# A Science and Math Literate Society

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**An Educated Nation**

A September, 2004 *Education at a Glance* report by the Organization for Economic Co-operation and Development, disclosed that 43 per cent of Canadians aged 25 to 64 have some form of post-secondary education. This is higher than any other industrialized nation, and almost double the OECD average of 23 per cent. Further, 83 per cent of Canadians have graduated from high school, compared with an OECD average of 65 per cent. In the United States, a recent report by the National Center for Public Policy and Higher Education claims that American high school students are increasingly better prepared for college (*note: "college" and "university" in American dialog often refers to the same thing, whereas in Canada there is generally a distinction between the two*).

While this certainly inspires confidence in the educational system's achievements for both countries, it does not mean that all is rosy in the corridors of academia. Numerous, yet independent, studies over the last decade suggest a critical need to improve the teaching of science, mathematics and technology (generally, meant to infer either "engineering" or "the tools to apply science") in the public schools.

**On Becoming A Science-Literate Society**

In 1990, the American Academy for the Advancement of Science released *Project 2061: Science for All Americans,* which presents a vision of science literacy to spur discussion on the base skills and knowledge that the youth of America should possess. The AAAS recognizes that most Americans are not science-literate. It backs up this claim using results from the 1998 release of the *Third International Mathematics and Science Study* (TIMMS), a study spearhead by UBC's Faculty of Education, where, in comparative ratings in both science and mathematics for several participating countries, U.S. students rank near the bottom. *Science for All Americans* is based on the belief that a science-literate person is one who can use scientific, mathematical and technological knowledge and technique to make sense of how the world works, to think critically and independently, and to lead interesting, responsible and productive lives in an era increasingly shaped by science and technology. It accuses textbooks and traditional methods of instruction as often impeding, not helping, progress towards a science-literate citizenry. It points out that few elementary and junior level teachers have even a rudimentary education in science or mathematics, and may even possess an underlying fear of the very fundamentals of science and mathematics that they are called upon to teach. These deficiencies, the report accuses, have long been tolerated by the institutions that prepare teachers, by the bodies that license them, by the schools or Boards that hire and assign their teaching loads, and by the teaching profession itself through their associations. *Science for All Americans* sets out a plan for change, and is a main resource for a decade-long review of American public education. It may partially account for a recent rise of enrolment in science, mathematics and engineering by U.S.-educated high school graduates at many American universities.

While our neighbours to the south were digesting *Science for All Americans*, Canada's National Advisory Board on Science and Technology presented its 1995 report *Healthy,*

*Wealthy and Wise: A Framework for an Integrated Federal Science and Technology Strategy* to the Prime Minister. Mostly focused on Canadian funding for scientific research to rebuild the nation's declining position of economic competitiveness, the report also notes that a strong scientific awareness of the general public also reduces the cost of health and social programs. It sees an interdependence of "wealth and job creation," "quality of life," and the "advancement of knowledge" as the cornerstone to (becoming) *Healthy, Wealthy and Wise*. It emphasizes that "Canadians must recognize that to be fully functional in the modern world a solid knowledge base in science, technology and mathematics is as essential as the ability to read and write. This is the foundation upon which will be built a strong research culture, innovative development activity and progressive social development" (p. 83). The Royal Society of Canada, in its 1988 report *Science and the Public* defines science literacy as having three distinct characteristics: the general understanding of the scientific process, the understanding of some scientific terms, and the understanding of some of the social impacts of science and technology. *Healthy, Wealthy and Wise* decries the lack of a strong science and technology culture in Canada. In general, it claims that while Canadians tend to be interested in science, they remain intimidated by it. They do not perceive it as an integral part of their lives, or even relevant to it. The report's authors believe that if these trends are not reversed, our society "will polarize into technically literate and illiterate factions, with the risk that a portion of our society may not be able to participate meaningfully in the new economy" (p. 81). *Healthy, Wealthy and Wise*, like its American counterpart *Science for All Americans*, points an accusing finger at teacher training in the public school system as cause for some of the present problem. It claims that science prerequisites for admission to education degree programs are mostly inadequate, as is the training of science for these teachers. "This often results in the poor quality of science education in schools, particularly at the primary level" (p. 86). It recommends that teacher training for the sciences be raised, and that the Council of Ministers of Education, Canada "require that recertification of science teachers become mandatory, and be contingent on regular attendance at workshops in science training and education" (p.86). The direction this recommendation has taken is unknown.

**How We Compare With Others**

So how do Canadian students compete with other developed nations in their competency of science and mathematics? Actually, not badly at all. The *TIMSS* report identified earlier showed that Canadian students in Grade 4, Grade 8 and at the end of their senior year (Grade 12 in most provinces) performed as well as, or better than average, when compared with their counterparts elsewhere. Indeed, at the Grade 8 level, "only one of the 41 countries performed statistically better than B.C. students in science, and only four countries performed better in math", said Moe Sihota, then Education, Skills and Training Minister in his November 20, 1996 news release (*note: the TIMSS report for Grade 8 came out two years ahead of the graduating class report*). In math, B.C. students in Grade 8 ranked below only Singapore, Japan, Hong Kong and Korea. In science, Singapore ranked on top. Both B.C. and the Canadian average slid several rungs as reported in the 1998 *TIMSS* release for graduating classes. Asian countries with top billings for the Grade 8 study chose to not participate in the Grade 12 equivalent study,

but even still, Canada dropped in math performance below such countries as the Netherlands, Sweden, Denmark, Switzerland and Iceland. B.C.'s standing dropped below the Canadian average. A similar, but not as significant result was found for science literacy. Nevertheless, Canada ranked in the upper middle of all other countries studied. In almost all countries, boys performed better than girls in both science and mathematics at the Grade 12 level. The cause for this downward trend between the ages of 13 and 17, and the emergence of an obvious gender imbalance, deserve further attention.

**Why Children and Science Part Company**

In June 2000, the Science Council of British Columbia, in partner with Science World of B.C., released a report called *Where Worlds of Children and Science Meet.* This study offers a summary of literature dealing with psychological influences on children's attitudes concerning science and technology. It points out that children begin to dream about their future career as early as age five, and science career planning crystallizes around age thirteen or fourteen. Unfortunately, however, attitudes towards science decrease each year thereafter for most boys and girls – with girls starting earlier at around age eleven or twelve. As any visitor to any interactive Science Centre will attest, children between ages six to ten have very keen attitudes about science. By age fourteen, however, things have decidedly changed for the majority. Kids from age five to twelve spend almost twice the amount of time with science interaction than their parents. Science, science education, and scientific exploration and discovery are generally viewed as fun and non-threatening. By age thirteen, only 40% demonstrate an interest in science, and by age 17 this drops to 25%. Indeed, in 1996, the percentage of high school students taking Biology 12 was 27%, Chemistry 12 was 23%, Physics 12 was 13% and Algebra 12 was 37% (*note: B.C. high school graduation required a Grade 11 science and a Grade 11 mathematics*). It is unlikely that these percentages have changed much since then.

What evidence is there for this declining interest in science and mathematics? In Grade 11, the science curriculum shifts from general science to specific courses in biology, chemistry and physics. Scientific principles become increasingly difficult to translate into everyday experience. There is more frequent inclusion of mathematical relationships and symbolic representations, and perhaps students begin to view their teacher in a less positive image. For the majority of boys and girls the earlier impressions of science as fun and exploration converts to science as abstract and rigorous. They come to see it as too hard and meaningless. But the declining interest in science begins even before Grade 11. *Where Worlds of Children and Science Meet* sets this earlier decline at the age of onset of puberty, an age where children begin to be more concerned with self-image (how others see them) – with girls reaching this stage at an earlier age than boys. Starting from about Grade 4 kids visualize a scientist as 'a white, lab coated, bald (or fuzzy haired), unkempt, bespectacled, social outcast loner, male nerd' who experiments with dangerous compounds or with people and animals – and this is exactly how scientists are usually portrayed on television, in movies, in comics and in video games. This is not exactly the kind of person the average kid (especially girls) wants to be seen as at the age of puberty, when self-imaging becomes a dominant part of their psyche, and, unfortunately, this

image does not improve through the mid-teenage years. The literature discussion on gender imbalance suggests that girls' thinking is more relational, caring, dependent and emotional, while the more rigidly distinct and analytic nature of science fits better with a boy's thinking process. Girls that choose science tend to pick the biological or life sciences, while boys prefer the physical sciences or engineering. Not surprisingly, the decline of interest in math parallels that of science, except that it begins at an earlier age, and for some almost at the onset of schooling. The reasons here are the same as for science, but they are perhaps reinforced even more strongly at home by parental discomfort with math – a primary school child can usually get parent help more readily on a science project than on a math assignment. Before leaving the issue of gender differences, it should be pointed out that frequently the top performers in any math or science class from Grades 9 through 12 are female, so it's not that they *can't* do math or science, it's simply that most *don't want* to.

**Where Numbers Go Wrong**

As for the Grade 8 students in the *TIMSS* study who faired better than the international average, they performed poorly in comparison in the following areas of mathematics:

- Fractions: operations with common fractions, multiplication and of decimals, and estimating percents;
- Geometry: similarity and congruence which included overlapping figures, and relationships between angles formed by intersecting lines;
- Algebra: fractional equations, inequalities, and working with expressions involving negative numbers;
- Measurements: multi-step problems;
- Proportionality: use of units within an item or those involving more than one step, and items not in standard form;
- Word problems: anything not expressed in simple mathematical equations.

These deficiencies, left uncorrected, become ever more evident and problematic as students move from one grade to the next, since they spawn even further failures in comprehension and application in all areas of math directly tied to these deficiencies. The interdependence of mathematics and science means that failings in the fundamental underpinnings of mathematics transfers to problems in grasping the fundamentals of science. If science can be imagined as the pea, then mathematics is the pod that surrounds it.

**One Step at a Time**

Despite any negative tone in the commentary above, British Columbia's (and all of Canada's) schools generate high numbers of bright and gifted science and math students. If proof is sought, simply look at the exceptionally high admission cut-offs in science and engineering at B.C.'s universities (the GPA requirement to enter UBC science in Fall 2004 approached 3.85 and the situation was not that different at SFU or UVIC). Students falling below the GPA entrance thresholds in B.C. could still seek admission at any of the province's colleges and university colleges (such as Kwantlen), where more personal attention is available due to smaller class sizes and greater instructor focus on teaching

over academic research. That said, the provincial grade average for Chemistry 12 (roughly 68%) and Mathematics 12 (roughly 64%) would necessitate further preparation for large numbers of high school graduates prior to enrolling in the first year level of these subjects. As illustration, Kwantlen's first year chemistry course (CHEM 1110) requires Chemistry 12 with a C+ or better as well as Mathematics 12 with a C or better, and entry to Calculus 1 (MATH 1120) requires at least a B in Mathematics 12. At Kwantlen, these courses might be CHEM 1094 or 1105 and MATH 1093 or 1112 in the above illustration.

The transition from high school to university or college is difficult for most, and, unfortunately, many university and college instructors believe that there is a growing gap between knowledge accrued in high school and what is expected upon entry into university. To rectify this, many colleges and universities are beginning to establish higher entry levels in English, are inserting quantitative requirements for all degrees, and are designing first year experience programs to facilitate easier adaptation to the post-secondary lifestyle. The upcoming Bachelor of Arts at Kwantlen for Fall 2005 will have an English 12 (B grade) and a Mathematics 11 (C grade) entry requirement, along with a minimum of three quantitative courses built into the degree. Learning Centres exist at each Kwantlen campus to provide tutorial assistance, and a First Year Experience Coordinator position was created to assist new students into the university college setting.

**It's Not a Game of Chance**

Are high school grades good predictors of success in university or college? In a nutshell, yes. In a 2002 success correlation study at Kwantlen, English 12 grades were found to be reasonable predictors of potential success in all academic areas except accounting, chemistry, mathematics and physics – where, interestingly, no correlation was observed. These are subjects where the language of mathematics is often more prominent than the language of instruction. Likewise, high grades in Biology 12, Chemistry 12, Mathematics 12 and Physics 12 were good predictors of success in first year biology, chemistry, mathematics and physics, respectively. But one should be careful in using these measures exclusively in establishing success patterns. Good high school grades do not guarantee success. A lot depends on study habits, attitudes regarding school, interfering parameters like part-time employment, commitments at home and financial support. Most students discover that they must work much harder and keep a study pace much more in tune with class delivery at university or college just to maintain an equivalent level of grade compared to what they had obtained in high school. It is not uncommon to see grades drop substantially in the first year, and many students experience the prospect of failure for the first time, whereas they had obtained good to very good grades in high school. Generally, students with an A grade from high school science and mathematics will possess the fortitude and knowledge to do well in the same subject at university or college. Anything lower than an A grade, however, becomes more unpredictable as it pertains to success potential. In essence, the lower the incoming grade, the harder the effort of study, the more out-of-class assistance the student seeks, and the earlier this help is sought, the more likely he or she will pass. Otherwise the outcome will unlikely be

what was anticipated. Attending school is no different than working; the harder and more consistent the effort, the greater the reward. Yet like work, there can be no assurance of compatibility, and failure may result even with hard effort.

**Is It Worth the Effort?**

So, after all the effort to obtain a degree in science, mathematics or engineering, will there be jobs out there in the real world? Sadly, there is divergent opinion on this. The trick is generating sufficient graduates simultaneous with market need, but as is often the case, employment needs precede the ability of colleges and universities to produce these graduates. Word gets out of a hot market, colleges and universities rush to fill the gap, and sometimes the result is a glut of qualified graduates that flood the market just as the need levels off. A good example of this was the bulge of information technology graduates just in time for the turn of the century information technology meltdown (although things have now stabilized in this field and jobs are opening up again). Science employment forecasts often focus only on the need for people with Masters Degrees or PhDs for high intensity research or university teaching positions, and overlook the need for people with a Bachelors Degree. In the 1980s the U.S. National Science Foundation, and similar manpower studies in Canada, warned that the nation would soon lack enough scientists and engineers to fill their needs – forecasts that turned out to be mostly inaccurate. A similar warning has recently re-emerged, this time resulting from an observed decline in international students at American universities that, until lately, have filled any manpower gap that otherwise might have existed in science and engineering. Indeed, both Canada and the U.S. have increasingly relied on immigration to fill the employment needs in science. The July 9, 2004 edition of The Chronicle of Higher Education, however, features the article *Is There A Science Crisis? Maybe Not* which suggests that the missing international students have, in fact, been replaced by higher numbers of domestic students pursuing graduate study in science. So, is there a manpower shortage crisis looming on the horizon? The debate continues, but debate or not, there are jobs out there to be taken.

We do know that the Canadian workforce is aging, and that up to 40% of those currently working will be retiring over the next decade. This includes all areas that require the minimum of a Bachelor of Science as well as all public school teaching careers which at some point invariably involve teaching either or both science and mathematics. Teaching positions in science and mathematics are also becoming harder to fill at colleges and universities. We also know, as discussed earlier, that there is a growing need for a science-literate society to maintain our competitive edge economically. Perhaps this should remind us to re-examine and expand our perception of the purpose of a Bachelor of Science Degree. Perhaps it's not just about securing a job in a scientific or engineering field, about using it as a step towards a health related profession, about obtaining an advanced degree in science or math to enter into research, or about becoming a teacher of science or mathematics. Any degree, whether it is in science or the arts or whatever, provides added maturity and lifelong knowledge, skills and attributes to make informed decisions, to become better beneficial contributors to society at large, to generate prosperity for oneself and the nation, as well as to fulfill our manpower aspirations. A

science degree does not exist to just find a career in science or engineering or a closely related field, a notion that has perhaps permeated for decades, but to also become better and healthier citizens overall.

**It's Entirely Up to You**

The extent of your involvement in becoming science-literate, and the extent of science awareness you contribute back to society is entirely up to you. Science surrounds you in your daily activities. You can opt to ignore this fact, or you can benefit by becoming informed. Kwantlen offers many opportunities to enrich your knowledge of science, whether you commence a science or science-related program here or take one of the growing number of science-interest courses offered for non-science students. Avoidance of science in high school, however, is a poor start to becoming science-literate, and will require added courses, time and cost at the post-secondary level if you later decide to take, or discover you require, science courses. Nevertheless, Kwantlen does offer the science and math preparatory courses needed to reach the level you require.

Since science and mathematics are interlinked, the same message as above also applies to mathematics. Being mathematically-illiterate generates as many missed opportunities in life as being illiterate in one's language of conversation, in writing or in reading.

The opportunity is waiting for you. All you need to do is enroll, study hard, keep pace with the class work, seek additional assistance as needed, and reap the benefits of becoming more aware of the world around you, more capable of making informed decisions on contentious issues, and more capable of making positive contributions towards a healthier lifestyle and planet.

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