

A Multilevel Analysis of Scientific Literacy:  
The Effects of Students Sex, Students' Interest in Learning Science, and School  
Characteristics

by

Chiung-I Huang

B.A., Soochow University, 1999

M.A., Nan-Hua University, 2001

A Thesis Submitted in Partial Fulfillment of the  
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Supervisory Committee

Dr. John O. Anderson, Supervisor

(Department of Educational Psychology and Leadership Studies)

Dr. John C. Walsh, Department Member

(Department of Educational Psychology and Leadership Studies)

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(Department of Educational Psychology and Leadership Studies)

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**ABSTRACT**

This study investigates the effects of student sex, student's interest in learning science and school characteristics – school type and school size- on 15-year-old scientific literacy in Canada through HLM. Using PISA data in 2006, the results showed 19% of the total variability in scientific literacy could be attributed to schools in Canada. There is a significant sex difference in scientific literacy in Canada at the student level. In addition, students' interest in learning science is related to their scientific literacy significantly. Students who have a higher interest in learning the subjects of physics, chemistry, human biology, astronomy, and geology are predicted to achieve higher science scores than those students who have less interest in learning these subjects. In terms of the school characteristics variables, students who attend public schools have better scientific literacy scores. Also, students who go to bigger schools significantly outperform in scientific literacy.

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## **Chapter One: Introduction**

### **Overview**

Generally speaking, students spend a great deal of time in school. According to Deci, Vallerand, Pelletier, and Ryan (1991), students spend about 15,000 hours in school in their first twenty years. Deci and Ryan (1985) also pointed out that students' cognitive abilities, development, and affective and psychological well being are all influenced by their experiences in school. Therefore, we may say that everything in school or related to school can affect students' learning and development.

For many years, how to enhance students' learning has been an important issue in the educational field, because many believe that "success in school is a critical component of the ability to participate fully in contemporary society" (Connolly, Hatchette, & McMaster, 1998, p.1). Students' learning experiences and achievement in school will influence their future careers, also their lives. Therefore, knowing what to do to improve students' achievement can help our next generation have a better life. The Organization for Economic Co-operation and Development (OECD) developed the Programme for International Student Assessment (PISA) in 1997 for collecting comparable evidence on student performance cross-nationally (OECD, 2001). The purpose of PISA is "to provide a new basis for policy dialogue and for collaboration in defining and implementing educational goals, in innovative ways that reflect judgments about the skills that are relevant to adult life" (OECD 2007, p.3).

Nowadays, people are in technologically complex societies and there is a particular premium associated with math-intensive, science-related skills (OECD, 2007). For the past few decades, science has played an increasingly important role in terms of

economic development for countries in an information technology age. It is important to know students' knowledge and skills of science and also their attitude toward science, and these were what PISA assessed in 2006 survey in order to enhance students' learning (OECD 2007).

Researchers and educators have long studied what factors influence students' learning and their performance. Entwistle, McCune, and Hounsell, (2003) describes a model in which they discern three groups of influencing factors on student learning: students' characteristics, teaching characteristics, and school characteristics. Among the student characteristics they mentioned were prior knowledge, intellectual abilities, learning style, personality, attitudes to courses, motivation, work habits, and study skills. Teaching characteristics encompassed level, pace, structure, clarity, explanation, enthusiasm, and empathy of teaching. School characteristics include course design and objectives, learning materials, assessment procedures, workload, freedom of choice, and study skills support. Furthermore, student behaviour can be influenced through teacher behaviour and school conditions.

In addition, many factors such as student sex, efforts, associations with positive peers, and school climate have been identified as influential on students' learning and their achievement (Stewart, 2008; Taplin & Jegede, 2001). Bem (1993) mentioned that sex may be one of the most pervasive factors within a society that affects a child's development and learning. This study will be examining the influence of sex differences, students' interest in science, and factors relating to school characteristics such as school size and school type on science achievement in Canada.

When considering students' achievement in science, people may be under the

impression that males do better than females in science. Although this is a kind of sex stereotype, it is a significant and well documented concern. For instance, Miller, Blessing, and Schwartz (2006) examined 79 high school students and found that female students have lower performance of science than male students do. Those research results that related to sex differences lead most people to believe that boys are good in mathematics and science related domain, and girls are outperforming in verbal related subjects (i.e. Breakwell, Vignoles, & Robertson, 2003; Marsh, 1993).

Also, students have similar thinking about sex stereotype in their self-concept. Marsh (1993) provided an alternative test of the differential socialization model, in which it was predicted that English self-concept would be more highly related to academic and general self-concept for girls, mathematics self-concept would be more highly related to academic and general self-concept for boys, and these sex differences between male and female students would grow larger with age. OECD countries have been given their efforts to reduce the learning outcome gap between boys and girls by finding what factors make differences and then making appropriate policies (OECD, 2007). In addition, one of PISA's reports concludes that there are significant sex differences in educational outcomes after researchers analyzed the data sets of PISA 2000, 2003 and 2006. As students progress in their education, the differences between boys and girls become more pronounced and the labour market outcomes show significant earning gaps in favour in males (OECD, 2009a). Therefore, one purpose of the present study is to investigate whether sex differences significantly exist in Canadian students' science achievement by analyzing PISA 2006 data set to better inform policy makers.

Previous researchers have been interested in the incidence of, and the reasons for,

sex differences in science achievement since the late 1970s (Eckes & Trautner, 2000). In the UK, girls have generally been found to like science less and achieve less in science than do boys (Breakwell, Vignoles, & Robertson, 2003). Moreover, in the U.S., the results of National Assessment of Educational Progress (NAEP) 2005 in science has shown that sex differences in science achievement exist as early as fourth grade, and the gap between girls and boys increases with their age (NAEP 2005). Beller and Gafni (1996) also found similar results in the 1991 International Assessment of Educational Progress (IEAP) in mathematics and sciences.

Not only students' sex but their attitudes towards learning will influence their achievement. Oakes (1985) stated that students who have lower attitude toward learning would lead them to lower achievement and reduces their interest of learning. Hallam and Deathe (2002) also showed that students' attitude towards learning and achievement have positive correlation in their study of 234 students. From the above, we understand that students' achievement can be affected by not only students' sex, but also students' attitude toward learning.

Students' attitudes such as their interest or enjoyment in learning can influence their learning achievement. Chiu and Zeng (2008) showed that students who have higher interest in learning perform better than others. In addition, Miller et al. (2006) examined sex differences in high-school students' attitudes towards their science classes. One of the results in their research was females generally found science less interesting.

In relation to sex differences, researchers have detected a number of possible factors that could tend to make girls perform more poorly than boys in science, including differences in teacher support, parental support, motivation, hands-on experience, and

school climate (e.g. Caselman, Self, & Self, 2006; Taasobshirazi & Carr, 2008).

Most researchers agree that school type and size contribute to student outcomes (Loukas & Murphy, 2007). Papanastasiou (2002) investigated the mathematics achievement of 8th grade students in Cyprus and found that school type and school size related to success in mathematics. Thus, this study will also examine how school characteristics (e.g. school type and school size) affect Canadian students' science performance.

In summary, there are not only individual factors and drives which could influence students' learning also factors come from their learning environment (e.g. school type and size).

### **Purpose**

The purpose of this study was to examine the student- and school-level correlates of science literacy for Canadian adolescents at age 15, with a particular focus on students' sex differences, students' interests in learning science, and the factors relating to school climate specifically in school type and school size. The data were provided by the Program for International Student Assessment (PISA) and analyses were conducted on data from Canada only. Hierarchical linear modeling (HLM) was applied to examine both student- and school- level variables.

### **Research Questions**

The research questions of this study are:

1. Do sex differences exist in Canadian students' science achievement while controlling the variables of students' interests in learning science, school type, and school size?

2. Is there a relationship between students' interests in learning science and science achievement?
3. When students' sex and interests in learning science are controlled, is there any association between school size, school type, and science achievement?

## **Chapter Two: Literature Review**

### **Overview**

This chapter reviews the variables related to students' academic achievement in this study begins with a brief introduction of scientific literacy. From previous research of biological and theoretical perspectives, sex differences do exist and are related to students' performance. In addition, students' interest in learning has been shown to have effect on their achievement. Finally, the association between school type (private, public), school size, and students' learning outcomes will also be explored.

### **Scientific Literacy**

Scientific literacy has become a contemporary educational goal even though there is no consensus about what counts as scientific literacy (Laugksch, 2000). From numerous definitions of this term "scientific literacy", McEneaney (2003) concluded that nearly all visions of scientific literacy involve at least some science, and there is an assumption that everyone can understand this science knowledge, given appropriate pedagogy. Durant (1993) gave the specific definition of scientific literacy as "what the general public ought to know about science" (p.129). Also Jenkins (1994) stated scientific literacy "commonly implies an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas" (p.5345).

In addition, scientific literacy was defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It also includes specific types of abilities" (National science education standards, 1996, p.22) .

Scientific literacy was described as “the ability to creatively utilize science knowledge in everyday life to solve problems” at a regional workshop for United Nations Educational, Scientific and Cultural Organization’s (UNESCO) “Project 2000+: Scientific and Technological Literacy for All” (UNESCO, 1998, p. ix). This statement underscores an orientation toward the construction of a particular type of individual and resonates with world-cultural principles (McEneaney, 2003). Moreover, Hand, Prain and Yore (2001) stated the operational definition of scientific literacy is being able to construct understanding of science and to solve the realistic science, technology, society, and environment problems and issues.

**Why Scientific Literacy Is Important.** From the extensive and diverse literature review, Thomas and Durant (1987) identify a range of arguments for promoting scientific literacy. They grouped a number of common arguments for promoting scientific literacy into a macro and micro view.

According to the macro view, the importance of promoting scientific literacy could be increasing the benefits to national economies. Scientific literacy is connected with the economic well-being of a nation. Competing successfully in international markets can bring national wealth and this relies on a vigorous national research and development programs to take the lead in the competition for new high-technology products (Thomas & Durant, 1987). Different from the macro view, the micro view emphasizes the direct benefits of scientific literacy to individuals. In this modern science- and technology-based society, scientifically literate individuals may therefore be in a favourable position to exploit new job opportunities and be able to take advantage of technical developments in their place of work (Thomas & Durant, 1987).

Promotion of scientific literacy not only gives the individuals advantage for their work but also their everyday life. Shortland (1988) suggested that “science is the distinctively creative activity of the modern mind” (p.310). When people increase their scientific literacy, they would get a better and larger understanding of science, which “would make people not merely wiser but better” (Shortland, 1988, p.311). Regardless of macro or micro views, scientific literacy is important for both the society and the individuals.

**The Concept of Scientific Literacy.** One of the earliest works that attempted to explain the concept of scientific literacy was written in 1966 and concluded that people need to understand: (a) the interrelationships between science and society; (b) ethics that control the scientist in his work; (c) and nature of science is the characteristics of the scientifically literate person (Laugksch, 2000).

In the early 1980s, scientific literacy was an issue in the United States and a number of researchers gave their opinions on scientific literacy and the challenges facing America (Laugksch, 2000). Among these researchers, Jon Miller was influential and proposed an important concept of scientific literacy. Miller (1983) stated that in today's scientific and technological society, scientific literacy includes: (a) understanding of the norms and the methods of science; (b) understanding of key scientific terms and concepts; and (c) awareness and understanding of the impact of science and technology on society.

A more recent and clear concept of scientific literacy was used by the American Association for the Advancement of Science (AAAS) in Project 2061. Scientific literacy is advocated in order for the “life-enhancing potential for science and technology” (p.13)

to be used for better decision-making at the individual, societal and national levels. (AAAS, 1989).

Although numerous scholars have attempted to define the concept of scientific literacy, the debate about what should be counted as scientific literacy still exists and is still active (McEneaney, 2003).

**Ways to Measure Scientific Literacy.** How to accurately measure an abstract subject such as scientific literacy is an important issue to researchers. Despite the active discourse about the issue of scientific literacy, few efforts have been made to measure it.

Miller (1983) briefly reviewed the previous efforts made to measure scientific literacy. He stated that most of the early empirical work in this field had focused on the measurement of scientific attitudes. The researchers stressed the use of everyday examples such as “Air is composed of molecules” or “A disease is a punishment for some particular moral wrong” to measure the students' utilization of scientific attitudes and thinking. However, early empirical studies are only concerned with knowledge levels of scientific norms and the ability of young people to think in logical terms.

During the 1950s and 1960s, students' knowledge of basic scientific constructs was measured when standardized testing expanded. A majority of tests were used by teachers and schools to evaluate individual students or to determine admission or placement (Miller, 1983).

The third dimension that early empirical studies were interested in was an individual's knowledge about organized science, which includes basic science, applied science and development. In the 1970s, some national organizations, like the Survey Research Center at the University of Michigan and the National Science Board,

conducted surveys to measure public attitudes and knowledge about organized science and technology (Miller, 1983).

In 1979, the National Science Foundation (NSF) conducted a survey of adult attitudes toward science and technology, and they included all of the items necessary to measure scientific literacy. In conducting this survey, the NSF measured the three dimensions appropriately and combined them into a single measure of scientific literacy. However, this measure has not been generally adopted; there is global consensus about the accurate way to measure the scientific literacy (Miller, 1983).

### **Sex and Gender**

While sex and gender are often considered to have the same meaning, they actually refer to two different concepts. According to Duberman and his colleagues (Duberman, Hacker, & Farrell, 1975), sex belongs to an ascribed status which is assigned to individuals without reference to their innate differences or abilities. Sex, just like other ascribed statuses such as age and race, is hard to alter. It refers to the biological differences between people. Men are born with male genitalia and women are with female genitalia. Therefore, sex is almost always unchangeable.

Gender differs from sex; it is an achieved status which is not assigned at birth and is left open to be filled through development (Linton, 1936). Duberman and his colleagues (1975) stated that gender roles such as masculinity and femininity are gained through learning, role-taking, imitation, observation, and direct instruction during one's lifetime. In other words, "gender" is a cultural concept, relating to social classifications such as masculinity and femininity. Because gender refers to culture and is socially constructed, it can be changed (Reid & Wormald, 1982).

To make short of this matter, sex is a status ascribed at birth and determined based on biological factors, whereas gender roles are learned and achieved according to one's sex status. Nevertheless, sex and gender are frequently confused in our society today. People use gender and sex interchangeably. Most of them do not understand that to be born male does not guarantee masculinity and to be born female does not ensure that one will be feminine.

To avoid the confusing with sex and gender, the present study used sex status instead of gender role.

### **Biological Sex Differences**

Maccoby and Jacklin (1974) summarized and analyzed studies of different behaviours, characteristics, and abilities that researchers have examined for sex differences. They concluded that females show higher verbal ability than males and males excel in visual- spatial and mathematical ability. These consistent sex differences are large enough to be considered meaningful.

If we are to understand the scope of sex differences, it is important to start from the biological differences between male and female.

**Sex Differences in Brain Size and Intelligence.** It has long been known that some differences exist between male and female brains. Studies of brain anatomy have reported some evidence of differences between male and female brains (Cowell et al., 2007). The results of Hines' (2004) study were that there are sex differences in human brain and male brains are larger and heavier than female brains. Physiological differentiation of the sexes begins at conception with the genetic determination of sex. Some researchers believe that the sex hormones have an impact on the developing brain,

differentiating it in some respects for males and females (Lips, 1993). Vernon, Wickett, Bazana, & Stelmack (2000) have found that intelligence correlates positively with brain size within each sex. Allen, Damasio, Grabowski, Bruss and Zhang (2003) also reported positive correlations between the size of small gray brain matter areas and intelligence, and males with greater brain structure volumes have a slight mean general intelligence advantage and a flatter dispersion score than females do. Additional studies on sex differences in brain size and intelligence were conducted by Rushton and Ankney (1996) who confirmed that males averaged a larger brain size than females even after adjusting for body size and advantaged in IQ and cognitive abilities.

According to the studies mentioned above, some people might think that women's intellectual inferiority was because of their smaller brain. However, female brains appear to be packed more densely than male brains. Female brains are indicated by a higher percentage of gray matter, greater cortical volume, and increased glucose metabolism, thought to reflect increased functional activity (Hines, 2004). This suggests that understanding biological sex differences in intellectual functioning needs more than comparisons of overall brain size.

**Sex Differences in Brain Structure and Function.** Because of new techniques such as magnetic resonance imaging (MRI), the investigation of sex differences in brain structure and function is now available. Although male and female brains are structured and function similarly in most respects, there are still some differences.

The human brain is divided into right and left hemispheres. Each half of the brain governs the motor activities of the opposite side of the body. Scientists believe that the two hemispheres of the brain control different abilities. The right side of the brain is for

more holistic and nonverbal information processing skills and certain types of spatial abilities and the other side of brain is for language and analytical skills. Some researchers have found that female superiority in verbal tasks and male superiority in some spatial tasks might be associated with the sex differences in the development and the function of the left and right sides of the brain (Lips, 1993).

Halpern (2000) mentioned that males' brains are more strongly lateralized than females' brains because of high levels of fetal hormones. Also, in Halpern's research, there was some support for the prediction that strong lateralization is associated with high spatial performance.

In addition, Rossell, Bullmore, Williams, and David (2002) investigated sex differences in brain activation during an experiment similar to a lexical decision task with six males and six females. The results of their study showed that men had a strongly left-lateralized pattern of activation, e.g., inferior frontal and fusiform gyrus, while women showed a more symmetrical pattern in language related areas with greater right-frontal and right-middle-temporal activation. This might explain why males tend to excel in certain measures of spatial and mathematical abilities, whereas females tend to excel in measures of verbal fluency and perceptual speed.

### **Theoretical Perspectives on Sex Differences**

**The Evolutionary Perspective.** Darwin's theory of evolution assumed that variations within species can be inherited, and competition for limited resources means that only a very small fraction of offspring survive. These combine to natural selection and occur through the differences between males and females (Kenrick, 1987).

Evolutionary pressures are also linked to sex differences in attention, learning, and

decision making (Kenrick, Li, & Butner, 2003).

According to Wood and Eagly (2002), evolutionary psychologists have developed a theory to explain the origins of differences between men and women; and evolutionary psychology is the most well-developed theory explaining sex differences. From the evolutionary perspective, human sex differences reflect the pressures of differing physical and social environments on females and males in primeval times. The two sexes developed different strategies to ensure their survival and reproductive success (Eagly & Wood, 1999).

Sex differences in spatial performance favouring males have been reported more consistently than any other cognitive differences (Lips, 1993). From an evolutionary approach, the spatial abilities of male would have been selected because males require navigation skills to maintain large home ranges for seeking potential mates and resources to attract mates. Also, because males usually locate and defend females in mate defense, they have to show superiority in spatial abilities to do so (Silverman & Eals, 1992).

To sum up, from evolutionary view point, the ultimate explanation of sex differences is viewed as dependent on reproduction, and changes that occur are biological as people adapt to changes in the environment during human evolution.

**The Social Structure Theory.** The social structural theory states that the critical cause of sex differences is social structure. Because men and women tend to have different social roles, they become psychologically different to adjust to these roles (Eagly & Wood, 1999).

Under the framework of social structure theory, Lips (1991) demonstrated that “power and status” and “the division of labour” are the important elements which can

affect the differences between males and females in most societies. When people are in a male dominant and female subordinate social setting, feminine behaviour is powerless behaviour. On the other hand, if women and men had equal status in society, many of the differences that are attributed to the sexes would disappear. For example, in male dominant societies, females tend to get assistant positions such as secretarial positions and males tend to get dominate ones such as executive positions even though no evidence shows that men will do better in that kind of position than women. This is all because under the social structure of male-dominated societies, males get the power and higher status. Everything related to females is viewed as being weak and subordinate.

Lips (1993) also declared that power and status differences between men and women come from the division of labour. A long time ago, men were the hunters and women stayed home taking care of the children. Nowadays, men still have more control over economic resources than women do. Men's control over economic resources often brings them power and status, and allows them to achieve better jobs with higher salaries. This makes women and children depend on men for support. The division of labour by sex leads males and females into different types of work.

As a result of these social structures, boys and girls tend to duplicate the adult's model and repeat the cycle.

**The Social Cognitive Theory.** Although some sex differences are biologically founded, most of the stereotypical attributes and roles associated with sex distinction arise more from cultural design than from biological effects. The social cognitive theory explains how people acquire and maintain certain behavioral patterns, while also providing the basis for intervention strategies (Bandura, 1997). The social cognitive

theory provides an approach combining personal factors (e.g., biological events, cognitive and affective), behaviour and environmental factors.

The social cognitive theory includes the above-mentioned elements but it focuses on the interplay of various factors within the broad social context. It integrates psychological and sociostructural determinants within a unified conceptual structure. Moreover, social cognitive theory adopts a lifespan perspective; it differs from other theories that focus only on the early years of development or adulthood (Bussey & Bandura, 1999).

According to the social cognitive view, sex differences in human behavior are due to the influence of socialization into masculine and feminine roles, and the understanding that governs the enacting of these roles is described in terms of knowledge structures, such as schemas, scripts and beliefs. Importantly, the proximal determinant of sex-typed behavior is the person's socially acquired, gender-based belief system (Ward & Voracek, 2004). Also Bussey and Bandura (1999) state that sex conceptions and roles are the products of a broad network of social influences operating interdependently in a variety of societal subsystems.

In Bandura's social cognitive theory, social modeling, performance experiences in which sexed conduct is linked to evaluative social reactions, and direct tutelage are the three major modes which affect children's sex development and lead to differences between boys and girls. Those three modes influence varies depending on the developmental status of individuals and the social structuring of experiences. However, modeling is omnipresent from birth and individuals learn conceptions through modeling is faster than from other two modes. Therefore, modeling is the most powerful way of

transmitting values, attitudes, and patterns of thought and behavior. Children get sex-linked information from their parents, peers, significant persons and also the mass media (Bussey & Bandura, 2004).

Models are typical examples of activities considered appropriate for the two sexes. Children can learn sex stereotypes from observing the differential performances of male and female models (Bussey & Bandura, 1999). According to Bussey & Bandura (1999), children repeat modeling of sex-typed behaviour in the home, in schools, and on television. Through modeling and the structuring of social activities, children learn the prototypic behaviours associated with each of the sex.

However, in social cognitive theory, children do not only imitate the particular actions exemplified from their models, but also extract and integrate this diverse information for conduct. Through modeling, observing the outcomes experienced by others, the outcomes they experience firsthand, and what they are told about the likely consequences of behaving in different ways of their sex, children develop their regulations of sexed conduct and role behaviour, and their self-efficacy (Bussey & Bandura, 1999).

Two decades of research findings have now confirmed that students' academic self-efficacy beliefs influence their academic achievement (Pajares, 1997). When sex differences in self-efficacy beliefs have been assessed and discussed, Pajares and Valiante (1999) have reported sex differences in writing self-efficacy is favoring girls as early as fifth grade.

### **Sex Differences in Ability and Achievement**

The Third International Mathematics and Science Study (TIMSS) had students in

41 countries tested in both mathematics and science in 1995. The results of this study showed males and females in the fourth grade had approximately the same average achievement in mathematics but a few significant differences were observed favoured males over females (TIMSS, 1995). Also in the result of TIMSS's study in 1999 showed that there was a modest but significant difference favouring boys on average across all countries, although the situation varied considerably from country to country (TIMSS, 1999).

**Verbal Ability.** Verbal abilities are not a unitary concept. It includes all components of language usage such as word fluency; grammar; spelling; reading; writing; vocabulary and oral comprehension (Halpern, 2000).

Generally speaking, people usually hold a belief that girls have better verbal abilities than boys do. In fact, according to Halpern (2000), females do perform better in all components of language usage such as grammar, verbal analogies, vocabulary, and oral comprehension. Weiss, Kemmler, Deisenhammer, Fleischhacker, and Delazer (2003) examined ninety-seven college students (51 women and 46 men) with a neuropsychological battery, focusing on verbal and visual–spatial abilities and found out in general, women tend to perform at a higher level than men on most verbal tests.

Verbal area is the first clear sex difference of human's ability to appear. Maccoby and Jacklin (1974) reviewed 2000 studies and concluded that around the age of ten or eleven, girls begin to outscore boys on a variety of verbal tests; throughout the school years, boys seem to have more reading problems and speech difficulties.

In addition, there is some research suggested that girls may talk earlier and make longer sentences than boys in their childhood. This evidence shows that girls have better

language skills than boys do. Because of better verbal abilities, girls tend to perform better in the social science area and be employed in social-related works (Hoffman, Tsuneyoshi, Ebina, & Fite, 1984).

Despite verbal ability, males get the attention in spatial and mathematical abilities from professionals and lay people.

**Spatial Ability.** Linn and Petersen (1985) provided the definition of spatial ability which “generally refers to skill in representing transforming, generating, and recalling symbolic, nonlinguistic information” (p.1482). This ability allows people to manipulate visually or to make judgments about the spatial relationship of items located in two or three dimensional space. Also Halpern (2000) explained that visual-spatial ability refers to the ability to imagine what an irregular figure would look like if it were rotated in space or the ability to discern the relationship among shapes and objects.

Currently, spatial skills are used extensively in engineering, architecture, chemistry, the building trades, and aircrew selection (Lohman, 1988). For several decades, many researchers have used students’ spatial ability as one of the factors in their studies of students’ achievement especially in mathematics and science. Moreover, spatial ability and its influence on performance in academic interests such as mathematics and the sciences could be very useful tools for educators to use while assisting students in designing appropriate academic paths (Rohde & Thompson, 2007).

Also in the study of predicting academic achievement with cognitive ability, Rohde and Thompson (2007) found that spatial ability continued to account for a significant amount of additional variance when predicting scores for the mathematical portion of the Scholastic Assessment Test (SAT) while holding general cognitive ability

constant. Regarding this, we understand that spatial ability is significantly associated with students' achievement, and if there are sex differences in spatial ability, it might influence students' achievement based on their sex. Greenglass (1982) stated boys receive higher average scores than girls on psychological tests for spatial ability in junior high school. While both girls and boys improve on these tests throughout high school, boys appear to progress at higher rate than girls.

**Mathematical Ability.** Mathematical ability or quantitative ability is another talent that people believe favours males. This thought is supported by a lot of research (e.g. Fan & Chen, 1997; Halpern, 2000). When studies reported differences in mathematical ability, they usually favoured boys and men.

Fan and Chen (1997) analyzed the data from the National Education Longitudinal Study of 1988, which collected data on approximately 24,500 students who were in the 8<sup>th</sup> grade in 1988, and then had the first follow-up of 1990 (Grade 10), the second follow-up of 1992 (Grade 12) by U.S. department of Education. The results showed that there were no differences between sexes when total-group means were compared. However, noteworthy sex differences favoring males have emerged when the high end of mathematics scores was examined. These differences became larger from the 8<sup>th</sup> grade to the 12<sup>th</sup> grade, and became more prominent at more extreme score ranges. In Fan's research, whites, Asians, and Hispanics had consistent results showing that there were sex differences in mathematics scores across major ethnic groups in the United States.

The finding that males outperform females in tests of quantitative ability is also significant. Consistent sex differences have been found in many studies. Males tend to outscore females on the quantitative portion of those tests (Halpern, 2000).

Sells (1976) studied a questionnaire survey, based on information presented in a 1973 study of San Francisco high school students and on the 1965 Coleman Report on Grade 12 median achievement in mathematics nationwide. From the results, he described mathematics as a “critical filter” that allows only a few people to pass into the higher paying jobs.

Quantitative skills are a condition for entry into jobs requiring scientific and technical skills. This may explain why males are much more present in mathematics- or science-related jobs.

### **Sex Differences in School Performance**

Understanding whether males and females differ in school performance and achievement - and, if so, try to reduce the gap - has long been a concern of educational scholars.

Scholars and governments around the world were concentrating for decades on enhancing girls' learning. Nevertheless, public attention has now shifted to boys' deficiencies in school performance because some recent studies found that in general girls outperform boys in school (e.g. Van Houtte, 2004; Steinmayr & Spinath, 2008).

However, there are studies showing that girls do not outperform in every subject in school. Hedges and Nowell (1995) used secondary analyses of six large data sets collected between 1960 and 1992. In their study, Hedges and Nowell found that girls do slightly better on reading and verbal tests, while sex differences in mathematics test scores show a small advantage for boys, especially those at the top end of the performance distribution.

Also, Halpern (2002) stated that boys have significantly and consistently higher

mathematics scores on the Scholastic Assessment Test (SAT). In addition, boys, on average, also score significantly higher on tests of science, geography, and mechanical and spatial reasoning (Bridgeman & Moran, 1996).

To sum up, the reasons that boys and girls perform differently in school are not yet understood. But we do know there are significant sex differences of development for many cognitive abilities between boys and girls. Girls have an advantage on most verbal abilities such as learning and using language throughout elementary school, therefore, they tend to outperform in verbal abilities related domains.

### **Sex Differences in Science Achievement**

With respect to sex differences and science achievement, Steinkamp and Machr (1983) reported that in science performance and cognitive ability, boys did slightly better than girls in a comprehensive review of studies about correlations among ability, achievement, and sex. Later, Becker, Chang and Michigan (1986) reexamined Steinkamp and Maehr's work in science achievement between males and females. In their study, Becker, Chang and Michigan had similar results that sex differences tended to favour males, but the significant differences were slight.

Most research related to sex differences and student science achievement has been conducted in the area of mathematics and science, where researchers report that girls enrol in fewer mathematics and science classes in part because they sex-type mathematics and science as male domains. Stereotypical beliefs that women are less competent than men in the area of mathematics are also partially responsible for women taking fewer mathematics and science courses than do men (Eccles, 1987).

**School characteristic**

School characteristics are important variables for students' learning, and include traits such as the quality and homogeneity of interpersonal relations within the school environment that influence students' cognitive, social and psychological well-being (Haynes, Emmons, & Ben-Avie, 1997). The present study will focus on school type and school size and to investigate whether these two elements of school characteristics affect students' scientific literacy.

**School Type and Student Achievement.** There are numerous types of schools in the world such as public schools, Catholic, Lutheran, conservative Christian, other private, and charter schools (Lubienski, Lubienski, & Crane, 2008a). The most common way is to separate different schools into two categories: one is “public school”; and the other one is “private school”. Traditionally, public schools are deemed to be those directly accountable to elected officials or funded by tax dollars. Those schools which do not fit within this criterion are counted as private schools (Hess, 2004).

Some aspects of the school characters have been found to differ by school type. For example, compared to the public school, research shows that private school teachers have more autonomy in their work, a greater sense of community within their schools, and more support from their principals. In addition, students in public schools have greater absenteeism and poorer attitudes toward learning in the U.S.(Lubienski, Lubienski, & Crane, 2008a). Therefore, some people believe in a positive private school effect, e.g. the advantages of private schools that mentioned above could boost student achievement in decades. Furthermore, the U. S. Department of Education’s National Center for Education Statistics (NCES) released a study in 2006. This study investigated the differences in

National Assessment of Educational Progress (NAEP) reading and mathematics scores of 4th and 8th graders attending public and private schools. The results from this study found private school students have higher mean scores both in reading and mathematics than those who attended public schools (Braun, Jenkins, Grigg, 2006). The study of NCES showed that private schools are more effective than public ones for students' learning.

However, recent analyses challenged this common belief regarding the superiority of private schools relative to public schools. Those studies raised questions about the school climate in shaping achievement in different types of schools (Lubienski, Lubienski, & Crane, 2008a). Lubienski, Crane and Lubienski (2008) conducted a new study based on a nationally representative sample of 30,000 students and the result overthrew their assumption that private school would get higher average scores than public ones. In their study, public school students outperformed in mathematics achievement than students in private schools.

This surprising result caught researchers and policy makers' attention. Therefore, new studies have paid more attention to the topic of understanding achievement differences across school types (Lubienski, Crane, & Lubienski, 2008).

**School Size and Student Achievement.** Although school enrolment size has been the major criterion used to identify small schools, there is no clear agreement on the dividing line between small and large schools (Swift, 1984). Swift (1984) defined small schools as those schools which enrol fewer than 300 students. However, in Cotton's literature review of school size and student performance, in the first place, of the 69 key reports, only 27 mention any numbers at all in their analyses of large versus small schools. In the second place, the upward limit for a "small" school in those 27 documents ranges

from 200 to 1,000 students; and the range for a "large" school is 300 to 5,000 students (Cotton & Northwest Regional, 2001).

Is smaller or bigger better? Debates over school size continue in discussions about student academic achievement. Generally, large schools are recognized for their ability to provide academic choices and efficient economies of scale. Also, as school size increases, so does the budget of the school. Therefore, larger schools with more resource opportunities are able to provide students with more curricula, more qualified teachers, and better school physical environments (Borland & Howsen, 2003).

However, small school proponents state that smaller schools have higher class and school participation, a better school climate, more individual attention, and fewer dropouts (Texas Education Agency, 1999). Similarly, small schools are also found to provide more opportunities for developing student leadership and enhancing interpersonal relationships (Borland & Howsen, 2003).

With respect to school size and student achievement, previously existing research produced conflicting results. Haller and his colleagues (1990) found a positive relationship between school size and student achievement.

Raywid (1997), reporting on a study of Philadelphia and Alaska schools, noted that students in small high schools were more likely to pass major subjects than students in larger high schools. Moreover, results from the Alaskan schools indicated that disadvantaged students at small schools significantly outperformed those at large schools on standardized tests of basic skills. Also Jewell (1989) found that states with smaller schools have higher Scholastic Assessment Test (SAT) and American College Testing (ACT) scores.

Mok and Flynn (1996) reported similar results that school size has a significant effect on student academic achievement. However, unlike the above researchers, Mok and Flynn (1996) argued that larger schools are more effective in students' achievement because of their wider range of teachers, comprehensive curricula, and updated teaching facilities.

Moreover, Young and Fraser (1992) examined the relationship between school effectiveness, science achievement and sex differences of an Australian database known as the Second International Science Study. They found school effects were statistically significant in explaining student differences in science achievement.

One of the purposes of this study is to reexamine the effect of school type and size on student science achievement while using different datasets to see whether there are significant differences exist.

### **The Role of Student Interest**

How does interest affect learning when a person becomes interested in a topic or domain? In the past, assumptions about the role of interest and its implications for meaningful learning have played an important role in both psychology and education. Surprisingly, the scientific study of student interest in learning is a fairly recent development (Boekaerts & Boscolo, 2002).

According to Boekaerts and Boscolo's (2002) brief historical review of interest, there is no single definition of what constitutes "interest". In addition, many teachers, educators, and researchers have used the term "interest" and "intrinsic motivation" interchangeably. Interest is closely linked to, but different from, intrinsic motivation. To avoid the confusion between interest and intrinsic motivation, Bandura (1986) tried to

discern these two concepts. He stressed intrinsic motivation as an inner drive and interest as a fascination with something or somebody.

Furthermore, Deci (1992) made an attempt to conceptualize “interest”. According to his conceptualization, interest is the effect that relates to the activities that provide the type of novelty, challenge, or aesthetic appeal that people desire.

Currently, there appear to be two research lines in the study of interest. One line of pre-existing research explores personal or individual interests. This kind of interest is built on stored knowledge of or value for a class of objects or ideas. This leads to a desire to be involved in activities related to that topic. For instance, students who have a high degree of personal interest in a particular topic would be more likely to seek out opportunities to learn more about that topic (Boekaerts & Boscolo, 2002).

Another line of research focuses on situational interest. This type of interest is generated in a situation in interaction with a text, topic or idea, and is dependent on favourable environmental conditions. The research of this line focuses primarily on the characteristics of learning environments that do or do not elicit situational interest (Boekaerts & Boscolo, 2002).

To sum up, research on personal or individual interest focuses on the impact of an individual's topical interest in comprehending the topic, and the situational interest is elicited by the interestingness of a text (Schiefele et al., 1988).

Given distinctions between personal interests, intrinsic motivation, and situational interests, this study will focus on the relationship between personal or individual interests and one's science achievement.

**Measurement of Interest.** According to Schiefele and his colleagues (1988), there are problems faced in measuring interest and the relationship between interest and achievement or learning. They addressed the problematic procedures in measuring interest was the basic deficit of previous approaches. Also Hidi (2001) stated that one of the methodological limitations of interest research is how to measure interest accurately.

How do researchers measure interest for their studies? The most common way to assess student interest on a specific topic is using interest questionnaires and self-rating scales (Hidi, 2001). However, the assessment methods used are relatively heterogeneous and include everything from extensive tests and questionnaires to one simple and direct question about interest in a specific topic. In many cases, it is unclear whether interest is actually being measured, rather than attitudes or personal preferences (Schiefele et al., 1988). In addition, when students are asked to rate their interests to a subject, they provide an expectancy measure. When ratings of interest are made after the assessment of a specific subject, students are asked to remember what they felt back in time. Without measuring students responses in real time, would be hard to collect the accurate results (Hidi, 2001).

In the following will be described how OECD measured students' interests in PISA 2006.

**Student Interests and Achievement.** Previous research has suggested that students' experiences in mathematics classrooms are significantly related to interest, and interest is a significant predictor of student achievement in mathematics. Recent research has further supported the influence of interest in learning (Singh, Granville, & Dika, 2002). In other words, interest in a subject can influence the intensity and continuity of

students' learning.

Regardless of other factors, students may invest or withdraw from learning depending on their interest in the subject matter (Hidi, 1990). Schiefele, Krapp, and Winteler (1992) carried out a meta-analysis of the association between interest and student achievement in different school subjects including mathematics, science, and social science. Their findings showed that student interests and achievement varying significantly from subject to subject. In addition, interest emerged as a significant predictor of several achievement measures, that is, highly interested students had better achievement.

### **Chapter Three: Methodology**

This study examined the student- and school-level correlates of science literacy for adolescents at age 15, with a particular focus on students' sex, perception of interest in science, and the factors relating to school climate specifically in school type and school size. The data were provided by the Program for International Student Assessment (PISA) and analyses were conducted on data from Canada only. Hierarchical linear modeling (HLM) was applied to examine both student- and school- level variables.

This chapter describes the research design and methods used in the study. In addition, an overview of PISA 2006, sampling procedures and instrumentation are described.

#### **Research Design**

**Secondary Data Analysis.** Secondary data analysis involves the analysis already existing sources of data. Data may be collected by governments, businesses, schools, and other organizations and stored in electronic databases to later access and analyze (Trochim, 2006). In the present study, data from PISA 2006 were analyzed. The distinction between primary and secondary data depends on who collected a data and who is analyzing it. If the data set in question was collected by the researcher for the specific purpose under consideration, it is primary data. If it was collected by someone else for some other purpose, it is secondary data (Boslaugh, 2007).

There are some advantages of working with secondary data. The first major advantage is economy. Because the data were already collected, the researchers do not have to devote their money, time, and resources to this phase of research. The second

advantage of using secondary data is the breadth of data available. Researchers can discover areas of a research problem and use different types of research techniques such as trend or cohort study on a data set. The third advantage in using secondary data is that often the data collection process is informed by expertise and professionalism which can provide standard items and standard indices (Boslaugh, 2007).

Despite its advantages, secondary data analysis also has its limitations. According to Boslaugh (2007), the major disadvantage is the data were not collected to answer analyst's specific research questions. The analyst can only work with the data that exist, not what he or she wish had been collected. Second disadvantage to using secondary data is that when you use data collected by others, researcher often do not know what problems occurred in the original data collection and the execution of the data collection process, he or she does not know how it was done. Therefore, the analyst does not know how reliably the data were done and how seriously the data were affected by problems such as low response rate (Boslaugh, 2007).

**Hierarchical Linear Modeling.** Hierarchical Linear Modeling (HLM) was used in the present study to model student- and school-level variables affecting 15-year-old scientific literacy scores in Canada. According to Hox (2000), HLM uses both student- and school- level variables to help explain variation in student outcome scores while accounting for the variance at each level. The aims of HLM are to predict a dependent variable on a using of independent variables at more than one level, and to examine the dynamics between micro- and macro-levels (Raudenbush & Bryk, 2002). Also, HLM allows the simultaneous modeling of student- and school-level factors while avoiding the problems of aggregation bias, mis-estimated standard errors, and heterogeneity of

regression (Lee, 2000). HLM recognizes that sampled units are nested within larger units, for instance, students that are nested within schools, and computes a regression equation for each larger units, instead of computing one regression equation for the whole dataset (OECD, 2005).

### **An Overview of PISA**

The purpose of the OECD Programme for International Student Assessment (PISA) is to find how well students, at age 15, are prepared for the challenges of the future (OECD, 2007). In order to achieve its goal, PISA assesses students reading, mathematics and scientific literacy, and problem solving every three years in the OECD member countries and a group of partner countries.

PISA 2000 focused on students reading literacy and in PISA 2003 had the main emphasis on mathematics literacy. PISA 2006 focused on students' competency in science. An international consortium of experts was responsible for designing and implementing the PISA surveys. For PISA 2006, students were assessed not only science knowledge and skills, but also the attitudes which students have towards science, and the science learning opportunities and environments which their schools offer. School principals also completed the school questionnaire while students completed a questionnaire (OECD, 2007).

The results of PISA can significantly improve our understanding of the outcomes of education and the factors affecting these outcomes. By focusing on students' abilities to solve problems relating to their real-life situations, PISA can enrich our knowledge of what countries are doing to prepare our next generation to meet the challenges of today's technology-based societies (OECD 2001, 2004, 2007).

**Sampling.** The target population of PISA assessment is 15-year-old students attending educational institutions in all 30 OECD member countries and 27 partner countries. Nearly 400,000 students, representing almost 20 million 15-year-olds enrolled in the schools of participating countries were assessed in PISA 2006. The target population of 15-year-olds was chosen because at this age, in most participating countries, students are approaching the end of their required schooling (OECD, 2007). The target population of PISA 2006 includes 15-year-olds who are enrolled in full-time and part-time educational institutions, vocational training or any other related type of educational programs. Students who are enrolled in foreign institutions within the countries as well as foreign students who are enrolled in programs in the first three categories were all included in the target population (OECD 2004, 2007).

PISA used a two-level stratified sampling method within countries where the first level sampling units were the individual schools having 15-year old students (OECD, 2005a). The second stage sampling units were the students in the sampled schools. The schools were sampled from a national list with probabilities that were proportional to schools' size that was measured by the number of eligible 15-year-old students enrolled. Once the school was selected, a list of 15-year-old students in the school was compiled. From this list, 35 students were randomly selected from the sampled schools. If there were more than 35 eligible students, 35 students were selected with equal probability. If there were fewer than 35 students, all students on the list were included in the assessment. In order to have a good representation of the population, exclusion rate within each country was kept below 5 percent. A minimum of 150 schools were selected in each country or all schools if less than 150 to increase accuracy and precision (OECD,

2009).

### **Instrumentation**

**Scientific Literacy in PISA.** Scientific literacy is the major domain being assessed in PISA 2006. The assessment of scientific literacy focuses on both the cognitive and affective aspects of students' scientific literacy including students' knowledge and their capacity to use this knowledge effectively (OECD, 2006).

The term scientific literacy was defined in PISA 2000 and 2003 as follows:

Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity (OECD, 2006, p.25).

The definitions of the 2000, 2003 and 2006 are fundamentally the same but the PISA 2006 definition of scientific literacy has been expanded by explicitly including attitudinal aspects of students' responses to issues of scientific and technological relevance. Thus, the definition of scientific literacy in PISA 2006 is:

An individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen (OECD, 2006, p.12).

In PISA 2006, students' scientific literacy was evaluated in relation to scientific knowledge or concepts; scientific processes which are centered on the ability to acquire, interpret and act upon evidence; and the situations or contexts which concern the application of scientific knowledge and the use of scientific processes (OECD, 2006).

**Students' Performance in Science.** Based on extensive research literature review, the OECD created a foundation to compare scientific literacy internationally. PISA assessed students performance in each of the science competencies (identifying scientific issues, explaining phenomena scientifically and using scientific evidence) and knowledge domains (knowledge about science and knowledge of science) (OECD, 2006).

*Science competencies.* Science competencies is composed by three parts which are identifying scientific issues, explaining phenomena scientifically and using scientific evidence.

The competency of identifying scientific issues involves recognizing questions that it is possible to investigate scientifically in a given situation and identifying keywords to search for scientific information. It also includes recognizing the key features of a scientific investigation, for example, what variables should be changed or controlled, or what things should be compared (OECD, 2006).

The competency of explaining phenomena scientifically includes applying knowledge of science in a given situation; describing or interpreting phenomena scientifically and predicting changes; and identifying appropriate descriptions, explanations, and predictions (OECD, 2006).

The last scientific competency that PISA 2006 assessed is student's ability of using

scientific evidence. Using scientific evidence includes 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 (OECD, 2006).

***Scientific knowledge.*** Scientific knowledge refers to knowledge of science and knowledge about science itself.

Knowledge of science means knowledge about the natural world. The goal of PISA is to describe the extent to which students can apply their knowledge to their lives. Therefore, the major fields of physics, chemistry, biology, earth and space science, and technology are selected and measured (OECD, 2006).

Another section of scientific knowledge is knowledge about science. To assess students' knowledge about science, two categories were identified. First category, scientific enquiry, centres on enquiry as the central process of science and the various components of that process. The second category is scientific explanations which are the results of scientific enquiry. We can think of enquiry as the means of science (how scientists get data) and explanations as the goals of science (how scientists use data) (OECD, 2006).

**Attitudes towards Science.** People's attitudes play an important role in their interest, attention, and response to science. Therefore, one goal of science education is for students to develop attitudes that make them likely to attend to scientific issues and apply scientific knowledge for individual, social, and global benefit (OECD, 2006).

PISA 2006 assessed students' attitudes in three areas: interest in science, support

for scientific enquiry and responsibility towards resources and environments. The data about such student attitudes are collected both by posing questions in the student questionnaire and in contextualised test items (OECD, 2006). This study used eight items in the student questionnaire to measure general interest in science learning in PISA 2006 (see Appendix A for item description). While the interest items which are embedded in the test instrument provide data on interest in specific contexts, the items here will provide data on students' interest in more general terms. All items were inverted for scaling and positive scores indicate higher levels of interest in learning science (OECD, 2009).

Students' interest in science is measured through knowledge about their engagement in science-related social issues, their willingness to acquire scientific knowledge and skills, and their consideration of science-related careers. The aspect of support for scientific enquiry in PISA 2006 includes the use of evidence or knowledge in making decisions, and the appreciation for logic and rationality in formulating conclusions. Attitudes in responsibility towards resources and environments have been the subject of extensive research since the 1970s. The International Implementation Scheme identifies environment as one of the three spheres of sustainability, along with society and economy that should be included in education for sustainable development programmes (OECD, 2006).

## **Procedure**

**Assessing Scientific Literacy.** It is important to have an appropriate balance of items assessing the various competencies of the scientific literacy framework. According to the PISA definition of scientific literacy, test questions require the use of the scientific

competencies within a context. This involves the application of scientific knowledge and reflects students' attitudes towards scientific matters (OECD, 2006). PISA 2006 test units include up to four cognitive items which assess students' scientific competencies. Each test item involves the use of one of the scientific competencies and requires knowledge of science or knowledge about science (OECD, 2006). There were four types of items used to assess the competencies and science knowledge in the framework. About one of third of the items required the selection of a single response from four options. A further third either required short constructed responses or complex multiple choice items. The remaining one-third of the items was open-constructed response items that required a written or drawn response from a student (OECD, 2006).

Most of the items are dichotomously scored either 1 credit or no credit. However, some of the complex multiple-choice and open-response items will involve partial scoring, that is, giving students credit for getting part of the question correct. For each partial credit item, a detail coding guide is provided. Because there are new units included in the PISA 2006 science test that assesses students' interest in learning about science or support for scientific enquiry, a unipolar response format such as “high interest”, “medium interest”, “low interest”, and “no interest” is used. Nevertheless, those items which involve students attitudes are not counted in the test score (OECD, 2006).

**Procedure.** The assessment takes place every three years, and the first assessment was in the year 2000 (OECD, 2006). The data that will be used in present study are PISA 2006, the third of three assessment cycles to date. Each cycle provides an in-depth look at one of the three domains and provides a summary profile of skills for the other domains. The major domain of 2006 was scientific literacy.

PISA items are arranged in units based around a common stimulus. The units of assessment in PISA 2006 consist of stimulus material including texts, tables and graphs followed by questions on various aspects of the text, table or graph to make students undertake the tasks as close as possible they are likely to encounter in the real world (OECD, 2009).

Each of the assessment areas of science, reading and mathematics has about 40% of the questions that required students to construct their own responses. This allowed the possibility of divergent individual responses and an assessment of students' justification of their viewpoints. Students would get partial credit for partly correct answers assessed by trained specialists using detailed scoring guides which gave direction on the codes to assign to various responses. There were two ways to ensure consistency in the coding process. First, a proportion of the questions were coded independently by four coders. Second, a sub-sample of student responses from each country was coded by an independent panel of expert coders in order to verify that the coding process was carried out in equivalent ways across countries (OECD, 2009).

A further 8% of the test questions were closed-constructed response questions which were scored as either correct or incorrect. The remaining 52% of questions were multiple-choice questions. In the multiple-choice format, students made either one choice from among four or five given alternatives or a series of choices by circling one of two optional responses in relation to each of a number of different propositions or statements (OECD, 2009).

PISA 2006 also included 32 questions associated with students' attitudes toward science. These questions required students to indicate their preferences or opinions

toward to science. Therefore, there was no right or wrong answers to these questions (OECD, 2009).

The main study items were allocated seven science clusters, two reading clusters and four mathematics clusters with each cluster representing 30 minutes of test time. The total assessment time of 390 minutes was organized in different combinations in thirteen tests booklets. Each student was randomly assigned one of these thirteen two-hour booklets composed of clusters (OECD, 2009).

### **Survey Design Weights and Plausible Values**

**Survey Design Weights.** Most surveys usually collect data from a sample rather than surveying the whole population. In the simplest case, each member of the target population has an equal chance of being selected. However, simple random sampling is not often used in large-scale national and international surveys. For instance, in some countries, it is not possible for researchers to identify all members of a target population because of the amount of time and budget this would take (Willms & Smith, 2005).

In sampling such population, biases may develop. For example, schools may not want to participate, and students may be absent on the day of the assessment. Generally, the sample design aims to help researchers get the results of their studies with the maximum precision, given the available resources (Willms & Smith, 2005).

To limit the size of the bias because of the non-response, international education surveys require a minimal student response rate. The minimum response rate of selected students within each school for PISA is 80% (OECD, 2009). If sampling units did not have the same probability of being selected as other units or if the population parameters

were estimated without taking these varying probabilities into account then bias may result. In order to compensate for these varying probabilities, data may need to be weighted (OECD, 2009). Design weights can make adjustment for the potential bias of non-response to the survey (Willms & Smith, 2005).

Weighting considers that some units in the sample are more important than others and contribute more to any population estimates. For example, a sampling unit with a small probability of being selected would be weighted as more important than a sampling unit with a high probability of being selected. Therefore, weights are inversely proportional to the probability of selection (OECD, 2009). According to Willms and Smith (2005), the role of the design weight is to eliminate or at least reduce these biases by weighting students differentially. The weight for a student should reflect the probability of his or her school being selected, and the probability of he or she being selected within those schools.

The sample is drawn in two stages. First stage, schools are drawn from a population of schools with a probability proportional to their size. In the second stage, a fixed number of students are sampled from within that school (Willms & Smith, 2005). The overall design weight used in present study was input into the multilevel regression package, HLM 6.05 (Raudenbush, Bryk, Cheong, & Congdon, 2004), to run a weighted multilevel regression analysis.

**Plausible Values.** PISA 2006 used a rotated-booklet design for testing students' scientific literacy. This means that each student completed only a small part of the whole set of test items. However, researchers are interested in giving a score to each student that is comparable across all students (Willms & Smith, 2005).

Plausible values are a representation of the range of abilities that a student might reasonably achieved if he or she had completed the whole test, and taking into account the measurement error in the test (Willms & Smith, 2005). In other words, the logic behind the plausible values consists of “mathematically computing distributions (denoted as posterior distributions) around the reported values and the reported length in the example; and assigning to each observation a set of random values drawn from the posterior distributions” (OECD, 2009, p. 95).

With HLM version 6.05 program (Raudenbush et al., 2004), there is an option to specify that there are plausible values to be taken into account. When the option is chosen, the analysis is replicated five times, one for each plausible value, and the correct standard errors for the regression coefficients are calculated (Willms & Smith, 2005).

## **Variables**

**Students’ interest in science.** The index of students' interest in science was derived from students’ level of interest in learning the following topics: (a) topics in physics; (b) topics in chemistry; (c) the biology of plants; (d) human biology; (e) topics in astronomy; (f) topics in geology; (g) ways scientists design experiments; and (h) what is required for scientific explanations (OECD, 2007). A four-point scale with the response categories “high interest”, “medium interest”, “low interest” and “no interest” was used. All items were inverted for Item Response Theory (IRT) scaling and positive values on this new index for PISA 2006 indicate higher levels of interest in science (OECD, 2007).

**School size.** The index of school size contains the total enrollment at school based on the enrollment data provided by the school principal, summing the number of males and females at a school. (OECD, 2007)

**School type.** Schools are classified as either public or private according to whether a private entity or a public agency has the ultimate power to make decisions concerning its affairs (OECD, 2007). The index of school type in PISA 2006 has three categories: (a) public schools controlled and managed by a public education authority or agency; (b) “government-dependent” private schools which principals reported to be managed by non-governmental organizations such as churches, trade unions or business enterprises and/or having governing boards consisting mostly of members not selected by a government agency and which receive 50% or more of their core funding from government agencies; and (c) “government-independent” private schools which principals reported to be controlled by a non-government organization or with a governing board not selected by a government agency which receive less than 50% of their core funding from government agencies (OECD, 2007, 2009).

### **Analytic Models**

The computer program HLM 6.05 (Raudenbush, et al., 2004) was chosen for this analysis because it is capable of producing multi-level models and is equipped to handle plausible values and sample weights (Willms & Smith, 2005).

**Null Model.** In the present study, the analyses began with a null model that was created for Canada to determine the extent to which observations within schools are correlated. This simplest analysis involves the use of one-way ANOVA with random effects (Raudenbush & Bryk, 2002). The null model is used to partition the variance in the dependent variable (e.g. scientific literacy) into within- and between-school components (Willms & Smith, 2005):

$$Y_{ij} = \beta_{0j} + r_{ij}$$

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where

$Y_{ij}$ , is the scientific literacy scores for student  $i$  in school  $j$ ;

$\beta_{0j}$  is the school mean scientific literacy;

$r_{ij}$  is unique error associated with the student  $i$  in school  $j$ ;

$\gamma_{00}$  is mean scientific literacy for all the schools in the sample; and

$u_{0j}$  is the unique error to the intercept associated with school  $j$  and has a variance of tau ( $\tau_{00}$ ).

The null model was used to answer how much do individual students differ around their school means? How much of total variance in scientific literacy is attributable to schools? How accurate an estimate of the population mean is the school mean  $\beta_{0j}$ ? Last, do school means vary significantly? Those questions were answered by examining the variance estimates for within schools and between schools. The intraclass correlation, which represents the proportion of variance in scientific literacy between schools, was examined.

**Random Coefficient Models.** The second step is to include Sex first into the student-level model in order to estimate the effect of Sex. The HLM is as follows.

$$\text{Student level: } Science_{ij} = \beta_{0j} + \beta_{1j}(Sex)_{ij} + r_{ij}$$

$$\text{School level: } \beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

where

$\beta_{1j}$  is the slope for Sex in school  $j$ ;

$\gamma_{10}$  is the across-school slope average.

By adding Sex into the student-level can derive the difference of the variance within school between this model and that of null model. Furthermore, whether the slopes for Sex ( $\beta_{1j}$ ) vary across schools can also be examined.

Similarly, the variance within school can be further reduced by adding other variables in student level in addition to Sex, which answers the variability in science achievement that can be further explained by these variables. The HLM model is as follows.

$$\begin{aligned}
 \text{Student level: } Science_{ij} = & \beta_{0j} + \beta_{1j}(Sex)_{ij} + \beta_{2j}(Students' \text{ interest in topics in physics})_{ij} \\
 & + \beta_{3j}(Students' \text{ interest in topics in chemistry})_{ij} \\
 & + \beta_{4j}(Students' \text{ interest in the biology of plants})_{ij} \\
 & + \beta_{5j}(Students' \text{ interest in topics in human biology})_{ij} \\
 & + \beta_{6j}(Students' \text{ interest in topics in astronomy})_{ij} \\
 & + \beta_{7j}(Students' \text{ interest in topics in geology})_{ij} \\
 & + \beta_{8j}(Students' \text{ interest in ways scientists design experiments})_{ij} \\
 & + \beta_{9j}(Students' \text{ interest in what is required for scientific explanations})_{ij} \\
 & + r_{ij}
 \end{aligned}$$

School level:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + u_{4j}$$

$$\beta_{5j} = \gamma_{50} + u_{5j}$$

$$\beta_{6j} = \gamma_{60} + u_{6j}$$

$$\beta_{7j} = \gamma_{70} + u_{7j}$$

$$\beta_{8j} = \gamma_{80} + u_{8j}$$

$$\beta_{9j} = \gamma_{90} + u_{9j}$$

where

$\beta_{1j}$  to  $\beta_{9j}$  are the parameters of student-level variables;

$\gamma_{10}$  to  $\gamma_{90}$  are the across-school slope averages;

$u_{1j}$  to  $u_{9j}$  are the errors to the intercept and level-1 gradients associated with school j.

**Intercepts- and Slopes-as-Outcomes Model.** The intercepts- and slopes-as-outcomes model allows us to model the variability of the regression coefficients (both intercepts and slopes) (Raudenbush & Bryk, 2002).

Student level:

$$\begin{aligned} Science_{ij} = & \beta_{0j} + \beta_{1j}(Sex)_{ij} + \beta_{2j}(Students' interest in topics in physics)_{ij} \\ & + \beta_{3j}(Students' interest in topics in chemistry)_{ij} \\ & + \beta_{4j}(Students' interest in the biology of plants)_{ij} \\ & + \beta_{5j}(Students' interest in topics in human biology)_{ij} \\ & + \beta_{6j}(Students' interest in topics in astronomy)_{ij} \end{aligned}$$

$$\begin{aligned}
& + \beta_{7j}(\textit{Students' interest in topics in geology})_{ij} \\
& + \beta_{8j}(\textit{Students' interest in ways scientists design experiments})_{ij} \\
& + \beta_{9j}(\textit{Students' interest in what is required for scientific explanations})_{ij} \\
& + r_{ij}
\end{aligned}$$

School level:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\textit{School size}) + \gamma_{02}(\textit{School type}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\textit{School size}) + \gamma_{12}(\textit{School type}) + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(\textit{School size}) + \gamma_{22}(\textit{School type}) + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}(\textit{School size}) + \gamma_{32}(\textit{School type}) + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}(\textit{School size}) + \gamma_{42}(\textit{School type}) + u_{4j}$$

$$\beta_{5j} = \gamma_{50} + \gamma_{51}(\textit{School size}) + \gamma_{52}(\textit{School type}) + u_{5j}$$

$$\beta_{6j} = \gamma_{60} + \gamma_{61}(\textit{School size}) + \gamma_{62}(\textit{School type}) + u_{6j}$$

$$\beta_{7j} = \gamma_{70} + \gamma_{71}(\textit{School size}) + \gamma_{72}(\textit{School type}) + u_{7j}$$

$$\beta_{8j} = \gamma_{80} + \gamma_{81}(\textit{School size}) + \gamma_{82}(\textit{School type}) + u_{8j}$$

$$\beta_{9j} = \gamma_{90} + \gamma_{91}(\textit{School size}) + \gamma_{92}(\textit{School type}) + u_{9j}$$

After running the first series of models, non-significant variables were removed and then the models were run once again. The resulting final models are discussed in the next chapter.

## **Chapter Four: Results**

The PISA 2006 dataset was used to analyze the relationship among variables at both the student and school levels, that influenced science achievement in Canada. Descriptive and correlational statistics were analyzed using SPSS 17 and two-level models were run using HLM 6.08. Student levels were comprised of sex and students' interest in science. School level variables were school size and school type. In this section, student and school level descriptive statistics, correlations, and HLM models for Canadian students are presented.

The Canadian data were collected from 22,646 15-year-old students in 896 schools. There were 11,542 females and 11,104 males with 2641 missing cases.

### **Descriptive Statistics**

The descriptive statistics for the variables at the student level (Table 1) and at the school level (Table 2) provide a basic understanding of the tendency and characteristics of the data.

Table 1

*Descriptive Statistics of Student Variables Used in Level-1 HLM*

	Minimum	Maximum	Mean	Std. Deviation
Sci interest - Physics	1	4	2.62	.95
Sci interest - Chemistry	1	4	2.80	.98
Sci interest - Plant biology	1	4	2.53	.94
Sci interest - Human biology	1	4	2.92	.97
Sci interest - Astronomy	1	4	2.64	.99
Sci interest - Geology	1	4	2.35	.89
Sci interest - Experiments	1	4	2.41	.93
Sci interest - Explanations	1	4	2.17	.89
Science Achievement	126.11	834.97	522.50	95.66

The mean scientific literacy is 522.50 in Canada. For the variable of sex, 1 = female and 2 = male. The questionnaire items in the PISA 2006 that assess students' interest in learning science used a unipolar response format from 1 to 4 (OECD, 2006). For example, if a student responded he/she had "no interest" in learning science, he/she would get a score of 1 in the scale. If a student indicated he/she had "high interest" in learning science, he/she would get a score of 4 in the scale after formatting.

The descriptive statistics and graphic representations (Appendix B) for student-level variables show that the distributions are approximately normal and consistent.

Table 2

*Descriptive Statistics of School Variables Used in Level-2 HLM*

	Minimum	Maximum	Mean	Std. Deviation
School Type	1	2	1.08	.27
School Size	10	3225	766.64	516.10

Table 2 presents the descriptive statistics for school-level variables used in the level-2 equations. For the variable of school type, 1 = public and 2 = private in the PISA 2006 Canadian data. The descriptive statistics and graphic representations (Appendix B) for school-level variables show most participant Canadian schools are public schools and most of schools have slightly fewer than 2,500 students each.

Table 3

*Correlations between Student Variables Used in Level-1 HLM*

	1	2	3	4	5	6	7	8	9	10
1.Sex	1									
2. Physics	.106**	1								
3.Chemistry	-.014*	.551**	1							
4.Plant-Biology	-.166**	.252**	.386**	1						
5.Human biology	-.276**	.268**	.377**	.623**	1					
6.Astronomy	-.010	.291**	.337**	.361**	.334**	1				
7.Geology	.018**	.343**	.349**	.452**	.372**	.559**	1			
8.Experiments	.091**	.409**	.438**	.340**	.294**	.324**	.421**	1		
9.Explanations	.051**	.439**	.461**	.394**	.340**	.317**	.425**	.696**	1	
10.Achievement	.007	.253**	.302**	.137**	.196**	.231**	.174**	.100**	.127**	1

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

The correlations between science achievement, students' sex, and students' interest in learning science are presented in Table 3. The intercorrelation matrices do not indicate any multicollinearity between the variables. The correlations between science achievement and students' interest in learning science at student level indicate that students' interest in learning science has a significantly positive correlation on science achievement. However, students' sex and scientific literacy has a very low correlation near 0.

Table 4

*Compare means of school type and school size*

<u>School Size</u>			
School Type	Mean	N	SD
Public	784.70	750	517.32
Private	548.19	62	450.24
Total	766.64	812	516.10

Table 4 presents the school size means between public and private school in Canada. The average population of public school is 785 students and 548 students in private schools. In other words, public schools have bigger school population than private ones.

### **Results from HLM Models**

The results of the HLM models are presented in Table 5-8. Variables that were statistically nonsignificant were dropped from the model. In addition, non-significant variance components ( $u_{ij}$ ) were removed after running the analyses.

**Null Models.** The null model is unconditioned in that no student or school level variables are entered in the model.

$$\text{Student level: } Science_{ij} = \beta_{0j} + r_{ij}$$

$$\text{School level: } \beta_{0j} = \gamma_{00} + u_{0j}$$

Table 5

*Output of the Null Model*

<u>Variables</u>	<u>Parameters Estimate</u>			
	<u>Coefficient</u>	<u>SE</u>	<u>t</u>	<u>p</u>
<u>Fixed Effects</u>				
Science Intercept ( $\gamma_{00}$ )	523.19	1.63	320.47	<.001
<u>Random Effects</u>				
	<u>Variance Component</u>	<u>SD</u>	<u><math>\chi^2</math></u>	<u>p</u>
School-Level Effect ( $u_{0j}$ )	1772.06	42.13	5041.77	<.001
Student-Level Effect ( $r$ )	7439.19	86.25		

*Note.* Reliability estimate of school mean scientific literacy score = .82

$$\text{Variance attributable to schools} = \frac{1772.06}{1772.06 + 7439.19} = .19$$

School means are significantly different one school to another ( $p < .001$ ). The student-level variability in scientific literacy is estimated at 7439.19 while the school-level variability is estimated at 1772.06. This yielded an intraclass coefficient of .19, showing that about 19% of the total variability in scientific literacy could be attributed to schools (i.e. between-schools variance). The science intercept is 523.19 ( $SE = 1.63$ ). There is significant variation in school means ( $\tau_{00} = 1772.06$ ,  $p < .001$ ). The reliability of this estimate is .82, indicating that the sample means tend to be quite reliable as indicators of the true school means.

**Random Coefficient Models.** Table 6 shows the results of the random coefficient model with students' sex in the level-1 model. Including students' sex first into the student-level model is to estimate the effects of students' sex.

$$\text{Student level: } Science_{ij} = \beta_{0j} + \beta_{1j}(SEX)_{ij} + r_{ij}$$

$$\text{School level: } \beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

Table 6

*Output of the Random Coefficient Models Including Sex*

<u>Variables</u>	<u>Parameters Estimate</u>			
	<u>Coefficient</u>	<u>SE</u>	<u>t</u>	<u>p</u>
<u>Fixed Effects</u>				
Science Intercept ( $\gamma_{00}$ )	518.06	2.47	209.83	<.001
<u>Within-School Effects</u>				
Sex ( $\gamma_{10}$ )	3.43	1.37	2.50	0.013
<u>Random Effects</u>				
	<u>Variance Component</u>	<u>SD</u>	$\chi^2$	<u>p</u>
School-Level Effect ( $u_{0j}$ )	1775.61	42.14	5047.89	<.001
Student-Level Effect ( $r$ )	7436.18	86.23		

Note. Student-level variance accounted for by Level 1 predictors =  $\frac{7439.19 - 7436.18}{7439.19} = 0.0004$

Table 6 shows the results of the models with students' sex included at student level. The science intercept is estimated at 518.06 with  $p < .001$ . At student level, a male student is predicted to score 3.43 units ( $p < .05$ ) more than a female student. About 0.04% of the variability in students' science achievement is explained by the variables modeled. It means that SEX accounts for about 0.04% of the student-level variance in the outcome. At school level, the slope for SEX is statistically homogeneous across schools in Canada (i.e., nonsignificant variance of SEX gradient).

In addition to SEX, seven students' interest related variables are added to the

student-level model in order to investigate the variability in science achievement that can be further explained by these eight variables.

$$\begin{aligned}
 \text{Student level: } Science_{ij} = & \beta_{0j} + \beta_{1j}(Sex)_{ij} + \beta_{2j}(Students'interest\ in\ topics\ in\ physics)_{ij} \\
 & + \beta_{3j}(Students'interest\ in\ topics\ in\ chemistry)_{ij} \\
 & + \beta_{4j}(Students'interest\ in\ the\ biology\ of\ plants)_{ij} \\
 & + \beta_{5j}(Students'interest\ in\ topics\ in\ human\ biology)_{ij} \\
 & + \beta_{6j}(Students'interest\ in\ topics\ in\ astronomy)_{ij} \\
 & + \beta_{7j}(Students'interest\ in\ topics\ in\ geology)_{ij} \\
 & + \beta_{8j}(Students'interest\ in\ ways\ scientists\ design\ experiments)_{ij} \\
 & + r_{ij}
 \end{aligned}$$

$$\text{School level: } \beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50} + u_{5j}$$

$$\beta_{6j} = \gamma_{60} + u_{6j}$$

$$\beta_{7j} = \gamma_{70}$$

$$\beta_{sj} = \gamma_{80}$$

Table 7 shows the result of the model including SEX and students' interest in learning science related topics as student-level predictors. At student level, there is significant sex gap ( $b = 6.11, p < .001$ ), a male student predicts a higher science score by 6.16 points than a female student after other variables are fixed. In addition, Table 7 shows students' interest in learning science is related with their scientific literacy significantly. Students who have higher interests in learning topics of physics, chemistry, human biology, astronomy, and geology are predicted to achieve higher science scores than those students who held lower interests in learning these subjects. On the contrary, students who show higher interests in learning the biology of the plants or the ways scientists design experiments are predicted to achieve lower in science.

At school level, SEX slope, interest in physics slope, interest in human biology slope, and interest in astronomy slope vary significantly among schools in Canada. About 16% of the variability in students' science achievement is explained by the variables modeled.

Table 7

*Output of the Random Coefficient Models Including Sex and Students' Interest in Learning Science*

<u>Variables</u>	<u>Parameters Estimate</u>			
	<u>Coefficient</u>	<u>SE</u>	<u>t</u>	<u>p</u>
<u>Fixed Effects</u>				
Science Intercept ( $\gamma_{00}$ )	405.35	3.66	110.68	<.001
<u>Within-School Effects</u>				
Sex ( $\gamma_{10}$ )	6.11	1.34	4.55	<.001
Interest in Physics ( $\gamma_{20}$ )	11.47	0.85	13.46	<.001
Interest in Chemistry ( $\gamma_{30}$ )	18.32	0.78	23.46	<.001
Interest in Biology of Plants ( $\gamma_{40}$ )	-4.10	0.84	-4.88	<.001
Interest in Human Biology ( $\gamma_{50}$ )	7.71	0.85	9.08	<.001
Interest in Astronomy ( $\gamma_{60}$ )	12.08	0.80	15.19	<.001
Interest in Geology ( $\gamma_{70}$ )	1.92	0.86	2.23	0.03
Interest in Ways Scientists ( $\gamma_{80}$ )	-8.63	0.75	-11.47	<.001
Design Experiments				
<u>Random Effects</u>	<u>Variance</u>	<u>SD</u>	<u><math>\chi^2</math></u>	<u>p</u>
	<u>Component</u>			
School-Level Effect ( $u_{0j}$ )	2318.18	48.15	939.46	<.001
Sex Slope ( $u_{1j}$ )	155.11	12.45	814.22	0.02
Interest in Physics Slope ( $u_{2j}$ )	82.78	9.10	832.00	0.01
Interest in Human Biology Slope ( $u_{5j}$ )	46.04	6.79	794.24	0.05

Interest in Astronomy Slope ( $u_{6j}$ )	65.13	8.07	808.79	0.02
Student-Level Effect ( $r$ )	6262.08	79.13		

---

Note. Student-level variance accounted for by Level 1 predictors =  $\frac{7439.19 - 6262.08}{7439.19} = 0.16$

### Intercepts- and Slopes-as-Outcomes Models.

$$\begin{aligned}
 \text{Student level: } Science_{ij} = & \beta_{0j} + \beta_{1j}(\text{Students' interest in topics in physics})_{ij} \\
 & + \beta_{2j}(\text{Students' interest in topics in chemistry})_{ij} \\
 & + \beta_{3j}(\text{Students' interest in topics in human biology})_{ij} \\
 & + \beta_{4j}(\text{Students' interest in topics in astronomy})_{ij} \\
 & + \beta_{5j}(\text{Students' interest in ways scientists design experiments})_{ij} \\
 & + r_{ij}
 \end{aligned}$$

$$\text{School level: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{School type}) + \gamma_{02}(\text{School size}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30} + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}(\text{School type}) + \gamma_{42}(\text{School size}) + u_{4j}$$

$$\beta_{5j} = \gamma_{50}$$

Table 8 displays the output of the final models for Canada. The average school science achievement intercept is estimated at 405.34 ( $p < .001$ ). The intercept pertains to average school scores; private schools have higher average science scores by nearly 67

points. As school size increases by 1 student, average school science achievement increases by 0.03 points.

At student level, students' interest in learning topics of physics increases 1 unit, their average science achievement increase by 16 points. As students' interest in learning chemistry increase 1 unit, their average science scores increase nearly 25 points. Similarly, students' interest in learning human biology increase 1 unit, so do their science scores by approximately 9 points. For the interest in astronomy slope, the intercept, school type and size are significant; it means a student is predicted to achieve higher science scores by 25 points with his/her interests in learning astronomy increase 1 unit, and students who attend public schools, their science achievement are higher by 9 points. In addition, the school size decreases 1 unit, students' average science scores increase 0.005 points. Students' interest in ways scientists design experiments decrease 1 unit, their average science scores increase about 10 points.

The variables of student's sex, interest in biology of plants, and interest in geology show statistically significant at student level in the random coefficient models but those three variables are not significant in the final model.

At school level, school average science scores, sex slopes, interest in physics slopes, interest in human biology slopes, interest in astronomy slopes, and interest in what is required for scientific explanations slopes vary significantly among schools in Canada. About 24% of the estimated between-school variability in scientific literacy is explained by the modeled school-level correlates.

Table 8

*Output of the Final Model for Scientific Literacy for Canada*

<u>Variables</u>	<u>Parameters Estimate</u>			
	<u>Coefficient</u>	<u>SE</u>	<u>t</u>	<u>p</u>
<u>Fixed Effects</u>				
Science Intercept ( $\gamma_{00}$ )	405.34	3.67	110.45	<.001
School Type Slope ( $\gamma_{01}$ )	67.24	13.93	4.83	<.001
School Size Slope ( $\gamma_{02}$ )	0.03	0.01	4.71	<.001
<u>Within-School Effects</u>				
Interest in Physics ( $\gamma_{10}$ )	16.36	4.51	3.63	<.001
Interest in Chemistry ( $\gamma_{20}$ )	24.82	3.89	6.37	<.001
Interest in Human Biology ( $\gamma_{30}$ )	8.50	3.40	2.13	0.03
Interest in Astronomy ( $\gamma_{40}$ )	25.13	3.44	7.31	<.001
School Type Slope ( $\gamma_{41}$ )	-8.54	2.65	-3.23	<.001
School Size Slope ( $\gamma_{42}$ )	-0.005	-0.002	-3.06	<.001
Interest in Ways Scientists Design Experiments ( $\gamma_{50}$ )	-10.20	4.31	-2.37	0.02
<u>Random Effects</u>				
	<u>Variance Component</u>	<u>SD</u>	<u><math>\chi^2</math></u>	<u>p</u>
School-Level Effect ( $u_{0j}$ )	1935.03	43.99	901.68	<.001
Interest in Physics Slope ( $u_{1j}$ )	88.98	9.43	799.01	0.02
Interest in Human Biology Slope ( $u_{3j}$ )	50.19	7.08	805.83	0.01
Interest in Astronomy Slope ( $u_{4j}$ )	58.57	7.65	805.71	0.01
Student-Level Effect ( $r$ )	6231.89	78.94		

*Note.* School-level variance in scientific literacy accounted for by school correlates =

$$\frac{1935.03}{1935.03 + 6231.89} = .24$$

$$\text{Student-level variance accounted for by Level 1 predictors} = \frac{7439.19 - 6231.89}{7439.19} = .16$$

## **Chapter Five: Discussion**

In 2006, PISA of the OECD focused mainly on measuring scientific literacy. In the present study, HLM was used to measure scientific literacy within and between schools in Canada. Nine student level variables and two school level variables were analyzed against the outcome variable of scientific literacy. In this section, research questions are posed to provide more insight on topics such as scientific literacy differences due to sex differences, the level of students' interest in learning science, school type, and school size.

In the present study, school means of scientific literacy are statistically significant in both the student- level and the school- level. In other words, there are significant differences of average school science scores within schools and between schools.

### **Do Sex Differences Exist in Scientific Literacy?**

The total variance in scientific literacy was partitioned into within- and between-school component. About 19% of the total variance in students' scientific literacy is attributed to schools and there is significant variation in school means.

Trumper (2006) identified a number of factors affecting students' scientific literacy in general. These can be largely categorized as students' sex, personality traits, structural variables, and curriculum variables. Of these, the most significant is students' sex. Do sex differences also affect Canadian students' scientific literacy significantly?

To answer the first research question of this study, there are sex differences in students' scientific literacy in Canada while controlling all other variables (Table 8). Students' sex is a significant but small effect predictor of 15-year-old scientific literacy. At the student-level (Table 6), male students were shown to outperform female students

with 3.43 units in scientific literacy while other variables were controlled. This finding is consistent with more recent research that indicates that trends still favour males in scientific literacy (Özel, Erdoğan, Uşak, & Prokop, 2009; Viadero, 2009). In addition, for the OECD countries as a whole, there was a statistically significant difference of two score points between the mean scores of male and female students in favour of males (OECD, 2007). In the first model, Canada has slightly higher differences in related to students' sex than the OECD countries as a whole while there was only one variable.

In the second model of the present study, the gap between male and female was increased after the variables of students' interest in learning scientific related subjects were controlled. Male students outperform female students to 6.11 units in scientific literacy while conditioning students' interest in learning science. This finding is consistent with prior research. Studies have shown that girls and boys have different interests in learning science (Jones & Howe, 2000; Osborne, Simon, & Collins, 2003). Kotte (1992) reported that beginning as early as elementary school and through high school, boys have typically possessed more interest in studying science than girls. In addition, there are sex differences in scientific literacy between schools in the second model.

However, when the school size and school type variables were entered into the level-2 equations, students' sex became nonsignificant at level 1. This means that male students and female students who attend the same kind of school have no significant differences in their scientific literacy while interest is controlled.

### **Is there a relationship between students' interest and scientific literacy?**

From the results, the level of student interest in learning science-related topics in

most subjects (e.g. Physics, Chemistry, Human Biology, Astronomy, and Geology) is shown to have a significant positive relationship with scientific literacy. Students who are one unit more interested in Physics, Chemistry, and Astronomy are predicted to achieve more than 10 units in scientific literacy. Particularly in Chemistry, when students' interest in learning this subject increases by one level, their scientific literacy increases by 18.32 units. This result echoes the finding of Barr, Matsui, Wanat, & Gonzalez (2010) research; they stated that chemistry courses are the major factor that affects students' learning in science more than other subjects. Students who reported less interest in chemistry courses performed weakly in their scientific literacy and tended to abandon their hopes of becoming a scientist.

However, not all of the subjects have significant positive relationships with scientific literacy in the present study. The level of students' interest in learning Biology of Plants and Ways Scientists Design Experiments is shown to have a significant negative relationship with students' scientific literacy. As students' interest in learning Biology of Plants and Ways scientists design experiments increase by one level, scientific literacy decreases by 4.10 and 8.63 units. Such a result may be explained by the contents of Biology of Plants and Ways scientists design experiments are less associated with the scientific literacy we know today.

After school type and school size variables were entered into the level-2 equations to account for between-school variability in scientific literacy while controlling for contextual student-level variables, students' interest in learning Geology and Biology of Plants became nonsignificant in students' scientific literacy. Particularly in students' interest in learning the Astronomy slope, the results in this study show that students who

are interested in learning astronomy, attend public schools, and go to smaller schools, tend to have higher scientific literacy.

To sum up, students' interest in learning science is an important factor associated with their scientific literacy according to the findings of the present study. Students who have higher level interests in learning specific scientific domains such as Physics, Chemistry, Human Biology, Astronomy, and Geology tend to have better scores in scientific literacy.

### **Is there any association between school size, school type, and scientific literacy?**

School-level variables were entered into the level-2 equations to account for between-school variability in scientific literacy. In the final model, school variables such as school type and school size are shown to be statistically significant in students' scientific literacy. The average of school science achievement varies significantly across schools in Canada. For the school type variable, the result in this study shows that private schools outperform public schools in scientific literacy by 67.24 points when controlling for students' sex, interest in learning science, and school size. This is consistent with previous research that shows private schools have a more positive impact on students' scientific literacy than public schools do (Gamoran, 1996).

Only a few researchers have delved into how public and private schools differ and how these differences translate into student achievement. Gamoran (1996) explains that public schools typically lack specific programs of study and offer little academic counselling; as a result, students often choose their courses haphazardly and see no connection between their schoolwork and their lives outside of the classroom. Students' lack of engagement with schoolwork is often accompanied by weak academic performance

and discipline problems, resulting in a poor and sometimes unsafe climate for learning. In addition, private school students are more attached to their schools. Gamoran determines that these differences could explain a slight advantage that he found for private schools students. More recently, Lubienski, Lubienski, and Crane (2008b) found that small classes were more common in private schools and this was positively correlated with student achievement. Interestingly, the results of the present study also found that students who attend public schools have higher interests in learning astronomy.

There is a popular perception that private schools are superior to public schools. It is this perception, at least in part, that has led to the many school-choice proposals across the nation. Despite the pervasiveness of this opinion and these plans, researchers have struggled to confirm the existence of a private school effect using quality statistical methods. Over the years, researchers have used numerous datasets and methods to address this question, but the results of these efforts have been underwhelming. At best, it appears that some private schools may benefit some students, but the effects are not great. Even when researchers have found evidence of a private school effect, few have been able to address the question of why private schools may be superior to public schools. This is an important concern for two key reasons. First, if we can identify the reason(s) that private schools are superior to public schools, we should have more confidence in the fact that private school effects are just that, and not uncontrolled selection bias. Second, if we know how private schools are superior to public schools, we may be able to use this knowledge to improve public schools.

For the school size variable, the results of this study show that students who attend bigger schools are predicted to have higher scientific literacy than students who attend

smaller schools. The population of a school increases by 100 students, scientific literacy increases by 3 units when controlling for students' sex, interest in learning science, and school type. This is inconsistent with previous research that shows small schools have positive effects on students' achievement.

### **Limitations**

It is important to interpret the results while keeping in mind that there are several limitations. Firstly, limitations associated with secondary data analysis may lead researchers to make assumptions about how the data were originally collected and which variables are appropriately grouped together, and may leave researchers restricted to the indices they can analyze (Trochim, 2006). Secondly, the questionnaire items may be too general and more appropriate for wide-ranging analysis, but not for examining any one variable in depth.

Thirdly, students' interest in science is difficult to measure in an accurate way. The PISA 2006 assessed students' interest in science by posing questions in the student questionnaire and in contextualized test items. For these assessments, a four-point scale with the response categories "high interest", "medium interest", "low interest" and "no interest" was used.

Lastly, secondary data analysis of a large national dataset does not allow causal interpretation of the school effects. That is, the HLM analyses of these students are correlational and nonexperimental. Although results in the present study have sometimes been described as effects, it was not possible to provide empirical evidence of causal direction.

### **Suggestions for Future Research**

The results in this study are limited to the 15-year-old samples in Canada. It is suggested that future researchers should investigate the relationships between scientific literacy, students' sex, students' interest in science, and school characteristics of different age groups and countries to check if there is any pattern in these relationships across age and countries.

In addition, scientific literacy was the outcome variable in this study. As a result, it would be possible to evaluate differences between students' interest in science and other variables. One of the ways researchers could analyze these differences would be to change the outcome variable to students' interest in science to check if there are differences between male and female students, or between different school types or sizes.

In particular, more research is needed to determine not only how the average public school compares to the average private school, but also how particular types of private schools (e.g., Catholic schools) compare to particular types of public schools (e.g., charter schools). In addition, future research should address how different types of schools compare for different types of students (e.g., low-performing students).

### **Policy Implications**

The major implication of this study for educators and policy makers is that students' interest in learning plays an important role in students' science achievement. A positive relationship between students' interest in learning science-related topics and their scientific literacy is shown in most subjects (e.g. Physics, Chemistry, Human Biology, Astronomy, and Geology).

The current study makes three recommendations for enhancing students' interest in

learning science-related subjects. The first recommendation is to have more science laboratory activities within schools science curricula to enhance students' interest in learning science to further their learning outcomes. The laboratory has been given a central and distinctive role in science education, and science educators have suggested that rich benefits in learning accrue from using laboratory activities (Hofstein & Lunetta, 2004; Kieff, 2005). As Hofstein and Lunetta (2004) suggest, laboratory activities have the potential to increase students' interest in science. Through these activities, students also get practical knowledge and abilities in science.

The second recommendation for teachers is to use appropriate instruments to assist their teaching in science (Radosevich, Salomon, Radosevich, & Kahn, 2008). Trumper (2006) mentioned that technological tools have a positive effect on students' interest in learning science-related subjects. To enhance students' interest in successful learning, instructors could use more and appropriate technological tools and instruments in science classrooms.

The last recommendation for enhancing students' interest in learning science is to bridge life experiences and learning about science for students (Shu-Nu Chang, Yau-Yuen Yeung, & Cheng, 2009). To help motivate students, teachers should, instead, choose fun, interesting, relevant, and current topics. Making more connections between science-related subjects and students' daily life experiences would increase students' interest in learning science (Kieff, 2005).

As for reducing the gap between male and female students in scientific literacy, Halpern and colleagues (2007) summarize research on various strategies for encouraging girls in science. They suggest that instructors could (1) teach students that academic

abilities are not fixed, but expandable and improvable; (2) expose girls to female role models who have succeeded in science; and (3) provide informational feedback. Through these three strategies, girls would have more confidence in science.

### **Conclusion**

The aim of this study was to uncover the relationship between scientific literacy and students' sex and students' interest in learning science-related subjects. Additionally, the predictive effects for school types and school sizes on scientific literacy were further explored in Canada.

The results of the present study show there is a significant sex difference in scientific literacy in Canada at the student level. However, at the school level, there is no sex difference across schools in Canada.

In this study, students' interest in learning science is related to their scientific literacy significantly. Students who have a higher interest in learning the subjects of physics, chemistry, human biology, astronomy, and geology are predicted to achieve higher science scores than those students who have less interest in learning these subjects. Nevertheless, students who show higher interests in learning the biology of the plants or the ways scientists design experiments are predicted to achieve lower scores in science. At the school level, there are significant sex differences and differences in students' interest in physics, human biology, and astronomy among schools in Canada.

In terms of the school characteristics variables, students who attend public schools have better scientific literacy scores. Also, students who go to bigger schools significantly outperform in scientific literacy.

To conclude, students' sex, interests in learning science-related subjects, and school

characteristics all have significant effects on students' scientific literacy. Researchers should continue to monitor academic achievement gaps, and identify other school correlates of achievement from the PISA survey to better inform policy makers.

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## Appendix A

## Item Descriptors of Students' Interest in Science Learning

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PISA 2006 Item	How much interest do you have in learning about the following <broad science> topics?
ST21Q01	a) Topics in physics
ST21Q02	b) Topics in chemistry
ST21Q03	c) The biology of plants
ST21Q04	d) Human biology
ST21Q05	e) Topics in astronomy
ST21Q06	f) Topics in geology
ST21Q07	g) Ways scientists design experiments
ST21Q08	h) What is required for scientific explanations

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Appendix B

Histograms of All Student-level and School-level Variables

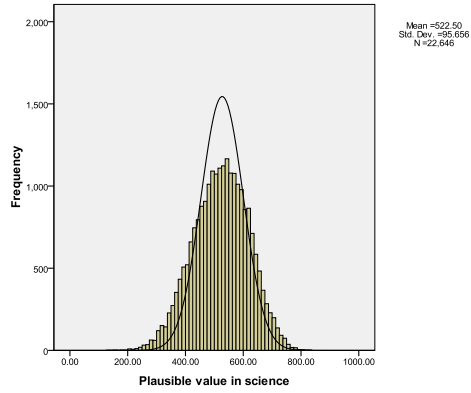


Figure A1. Histogram of plausible value in science with normal curve.

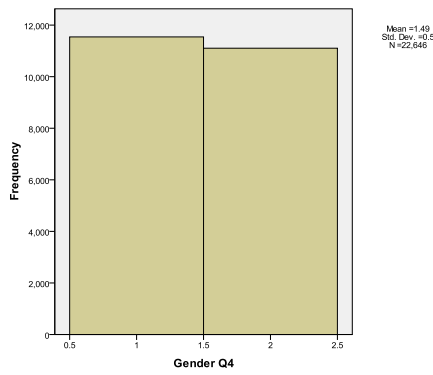


Figure A2. Histogram of sex.

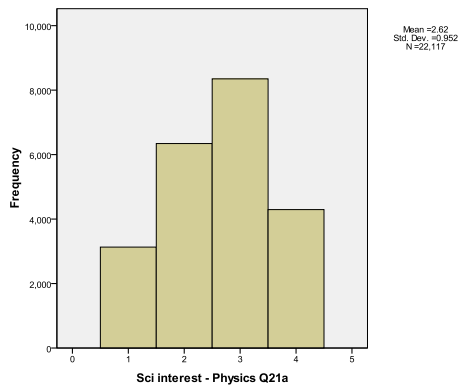


Figure A3. Histogram of students' interest in learning physics.

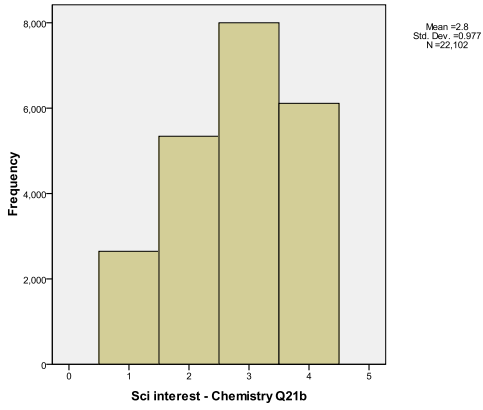


Figure A4. Histogram of students' interest in learning chemistry.

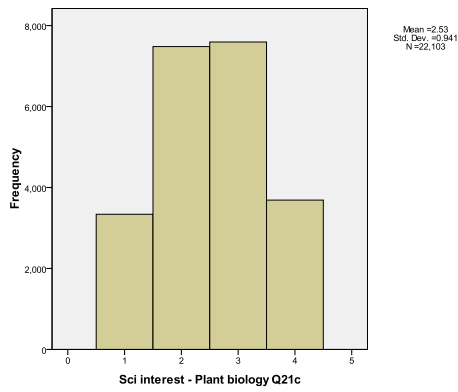


Figure A5. Histogram of students' interest in learning biology of plants with normal curve.

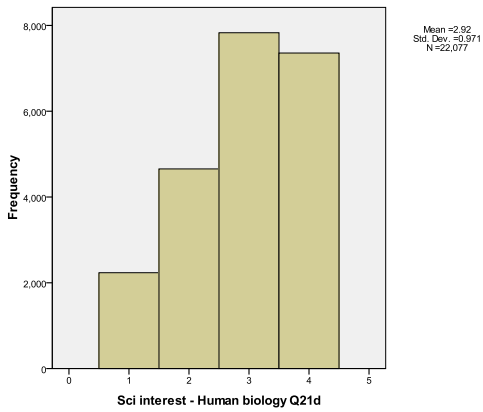


Figure A6. Histogram of students' interest in learning human biology with normal curve.

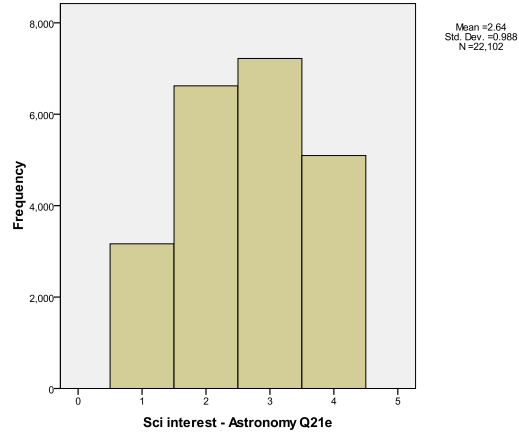


Figure A7. Histogram of students' interest in learning astronomy with normal curve.

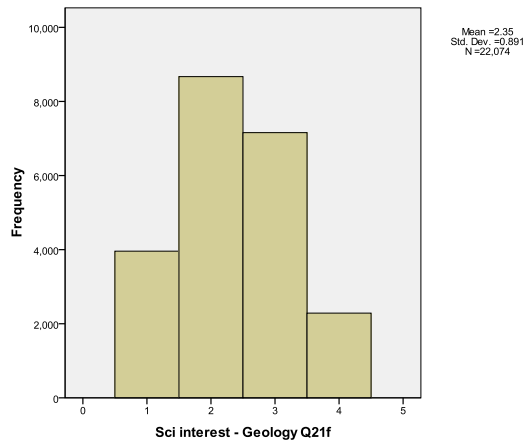


Figure A8. Histogram of students' interest in learning geology with normal curve.

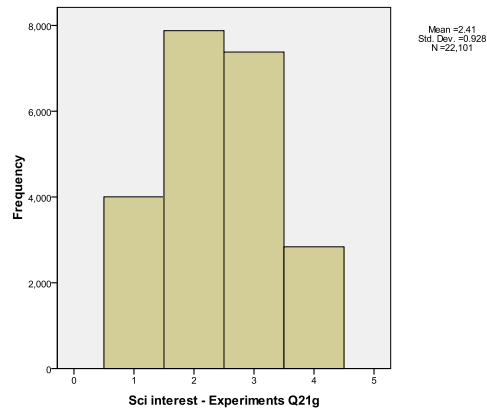


Figure A9. Histogram of students' interest in learning ways scientists design experiments with normal curve.

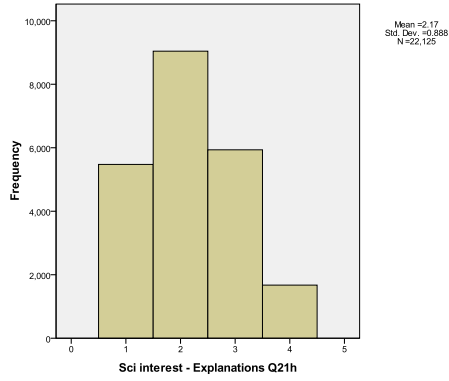


Figure A10. Histogram of students' interest in learning what is required for scientific explanations with normal curve.

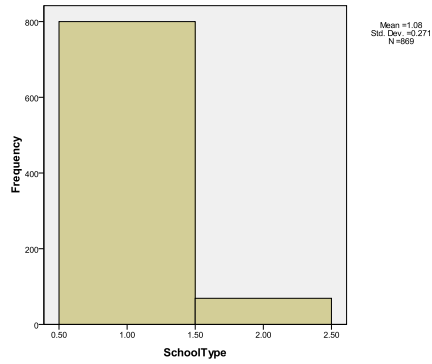


Figure A11. Histogram of school type with normal curve.

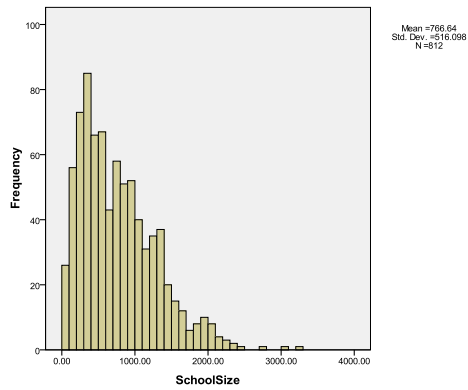


Figure A12. Histogram of school size with normal curve.