PISA 2006 Science in Canada：
Context, Results and Possible Explanations

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Abstract

Canada is a vast country with a small population density, 13 different education systems and two official languages. It has no national education system. Despite these challenges, 15-year-old students in Canada ranked 3rd in the world on the PISA 2006 science assessment. Two of the many factors which may explain this high ranking are the relatively good results obtained by the immigrant student population and the relatively small social inequity among Canadian students. In addition, a comparison of the overlap between the PISA 2006 science assessment framework and the Canadian document Common Framework of Science Learning Outcomes K to 12 *which serves as a guide to science curriculum developers in Canada shows that approximately 86 percent of the Canadian document can reasonably be linked to the PISA 2006 science assessment framework. This suggests that Canadian students should have had the opportunity to learn most of what was assessed by the OECD, which may also explain their high ranking.*

Scientific literacy in Canadian education: the context

Canada is the world's second largest country geographically but with only 33 million people ranks 33rd in population. English and French are Canada's two official languages both of which are used in each of its 10 provinces and 3 territories covering 5 time zones.

There is no Canadian national education system. Each province and territory has complete authority over its education system. The autonomy which provinces and territories have in education can sometimes present challenges at the national level. For example, obtaining comparative data such as dropout rates and spending per student can be problematic because different standards are used to calculate these indices.

Provincial and territorial autonomy often results in considerable differences in curriculum and assessment programs across the country. To avoid unnecessary and costly duplication and to profit from each other's strengths, it is not rare to see provinces collaborate in the areas of mathematics, English language arts and social studies (Council of Atlantic Ministers of Education and Training, 2004; Laurie, 2006; Ogura et al., 2006; WNCP, 2000).

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In light of the need for a pan-Canadian voice on many national and international issues, the Council of Ministers of Education, Canada (CMEC) was established in 1967. The CMEC serves as a forum to discuss policy issues and to facilitate joint activities of mutual interest, as the mechanism through which education ministers consult and act on matters of mutual interest, and as a means by which to consult and cooperate with national education organizations and the federal government. The CMEC also represents the education interests of the provinces and territories internationally on projects such as the OECD's Programme for International Student Assessment, PISA (Council of Ministers of Education, Canada, 2007).

An important CMEC initiative in the area of science was the introduction of a pan-Canadian science assessment in 1996 which complemented assessments in reading, writing, mathematics and problem solving as part of the School Achievement Indicators Program or SAIP (Council of Ministers of Education, Canada, 1996a, 1996b). SAIP assessed 13 and 16-year-old students on a yearly basis with each year featuring one of the domains.

An important feature of the SAIP Science assessment was its focus on aspects other than scientific knowledge: practical tasks, the nature of science and the relationship of science to technology and societal Issues had as much importance as each of the traditional science knowledge domains.

The impact across Canada of assessing areas other than scientific knowledge broadened the scope and the goal of science education throughout the country. Teachers and curriculum developers realized the importance of areas that were generally absent from classroom teaching and learning. More and more educators now understand that it is important for Canada to produce scientifically literate citizens. This new paradigm is generally accepted by educators who realize that teaching for scientific literacy does not preclude preparing students for future studies in science.

Shortly after the introduction of SAIP'S science component the CMEC introduced a science curriculum framework document, the *Common Framework of Science Learning Outcomes K to 12* (Council of Ministers of Education, Canada, 1997). Based on some of the major initiatives in science education at that time (American Association for the Advancement of Science, 1993; Australia Curriculum Corporation, 1994; Bingle & Gaskell, 1994; Driver, Guesne & Thibergien, 1985; Eisenhart, Finkel & Marion, 1996; Hart, 1987; Jenkins, 1995; National Research Council, 1996, National Science Teachers Association, 1992, 1993; and Rutherford & Ahiglen, 1990), the document served as a basis for the development of provincial science curricula across Canada. Thus, each province and territory retained its autonomy whilst ensuring a certain level of consistency in science curricula across the country.

Following the publication of the *Common Framework of Science Learning Outcomes K-12* the next major change in Canadian science education was in the area of assessment. In an effort to modernize its assessment program, the CMEC replaced the School Achievement Indicators Program (SAIP) with the Pan-Canadian Assessment Program (PCAP) in the spring of 2007. Modeled after PISA, PCAP assesses reading, mathematics and science and designates one of these domains as the major domain with the other two being minor domains. PCAP assesses 13-year-old students exactly two years prior to the next PISA assessment. The same major domain is used in PCAP and PISA for the same cohort of students. In the spring of 2007, 13-year-old students were assessed in reading (major domain), mathematics and science (minor domains) thus mimicking the PISA 2009 assessment. PCAP is expected to show strong predictive validity with future PISA results for the same cohort. The results of the first PCAP assessment will be published in March 2008.

Status of scientific literacy in Canada — PISA 2006 results

Canada has participated in PISA since its introduction in 2000. Due to the small number of 15-year old students in the three territories, only the 10 provinces participate in PISA. Consistent with provincial autonomy, each province over-samples the required number of students by the OECD so that results can be published at the provincial level. In addition, five provinces over-sample even more in order to report on each of their English and French populations. These levels of over-sampling explain why Canada has more participating students than most countries. Approximately 22500 students from 1000 schools across Canada were selected to participate in PISA 2006. Students were administered assessment booklets in their language of instruction, either English or French.

In PISA 2006, Canada ranked 3rd in the world behind only Finland and Hong Kong (China). With a score of 534 points, Canada ranked ahead of Japan (531 points), the United Kingdom (515 points) and the United States (489 points). Although direct comparisons cannot be made between the PISA 2003 and PISA 2006 science scores, Canada's result still shows a marked improvement relative to other countries since Canada ranked 11th in PISA 2003 Science (OECD, 2007a).

As can be expected, scores varied from one province to another within Canada (see table 1). Scores ranged from a high of 550 points in Alberta to 506 points in New Brunswick which ranked last in Canada but still above the OECD average of 500 points.

Predictably, most Canadian media reports on the PISA 2006 results were quite positive. There was however, some discontent in the lower ranking provinces, especially in Eastern Canada where 3 of the 4 lowest ranking provinces are situated. For example, the New Brunswick Telegraph Journal condemned the state of education in that province.

Table 1. PISA 2006 science scores by Canadian province

PROVINCE	SCIENCE SCORE
Alberta	550*
British Columbia	538
Ontario	537
CANADA	**534**
Québec	531
Newfoundland and Labrador	526**
Manitoba	523**
Nova Scotia	520**
Saskatchewan	516**
Prince Edward Island	509**
New Brunswick	506**
OECD	**500****

* significantly above the Canadian mean
** significantly below the Canadian mean

> "*New Brunswick's students are failing the most basic tests expected of adults in a modern society. They can't read well enough; they can't write well enough; they can't perform math well enough; and they know little of the scientific principles on which our technological culture is constructed.*" (December 7, 2007 page A6)

That PISA didn't assess students' writing skills didn't concern this newspaper. Clearly, the media, along with many parents and other stakeholders, pressure the education system to produce better performing students. This incessant pressure on the system and on the students may help explain why Canadian students' performance in science is relatively good.

Understanding Canada's results

Student performance is influenced by a vast number of variables. In Canada a questionnaire dealing with students' school activities, work activities, and their relationships with others was administered as a national option. These data complement the PISA data and serve as the basis of the Canadian PISA report (Bussière, Knighton, and Pennock, 2007).

Among the many variables on which PISA collects data, immigrant student performance and socioeconomic status, are particularly informative when trying to understand Canada's results on PISA 2006. Another way of explaining Canada's results is to focus on students' opportunities to learn what was assessed by PISA. This section will discuss each of these three factors.

Immigrant student performance

Canada prides itself on being a country which welcomes immigrants from all over the world. Canadians wish to live in a society which embraces, promotes and respects different cultures.

One person in five currently living in Canada was not born in Canada (Statistics Canada, 2007). Given the important multicultural nature of Canadian society it follows that data on immigrant student performance are most relevant to Canadian educators and policy makers.

PISA identifies two groups of immigrants: second-generation immigrants are those born in Canada from immigrant parents while first-generation immigrants are those born outside Canada. All students born in Canada from parents also born in Canada are defined as non-immigrant students.

A total of 9.9 percent of students in Canada who participated in PISA 2006 were first-generation immigrants while 11.2 percent were second-generation immigrants. These percentages are more than double the average for the OECD countries which report percentages of 4.6 percent and 4.8 percent respectively (see table 2).

PISA science results show that the longer students were in Canada the better they performed in science on PISA 2006. Non-immigrant Canadian students obtained a mean score of 541 points while second-generation students obtained a mean score of 528 points (see table 2). First-generation immigrant students obtained a mean score of 519 points. The positive relationship between time educated in Canada and performance in science is consistent with results from the 2003 International Adult Literacy and Skills Survey for literacy, numeracy and problem solving (Barr-Telford, Nault, & Pignal, 2005; Murray, Owen, & McGaw, 2005).

A similar trend to Canada's PISA science results for immigrant and non-immigrant students is seen in the OECD countries. However, when PISA science results of non-immigrant, second- and first-generation immigrant students in Canada are compared to those of the OECD countries one notices that in all cases the performance of students in Canada is significantly better than that in the OECD countries. Importantly, the 21 point difference between non-immigrant students and first-generation immigrants in Canada is much smaller than the 56 point difference seen in the OECD countries. In fact, the performance gap among immigrants in Canada is the smallest of OECD countries (Bussière, Knighton, & Pennock, 2007). This provides evidence that Canadian schools have a strong positive impact on student performance.

The relatively small difference in performance between non-immigrant and immigrant stu-

Table 2. Differences in percentage of Canadian and OECD students and student performance in science by immigrant status. (mean values and standard errors)

	Non-immigrant		Second-generation immigrants		First-generation immigrants	
	Percentage of students	Science Score	Percentage of students	Science Score	Percentage of students	Science Score
Canada	78.9 (1.2)	541 (1.8)	11.2 (0.7)	528 (4.8)	9.9 (0.7)	519 (5.2)
OECD	90.7 (0.1)	506 (0.5)	4.6 (0.1)	468 (3.7)	4.8 (0.1)	450 (3.4)

dents suggests that Canadian schools are addressing immigrants' needs as they adapt to life in Canada. In areas where the influx of immigrants is strong, there exist intensive literacy and numeracy programs to help immigrants who are often not only behind their peers academically but also unable to converse in either English or French. Such intensive programs have been introduced in Toronto, a magnet for immigrants entering Canada, and are reportedly experiencing excellent results (Mahoney, 2007). In addition, Bussi■re, Knighton, and Pennock (2007) report that high performing countries such as Canada and the Republic of Korea are characterized by a high number of high achievers and few low achievers, equitable education systems where the quality of teaching is almost homogeneous regardless of the school. Educational environments such as these facilitate the integration of all incoming students regardless of their origins.

Canada's social equity

The relationship between socioeconomic background and student performance can help assess the benefits of schooling to students of varying socioeconomic backgrounds. In PISA 2006, socioeconomic status (SES) was measured by an index that includes information describing family structure, parental education and occupation, parental labor market participation and whether a students' family has specific educational and cultural possessions at home (Bussi■re, Knighton, & Pennock, 2007). Similar to Canada's results in the first two PISA cycles, student performance is once again related to socioeconomic status (SES) even though PISA data show that Canada is the country where SES has the least influence on school achievement (OECD, 2007b).

A direct way of seeing the effect of SES on student performance is to calculate the mean student performance score for each of the four quarters when students are ranked based on their socioeconomic status. As shown in table 3, Canadian students in the top socioeconomic quarter had a mean score of 569 while those in the bottom socioeconomic quarter had a mean score of 501. The difference between the mean scores in the top and bottom quarter is much smaller in Canada (68 points) than for the OECD countries (119 points). This smaller difference points to a higher degree of social equity in Canada than in the OECD average.

Predictably, although the difference between the mean student performance scores in the top and bottom socioeconomic quarters is rather small there exists variation across Canadian provinces. This is demonstrated in figure 1 where differences ranging from 55 points in Prince

Table 3. Student performance in PISA science by socioeconomic quarter.

	Bottom quarter	Second quarter	Third quarter	Top quarter	*Difference (top and bottom quarter)*
Canada	501	527	548	569	68
OECD average	430	481	512	549	119

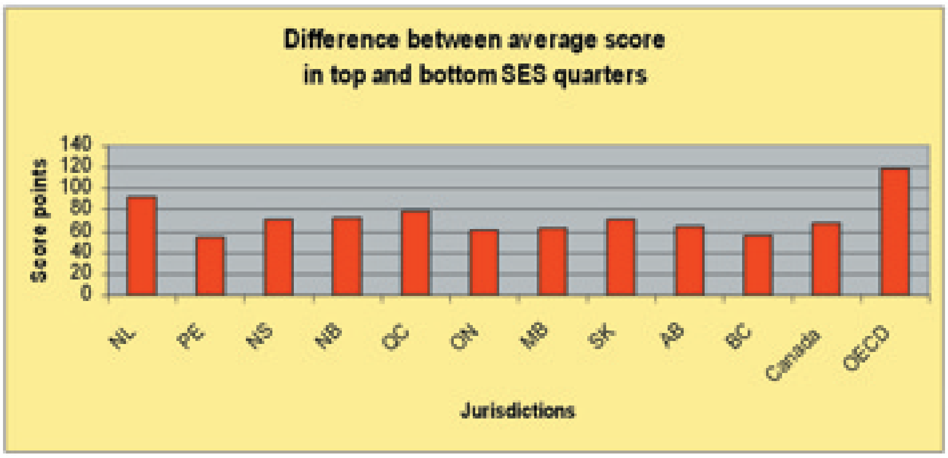

Figure 1. Difference in the mean score between the top and bottom socioeconomic quarters for each Canadian province, Canada and the OECD countries

Edward Island to 93 points in Newfoundland and Labrador are observed. The OECD average of 119 points is 26 points more than Newfoundland and Labrador which has the highest difference among Canadian provinces.

Another way of assessing the effect of SES on student performance is to plot student performance against their socioeconomic status. Best-fitting lines called socioeconomic gradients show the relationship between student performance and SES. Figure 2 presents the SES gradients for the OECD countries, Japan, Finland, the United Kingdom, the United States and Canada. The gradient is obtained using SES scores from the middle 90% of students (between the 5^{th} and 95^{th} percentiles). The range of SES in a given country or province indicates how widely the student population is dispersed in terms of SES background. From this, one can conclude that the range of SES for Japanese students is much smaller than that of the average student in the OECD.

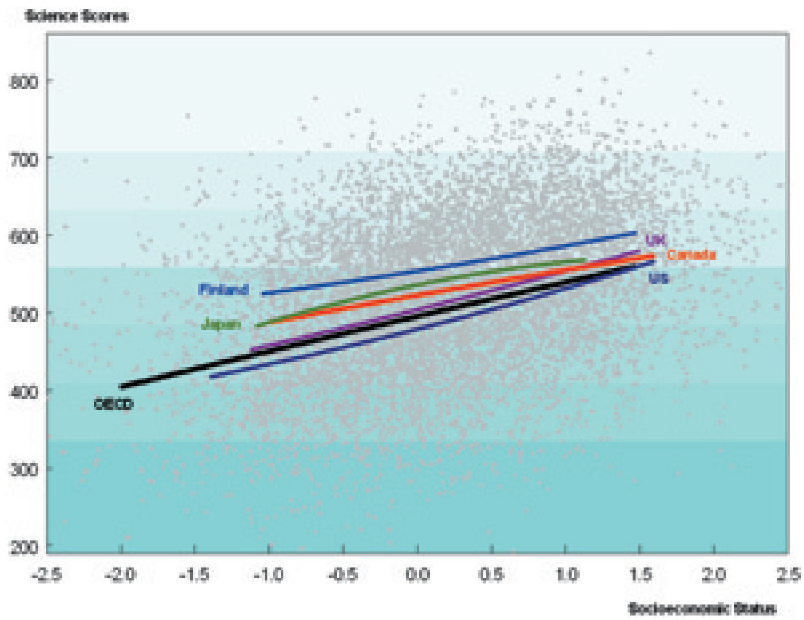

Figure 2. SES gradients for OECD, Japan, Finland, United Kingdom, United States and Canada[1]

Each of the 10000 points on the graph represents a randomly selected student from the OECD population. The vertical axis shows PISA science scores (mean=500, standard deviation=100) while the horizontal scale shows the PISA values for the socioeconomic status which have been standardized to a mean of 0 and standard deviation of 1 for all OECD countries.

Socioeconomic gradients such as those in figure 2 are characterized by their slope, their level, and their strength. The slope of the SES gradient indicates the extent of inequality which can be attributed to SES. Steep slopes such as those seen for the UK and the US indicate a strong impact of SES on student performance in science. There exists more inequality among UK and US students based on SES than among students in Finland and Canada where the SES gradients have gentler slopes.

The level or average height of the SES gradient is defined as the expected score for a child with average SES (Willms, 2003). The level or height of a country's SES gradient is an indication of its overall performance. From figure 2 we can see that the level of the SES gradient for Finnish students is higher than that of their peers in other countries. Figure 2 also shows that for all SES values Finnish students have a higher performance levels than their peers. In all countries students of high socioeconomic status perform better than students of low socioeconomic status.

Although Canada has an SES gradient which shows a gentle slope and rather high level there is considerable variability for these two characteristics when each province is looked at individually as in figure 3.

Contrasting the SES gradients of Alberta (AB) and New Brunswick (NB) one sees that the

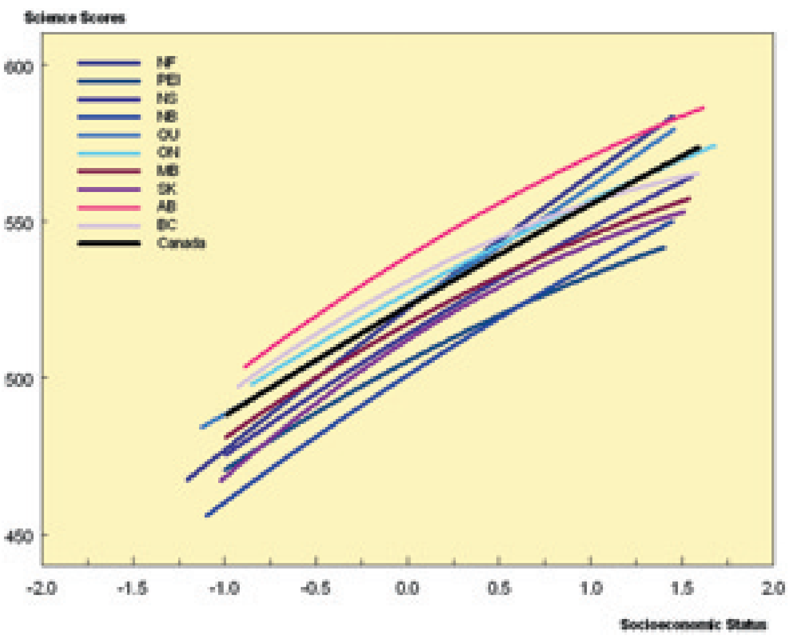

Figure 3. SES gradients for Canada and its 10 provinces

range of SES for students of both these provinces is about the same but that of Alberta students is situated at higher SES values than that of New Brunswick students. This is consistent with the relative wealth of both provinces. The slopes of the two SES gradients show that there is more inequality in New Brunswick than in Alberta. It is noteworthy that for higher SES levels, the Alberta SES gradient starts to level off which indicates that there is less inequality between Alberta students of relatively high SES than New Brunswick students. This leveling off of the slope is also observed in British Columbia (BC), Ontario (ON), Manitoba (MB), Saskatchewan (SK) and Prince Edward Island (PE). Interestingly, the SES gradient for Québec (QC) shows a strong and opposite trend. In this province the inequality between students increases at higher SES values.

Although Canada's SES gradient has a rather gentle slope and high level, most of the provincial SES gradients are below that of Canada's. This is evidence that the population varies from province to province. In fact, the top 4 provinces in the PISA ranking account for approximately 86 percent of Canada's total population (Statistics Canada, 2007).

The third characteristic of SES gradients is its strength. A gradient's strength refers to how much individual student performance scores vary above and below the gradient line. A strong relationship indicates that a considerable amount of the variation in the student performance scores is associated with SES whereas a weak relationship indicates that relatively little of the variation in the student performance scores is associated with SES. The strength of the gradient is commonly measured by a statistic called R-squared. This statistic represents the portion of the variance in the student performance scores explained by SES. For the five countries in figure 2, Japan has the smallest gradient strength with 7.4 percent of the variation in student performance being explained by SES. This contrasts with 17.9 percent of the variation in student performance being explained by SES in the United States. Canada, Finland and the UK have values of 8.2 percent, 8.3 percent and 13.9 percent respectively.

Canada's Common Framework of Science Learning Outcomes K to 12

The OECD expects students to use content-specific knowledge along with their ability to reflect on that knowledge and their experience and to apply these to real world issues (OECD, 2007a). It is therefore important to consider students' opportunity to learn since the presence or absence of such opportunities can influence their performance. A recent study found significant overlap between the *Common Framework of Science Learning Outcomes K to 12* and provincial science curricula (Council of Ministers of Education, Canada, 2005) thus providing evidence of its widespread acceptance across the country.

Perhaps the most important commonality between the *Common Framework of Science Learning Outcomes K to 12* and provincial curricula is that scientific literacy is the stated goal of science education in each Canadian province and territory. There is widespread agreement across Canada that students should understand the nature of science and technology, the relationships between science and technology and the social and environmental contexts of science and technology.

Other commonalities pertaining to skills, knowledge and attitudes were found. Skill development across grade levels for scientific inquiry, problem solving, and decision making is a strong commonality in provincial science curricula. In Canada, students are expected to apply these skill sets to real-life situations to solve problems and make informed decisions. Such applications include using and validating evidence, and making judgments about evidence when dealing with social, environmental, health, and technological impacts and consequences.

Common to the skill sets for scientific inquiry, problem solving, and decision making is being able to formulate a testable question or identify a problem, planning a valid investigation, carrying out the investigation, analyzing the data, and drawing valid conclusions. The importance of developing communication skills is also emphasized throughout Canadian science curricula. Other commonalities such as laboratory skills in science (for example, the proper use of equipment such as microscopes and balances, and the safe use of tools, equipment, and materials) are also found in science curricula across Canada even though they are not as prevalent.

Developing positive attitudes about continuing interest in science, respect for the ideas of people with various backgrounds and views, support for scientific processes, collaboration with others, stewardship for the natural environment and safety in science represent major components in many science curriculum documents across Canada. The emphasis on student attitudes in science provincial curricula and in the *Common Framework of Science Learning Outcomes K to 12* is pertinent in light of the importance given to attitudes in science in the PISA 2006 science assessment.

Because of the many commonalities between the *Common Framework of Science Learning Outcomes K to 12* and science curricula across Canada it is pertinent to compare the former document with the PISA 2006 science assessment framework. Strong alignment between these two documents would point to another possible explanation of the Canadian results on PISA 2006.

Comparing the Common Framework of Science Learning Outcomes K to 12 to the PISA science assessment framework

One of the effects of the *Common Framework of Science Learning Outcomes K to 12* has been to standardize science curricula across all Canadian provinces and territories relative to what was present a decade ago. However, several conditions must exist before the suggested outcomes in the *Common Framework of Science Learning Outcomes K to 12* are learned by students. First, provincial curriculum developers must use the *Framework* as a basis for what officially becomes the province's intended curriculum. Next, teachers must teach the intended curriculum which, in effect, becomes the taught curriculum. What students actually learn from the taught curriculum becomes the learned curriculum. Assessments only test a limited part of what is intended by curriculum developers, taught by teachers and learned by students (Cuban, 1995). It is therefore appropriate to recognize the existence of the tested curriculum.

Large-scale assessments such as PISA 2006 do not intend to assess a particular curriculum but rather important knowledge and skills important in life. Such knowledge and skills, along with a number of attitudes, are described in the PISA 2006 science assessment framework (OECD, 2006). Despite the absence of a national science curriculum in Canada we nevertheless have a situation where a <u>suggested</u> curriculum has been shown to influence the <u>intended</u> curricula parts of which become the <u>taught</u> curriculum. What is learned by students, the <u>learned</u> curriculum, is generally what determines student performance on assessments that reflect the <u>tested</u> curriculum. Canadian students ranked 3rd in the world on PISA 2006. Even if student learning in science encompasses much more than what is taught in school, the excellent Canadian results suggest a strong alignment between the *Common Framework of Science Learning Outcomes K to 12* and the PISA 2006 science assessment framework.

The PISA 2006 science assessment framework describes four aspects that are the focus of the assessment: scientific competencies, knowledge of and about science, and attitudes. Three scientific competencies are described: identifying scientific issues, explaining phenomena scientifically, and using scientific evidence. Knowledge of science encompasses knowledge from the fields of biology (living systems), chemistry and physics (physical systems), Earth and space systems and technology systems. Knowledge about science is comprised of two categories: scientific enquiry and scientific explanations. Finally, PISA 2006 describes three areas for the assessment of attitudes: interest in science, support for scientific enquiry, and responsibility towards resources and environments.

The *Common Framework of Science Learning Outcomes K to 12* describes four foundation statements which delineate the critical aspects of scientific literacy. Foundation 1 (science, technology, society and the environment, STSE) is composed of the nature of science, the relationships between science and technology, and the social and environmental contexts of science and technology. Foundation 2 (skills) is composed of scientific enquiry skills such as initiating and planning, performing and recording, analyzing and interpreting, and communication and teamwork. Foundation 3 (knowledge) includes scientific knowledge in the fields of life science, physical science, and Earth and space science. Finally, Foundation 4 (attitudes) refers to generalized aspects of student behavior. These attitudes include the appreciation of science, interest in science, scientific enquiry, collaboration, stewardship and safety. What follows is a mapping of the *Common Framework of Science Learning Outcomes K to 12* targeted for grade 10 students. These outcomes have been selected for comparison to the PISA framework because the vast majority of 15-year-old students are at that grade level when they write the PISA assessment. A total of 91 outcomes are presented at the grade 10 level. Foundation 1 (STSE) has 24 specific learning outcomes, foundation 2 (skills) has 29 specific learning outcomes and foundation 3 (knowledge) has 23 specific learning outcomes. Because of the nature of the attitudes foundation which states that "students will be encouraged to develop attitudes that..." instead of expecting students to demonstrate specific attitudes, only general learning outcomes are presented. There are 15 attitude general learning outcomes.

PISA competencies and the Common Framework of Science Learning Outcomes K to 12

A total of 8 specific learning outcomes from the grade 10 level of the *Common Framework of Science Learning Outcomes K to 12* can be reasonably matched to the PISA competencies as shown in table 3[2]. The first two of these outcomes are from foundation 1 (STSE) while the other 6 are from foundation 2 (skills).

Table 3. Grade 10 specific learning outcomes mapping to the PISA competencies

PISA competencies	*Common Framework of Science Learning Outcomes* (*grade 10*)
Identifying Scientific Issues · Recognising issues that are possible to investigate scientifically · Identifying keywords to search for scientific information · Recognising the key features of a scientific investigation **Explaining phenomena scientifically** · Applying knowledge of science in a given situation · Describing or interpreting phenomena scientifically and predicting changes · Identifying appropriate descriptions, explanations, and predictions **Using Scientific Evidence** · Interpreting scientific evidence and making and communicating conclusions · Identifying the assumptions, evidence and reasoning behind conclusions · Reflecting on the societal implications of science and technological developments	· illustrate how science attempts to explain natural phenomena · provide examples of how science and technology are an integral part of their lives and their community · identify questions to investigate that arise from practical problems and issues · compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots · interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables · provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion · communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others · select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

PISA knowledge of science categories and the *Common Framework of Science Learning Outcomes K to 12*

A total of 34 specific learning outcomes from the grade 10 level of the *Common Framework of Science Learning Outcomes K to 12* can be reasonably matched to the PISA knowledge of science categories as shown in table 4. Ten specific learning outcomes map to the physical systems category all of which are in the knowledge foundation. Nine specific learning outcomes map to the living systems category. One of these outcomes is from the skills foundation while the others are from the knowledge foundation. Eleven specific learning outcomes map to the technology systems category, all of which are found in the STSE foundation. That only 4 specific learning outcomes — all from the knowledge foundation — relate to the Earth and space systems category reflects the reduced importance of this knowledge category in the *Common Framework of Science Learning Outcomes K to 12*. In turn, this reflects the reduced science class time dedicated to Earth and space science relative to the other domains because some provinces include Earth science in their geography courses which are usually grouped with the humanities or social studies classes. Similarly, space science is sometimes studied in the context of an advanced physics class.

Table 4. Grade 10 specific learning outcomes mapping to the PISA knowledge of science categories

PISA Knowledge of Science	*Common Framework of Science Learning Outcomes* (*grade 10*)
Physical systems • Structure of matter (e.g. particle model, bonds) • Properties of matter (e.g. changes of state, thermal and electrical conductivity) • Chemical changes of matter (e.g. reactions, energy transfer, acids/bases) • Motions and forces (e.g. velocity, friction) • Energy and its transformation (e.g. conservation, dissipation, chemical reactions) • Interactions of energy and matter (e.g. light and radio waves, sound and seismic waves)	• name and write formulas for some common ionic and molecular compounds, using the periodic table and a list of ions • classify substances as acids, bases, or salts, based on their characteristics, name, and formula • illustrate, using chemical formulas, a wide variety of natural and synthetic compounds that contain carbon • represent chemical reactions and the conservation of mass using molecular models, and balanced symbolic equations • describe how neutralization involves tempering the effects of an acid with a base or vice versa • illustrate how factors such as heat, concentration, light, and surface area can affect chemical reactions • describe quantitatively the relationship among displacement, time, and velocity • analyse graphically and mathematically the relationship among displacement, velocity, and time • distinguish between instantaneous and average velocity • describe quantitatively the relationship among velocity, time, and acceleration
Living systems • Cells (e.g. structures and function, DNA, plant and animal) • Humans (e.g. health, nutrition, subsystems [i.e. digestion, respiration, circulation, excretion, and their relationship], disease, reproduction) • Populations (e.g. species, evolution, biodiversity, genetic variation) • Ecosystems (e.g. food chains, matter and energy flow) • Biosphere (e.g. ecosystem services, sustainability)	• describe and apply classification systems and nomenclature used in the sciences • illustrate the cycling of matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen • describe the mechanisms of bioaccumulation, and explain its potential impact on the viability and diversity of consumers at all trophic levels • explain why ecosystems with similar characteristics can exist in different geographical locations • explain why different ecosystems respond differently to short-term stresses and long-term changes • explain various ways in which natural populations are kept in equilibrium and relate this equilibrium to the resource limits of an ecosystem • explain how the biodiversity of an ecosystem contributes to its sustainability • analyse the impact of external factors on an ecosystem

	• describe how soil composition and fertility can be altered and how these changes could affect an ecosystem
Earth and space systems • Structures of the Earth systems (e.g. lithosphere, atmosphere, hydrosphere) • Energy in the Earth systems (e.g. sources, global climate) • Change in Earth systems (e.g. plate tectonics, geochemical cycles, constructive and destructive forces) • Earth's history (e.g. fossils, origin and evolution) • Earth in space (e.g. gravity, solar systems)	• describe and explain heat transfer in the hydrosphere and atmosphere and its effects on air and water currents • describe how the hydrosphere and atmosphere act as heat sinks within the water cycle • describe and explain the effects of heat transfer within the hydrosphere and atmosphere on the development, severity, and movement of weather systems • analyse meteorological data for a given time span and predict future weather conditions, using appropriate methodologies and technologies
Technology systems • Role of science-based technology (e.g. solve problems, help humans meet needs and wants, design and conduct investigations) • Relationships between science and technology (e.g. technologies contribute to scientific advancement) • Concepts (e.g. optimisation, trade-offs, cost, risk, benefit) • Important principles (e.g. criteria, constraints, innovation, invention, problem solving)	• evaluate the role of continued testing in the development and improvement of technologies • distinguish between scientific questions and technological problems • describe the historical development of a technology • identify examples where scientific understanding was enhanced or revised as a result of the invention of a technology • identify examples where technologies were developed based on scientific understanding • describe the functioning of domestic and industrial technologies, using scientific principles • analyse natural and technological systems to interpret and explain their structure and dynamics • compare examples of how society supports and influences science and technology • identify possible areas of further study related to science and technology • compare the risks and benefits to society and the environment of applying scientific knowledge or introducing a technology • evaluate the design of a technology and the way it functions on the basis of identified criteria such as safety, cost, availability, and impact on everyday life and the environment

PISA knowledge about science categories and the *Common Framework of Science Learning Outcomes K to 12*

A total of 20 specific learning outcomes from the grade 10 level of the *Common Framework of Science Learning Outcomes K to 12* can be reasonably matched to the PISA knowledge about science categories as shown in table 5. Five specific learning outcomes belong to the STSE foundation while 15 are found in the skills foundation.

Table 5. Grade 10 specific learning outcomes mapping to the PISA knowledge about science categories

PISA Knowledge about Science	*Common Framework of Science Learning Outcomes* (*grade 10*)
Scientific Enquiry • Origin (e.g. curiosity, scientific questions) • Purpose (e.g. to produce evidence that helps answer scientific questions, current ideas/models/theories, guide enquiries) • Experiments (e.g. different questions suggest different scientific investigations, design) • Data type (e.g. quantitative [measurements], qualitative [observations]) • Measurement (e.g. inherent uncertainty, replicability, variation, accuracy/precision in equipment and procedures)	• describe the usefulness of scientific nomenclature systems • design an experiment identifying and controlling major variables • state a prediction and a hypothesis based on available evidence and background information • design an experiment and identify specific variables • evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making • develop appropriate sampling procedures • use instruments effectively and accurately for collecting data • compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data • select and use apparatus and materials safely • compare theoretical and empirical values and account for discrepancies • evaluate the relevance, reliability, and adequacy of data and data collection methods • identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty • propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan • identify new questions or problems that arise from what was learned • identify multiple perspectives that influence a science-related decision or issue • develop, present, and defend a position or course of action, based on findings
Scientific Explanations • Types (e.g. hypothesis, theory, model, law) • Formation (e.g. data representation, role of extant knowledge and new evidence, creativity and imagination, logic) • Rules (e.g. must be logically consistent based on evidence, historical and current knowledge) • Outcomes (e.g. produce new knowledge, new methods, new technologies lead to new questions and investigations)	• explain how a paradigm shift can change scientific world views • describe the importance of peer review in the development of scientific knowledge • explain how scientific knowledge evolves as new evidence comes to light • propose a course of action on social issues related to science and technology, taking into account human and environmental needs

PISA attitude areas and the *Common Framework of Science Learning Outcomes K to 12*

A total of 15 learning outcomes from the grade 10 level of the *Common Framework of Science Learning Outcomes K-12* can be reasonably matched to the PISA attitude areas as shown in table 6. Two specific learning outcomes belong to the STSE foundation while 13 general learning outcomes are found in the attitude foundation.

Table 6. Grade 10 learning outcomes mapping to the PISA attitude areas

PISA Attitudes	*Common Framework of Science Learning Outcomes (grade 10)*
Interest in Science • Indicate curiosity in science and science-related issues and endeavors • Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods • Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science-related careers	• identify and describe science-and technology-based careers related to the science they are studying • show a continuing and more informed curiosity and interest in science and science-related issues • acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research • consider further studies and careers in science-and technology-related fields
Support for Scientific Enquiry • Acknowledge the importance of considering different scientific perspectives and arguments • Support the use of factual information and rational explanations • Express the need for logical and careful processes in drawing conclusions	• defend a decision or judgement and demonstrate that relevant arguments can arise from different perspectives • value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not • appreciate that the applications of science and technology can raise ethical dilemmas • value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds • confidently evaluate evidence and consider alternative perspectives, ideas, and explanations • use factual information and rational explanations when analysing and evaluating • value the processes for drawing conclusions
Responsibility towards resources and environments • Show a sense of personal responsibility for maintaining a sustainable environment • Demonstrate awareness of the environmental consequences of individual actions • Demonstrate willingness to take action to maintain natural resources	• have a sense of personal and shared responsibility for maintaining a sustainable environment • project the personal, social, and environmental consequences of proposed action • want to take action for maintaining a sustainable environment • be aware of the direct and indirect consequences of their actions

Analysis of the mapping results presented in tables 3-6 may raise questions as to its appropriateness. We reiterate here that a reasonable, rather than exact match was used in the mapping. Some outcomes from the *Common Framework of Science Learning Outcomes K to 12* can reasonably be mapped to more than one PISA "outcome" depending on the particular task assigned by the teacher. For example, the STSE specific learning outcome "It is expected students will defend a decision or judgement and demonstrate that relevant arguments can arise from different perspectives" can be mapped to the PISA scientific competency of using scientific evidence because it may apply to "identifying assumptions, evidence and reasoning behind conclusions". Depending on how teachers vary their class activities it is reasonable to imagine that the competency of "interpreting scientific evidence" can also apply to this outcome. In addition, the same outcome can also relate to the knowledge about science category of scientific explanations as it applies to recognizing "historical and current knowledge". Finally, this same outcome can also be reasonably mapped to the support for scientific enquiry area of the attitudes.

Notwithstanding the limitations regarding the reliability of the mapping, it has been possible to demonstrate the extent to which the *Common Framework of Science Learning Outcomes K to 12* aligns with the PISA 2006 science assessment framework. Of the 91 outcomes, all but 13 specific learning outcomes and 2 attitude general learning outcomes cannot reasonably be mapped to the PISA framework. Viewed differently, approximately 86 percent of the outcomes in the *Common Framework of Science Learning Outcomes K to 12* can reasonably be mapped to the PISA framework. Hence, while the impact of such a strong alignment between the two documents may be difficult to quantify, there is little doubt that Canadian students profited by this situation on the PISA 2006 Science Assessment. This may, in part, explain their excellent results.

Looking ahead

Despite Canada's excellent performance on the PISA 2006 science assessment and its improvement of 8 ranks from the 2003 assessment caution should be exerted when trying to predict future Canadian performance on PISA science assessments. Two factors warrant this caution. The first factor is the shortage of qualified science teachers across Canada. With the massive retirement of the baby-boom generation teachers, schools are finding it increasingly difficult to recruit science teachers with a strong science background. Given that student performance is strongly related to quality teaching it is difficult to be optimistic based on this point alone.

Paradoxically, the second factor pertains to the current strong alignment of the *Common Framework of Science Learning Outcomes K to 12* with provincial science curricula as described above. The pan-Canadian curriculum document is now more than a decade old and no new version is formally planned. Given that most provincial curricula have a life-span of about a decade, provinces will soon update their respective science curricula without the guidance of a pan-Canadian framework. In fact such changes have already begun in some provinces. It is reasonable to assume that there will be more inter-provincial variation in science curricula than currently exists. Consequently, this will result in an overall weaker alignment with the PISA science framework when viewed at the country level. Thus, Canadian students may not have as many opportunities to learn, at least in school, some of the competencies, knowledge and attitudes that the PISA definition of scientific literacy requires of them.

Conclusion

Despite the absence of a national science curriculum and the inevitable differences in science curriculum across Canada, Canadian students in every province performed above the OECD average on the PISA 2006 science assessment. Ranking 3rd in the world with a score of 534 points, Canada improved 8 places from its 2003 PISA science ranking.

Three possible explanations for these results were presented. The first is the relatively strong performance of immigrant students. This performance is interpreted as a success story in Canada given the country's multicultural composition. A second explanation is the relative equity seen across Canada with regard to students' socioeconomic status. Canada, along with a few other high performing countries, has managed to implement social policies which help reduce the inequity between students of differing socioeconomic status. Finally, the strong alignment with Canada's *Common Framework of Science Learning Outcomes K to 12*, provincial science curricula and the PISA 2006 science assessment framework suggests that students were exposed to opportunities to develop and learn the competencies, knowledge and attitudes expected of them by the OECD.

Whether Canadian 15-year-old students will maintain their excellent ranking on future PISA science assessments remains to be seen given the paucity of highly qualified science teachers and the probable increase in variability in science curricula across Canadian provinces in the short term.

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2 Although several outcomes from the *Common Framework of Science Learning Outcomes K to 12* can be reasonably linked to more than one aspect of PISA scientific literacy, each is presented only once in the following tables.