. To hold a million dollars in hundred dollar bills would take a wallet about four meters thick, or roughly half the length of a typical living room. What about federal government program spending of 230 billion dollars this year? Well, that would take a wallet more than 900 kilometers thick – or hundred dollar bills, on edge, all the way from here in Halifax to somewhere near Quebec City. Think about it the next time you take a long drive.

We also lack an intuition for really small numbers, and they count just as much as the really big ones. At the frontier of microelectronics, transistors can now be about the size of a virus. Modern electronics is the product of "thin film" technology. How thin? Today's state-of-the-art films, on which the micro-circuits of computers are etched, have

a thickness about equal to the amount your fingernail grows – in two *seconds*! That is why pretty soon you will be able to put everything in the Dal math library on a memory stick the size of a fingernail.

What about the ultra fast? Well, nothing is faster than the speed of light or, equivalently, the speed of the electromagnetic signals that propagate through our global communications systems. They zip along at 300,000 kilometers per *second* – again, unimaginable. But this means that a pulse along a transoceanic optical fibre can travel from here to New Zealand and back in about one-tenth of a second, or roughly the time it takes my voice – chugging along at the speed of sound – to reach the back of this room.

These are more than catchy factoids. They are the kind of metaphors on which quantitative literacy depends. These happen to appeal to me because they are startling enough to be remembered. You can develop your own. The important thing is to carry around in one's head a few quantitative benchmarks against which to judge the confusing welter of numbers in the daily media and dinner party conversation. You actually don't need very many, but you do need to develop some facility in manipulating them, and recognizing when they apply.

Impediments to quantitative literacy

The kind of quantitative literacy that these examples illustrate opens up new windows on the world. It creates context and enables judgements to be exercised that are vital for aware and responsible citizenship. Unfortunately, too few people possess this type of quantitative literacy. Even those who may be "good with figures" in a mechanical sense, often don't integrate quantitative insight in their framework for understanding the world around them. Why is this?

It is certainly not because people lack the basic capability. While there is a small minority for whom numbers will always be truly opaque – much as the printed page is opaque for those suffering severe dyslexia – the vast majority of people are perfectly capable of acquiring the level of quantitative literacy we have been talking about.

Indeed, the required quantitative and logical skills are no more inaccessible than what it takes to play bridge or crib or poker; to do a Sudoku puzzle; or make the measurements needed to hang three pictures in parallel on your living room wall; or to convert a recipe for four into a meal for seven. Millions of Canadians do these things every day and don't think a thing of it. But talk about math or "quantitative literacy" and either they freeze, or their eyes glaze over.

Indeed, mathematical *illiteracy* is something many people are almost proud of, whereas an inability to read or write is a matter of almost universal shame. What explains the difference in attitude between numeracy and literacy? I believe it begins with a vast difference in the perceived utility of the two, and the reinforcement of this perception in daily life. We "practice" reading and writing every day. But too many of us don't practice even very basic mathematics once we are out of school. Our quantitative skills atrophy rapidly. So mature quantitative literacy, and its associated intuition, never develops. But for all the reasons I have advanced in these remarks, this is not a situation we should any longer accept.

Achieving greater quantitative literacy in Canada

What is to be done? I will conclude with three observations germane to the challenge, but it would be presumptuous to give detailed advice to professional educators and policy makers worldwide who have been grappling with the vexed issue of quantitative literacy for many years. There is much wisdom in the literature and it should be heeded.

That said, it is clear that we should look first at the K-12 school system and ask how we are doing in Canada, measured province by province and against international benchmarks. The answer – which will be surprising to many parents and employers – is that Canada appears to be doing very well indeed.

The best evidence is to be found in the performance of Canadian students on tests of 15-year-olds under the OECD's Program for International Student Assessment, or PISA. This involves the most sophisticated evaluation ever undertaken of student learning in the

fields of reading, science and mathematics. The most recently analyzed round, in 2006, tested more than 400 thousand students in 57 countries (22,000 students in Canada) and included an evaluation of mathematical skills – not on rote learning to meet specific curriculum objectives, but rather on the knowledge and skills needed by the average citizen in adult life – or what I have been calling quantitative literacy.

The results are very encouraging. Among the 57 countries, only Korea, Finland, Hong Kong and Taiwan had statistically significantly better results in mathematics than Canada. All Canadian provinces performed above the OECD average.
Students from Quebec had the strongest performance in Canada, placing them right up with the world's best. Alberta, BC, Ontario and Manitoba were at the Canadian average. Those from the Atlantic Provinces and Saskatchewan had comparatively weaker results but all were above the world and US averages.

My first observation in conclusion, therefore, is that grade-school mathematics education in Canada is in good shape overall, though not uniformly so across all jurisdictions. Fortunately, we have here at home several world-leading systems – like those in Alberta, B.C. and Quebec – and therefore a wealth of best-practices to be transferred and adapted among the provinces in a cycle of continuous improvement.

If every provincial education ministry seizes this opportunity to learn from its peers, young Canadians everywhere can be provided with an excellent foundation for quantitative literacy.

The fundamental challenge, of course, is to create the conditions during the K-12 years that will produce *sustainable* quantitative literacy – which is to say a set of basic skills and a quantitative intuition that survive the passage from formal education to life in the work-a-day world. That is why numeracy skills must be taught and learned in settings that are both meaningful and memorable.

My second conclusion is that this will require an approach to the grade school curriculum that integrates the perspectives of logic and quantification well beyond the math class and into a wide range of courses. Only in that way will quantification become understood, from the earliest years, as a window on the world that is complementary to the perspectives provided by art, literature and religion.

This integrative approach can not be achieved overnight since it will require considerable innovation in curriculum development and in teacher training. In particular, the application of quantitative reasoning has to be taken beyond the ghetto of the grade-school math department. A transdisciplinary approach to knowledge is the way of the future in both research and education.

My third and final observation returns to the theme of information technology. Our education system simply has to come to terms with the computer – not only in the context of mathematics to which it has always been naturally suited – but throughout the curriculum. Technology based on the microchip – whether in phones, video games, blackberries or whatever – is now part of the experience of virtually every child from their time of earliest awareness. For today's youngsters, these devices are simply part of the world as they find it.

Information technology, whether we like it or not, is therefore shaping how children learn and will alter forever the relationship between the individual and the accumulated stock of human knowledge. With resources like Google and Wikipedia at everyone's fingertips, simply mastering and retaining a body of facts becomes rather pointless. This is a strange new world for educators that must be profoundly disorientating. Because when it comes to information technology, the role of teacher and student today is inverted, with adults as the neophytes and children with the monopoly on experience and therefore also on what might be called "digital intuition". But just as knowing how to swing a hammer does not make a carpenter, the fact that packets of knowledge can be accessed instantaneously is not the same as knowing *what* to look for and *how* to knit it together in novel ways that respond to the challenges at work and in our daily lives.

What is called for, it seems to me, is a profound re-evaluation of the education paradigm to place information technology at the center. How else to remain relevant to a generation that is already there? More than that, information technology, properly employed, presents unparalleled opportunity. It must not be seen simply as a better tool to keep doing things the same old way – though that is a necessary transition phase as we grope toward something more profound. Ultimately, the goal must be to teach young people to use the microchip as a *mind amplifier* and not as a sly way to crib their essays off the web. Quantitative literacy in the future needs to be grounded in the skilled and intuitive use of information technology as a natural extension of one's own mental abilities. Only then will we be equipped to extract insight from the torrent of data that the computer itself will disgorge in ever growing volume. That is the new imperative of quantitative literacy, and both the challenge and the opportunity for the educators of tomorrow.

In Summary

I have argued that quantitative literacy matters, and that it will matter increasingly as science and information technology continue to inundate both the economy and society with data of every description.

I have emphasized that quantitative literacy is not about higher math – it is about developing the basic skills and habits of mind that enable us to deal effectively with the quantitative and logical information that we will encounter increasingly in the workplace, in the marketplace and in our role as citizens.

The evidence is that Canadians are falling short, and the result is costly for the individual and for society. If there is an adult literacy problem in Canada, there is an even bigger adult numeracy problem.

But there is also good news. The quantitative literacy of Canadian youngsters appears, on the whole, to be near the top of the world rankings, despite fairly wide variations in

performance across the country. So we need to learn from the best systems right here at home and use their methods to lift the level of the nation.

We also need to integrate quantitative methods and insights throughout the school curriculum so that students acquire a quantitative literacy that is relevant, and therefore sustainable.

Finally, we need to acknowledge that information technology is changing forever the rules of learning. It is a challenge – but far more, it is an opportunity to extract unprecedented insight from the inevitable torrent of data in our future, and thus to achieve levels of quantitative literacy in Canada that were never thought possible.

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President and Chief Executive Officer
The Council of Canadian Academies

Peter Nicholson became the inaugural president of the Council of Canadian Academies in February, 2006. The Council supports expert panels that assess the science that is relevant to issues of public importance. He holds bachelor's and master's degrees in physics from Dalhousie University (1965) and a Ph.D. in Operations Research from Stanford University (1969). He has served in numerous posts in government, business, science, and higher education. Before assuming his current position, he was Deputy Chief of Staff, Policy in the Office of the Prime Minister of Canada. He has served in a number of public service positions over the past 30 years including as a member of the Nova Scotia Legislature, Clifford Clark Visiting Economist in Finance Canada, and as Special Advisor to the Secretary-general of the OECD in Paris. Dr. Nicholson's business career has included senior executive positions with the Scotiabank in Toronto and BCE Inc. in Montreal. Dr. Nicholson began his professional career at the University of Minnesota in 1969 where he taught computer science for four years. He was an original member of the Prime Minister's National Advisory Board on Science and Technology, the founding Chair of the Board of the Fields Institute for Research in Mathematical Sciences and was the founding Chair of the Members of the Canada Foundation for Innovation as well as of the Millenium Scholarship Foundation. Dr. Nicholson is a Member of the Order of Canada.

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