WHO LIKES SCIENCE AND WHY?

INDIVIDUAL, FAMILY, AND TEACHER EFFECTS

by

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Abstract

The worldwide concern towards declining interest in science and technology among young people is shared by Canadian educators, as ongoing progress requires a science literate population from which top research talent can grow. This study is grounded in the optimistic premise that the “genuine curiosity” and “spontaneous interest” of children offer a reliable foundation on which to grow an attitude of “liking of science” over the school years. The research employs the 2004 School Assessment Indicators Programme (SAIP) surveys developed by the Council of Ministers of Education Canada, which aim to capture the general level of science literacy, knowledge of science concepts, ability to apply science to everyday situations, and understanding of the nature of science among 13 and 16-year-old students. It is certainly discouraging to find that, although over 85% of students in this study agree that science is useful for society, too many remain disengaged from the process of science learning; in fact, less than 40% expect to use science in their careers. In addressing the issue of student disengagement, this study examines the role of the three principal actors in the process of acquiring scientific literacy: teachers, parents, and the students themselves. It builds on previous research which indicates that participation and success in mathematics and science, either at the level of literacy or further pursuit of related careers, involves not only skills and knowledge, but is largely determined by positive attitudes toward these disciplines during school years. Findings show the prevalent impact of student factors on outcomes and the specific role of parents (e.g., parental encouragement and expectations) in shaping students’ attitudes, as well as that of teachers (e.g., qualification and attitudes) in enhancing test performance. Students’ attitudes toward school, decisions for post-secondary education, satisfaction with school results in science and interest in working in fields based on math and science education constitute the main determinants of outcomes. Although making science more attractive for students is a goal that needs to be considered and addressed by educators, there are inherent requirements within this field in order to grow one’s knowledge and skills continuously, which call for students themselves to adopt more positive and responsible attitudes. In short, science culture and youth culture have to be connected.

Résumé

Un sujet qui suscite inquiétude au Canada comme partout dans le monde, c'est le désintérêt de la jeune génération pour les matières scientifiques. La poursuite du progrès économique ne peut être menée que si on dispose d'une population ayant une culture scientifique dont on pourra identifier le talent pour les sciences. Cette étude est basée sur la prémisse optimiste que la "curiosité" et "l'intérêt spontanée" de l'enfant offrent une base solide pour construire "le goût de la science" pendant les années scolaires. Le Programme d'indicateurs du rendement scolaire 2004 (PIRS) développé par le Conseil des ministres de l'Éducation du Canada vise à évaluer le niveau général de la connaissance scientifique, l'acquisition des concepts scientifiques, la capacité à appliquer la science aux situations quotidiennes et la compréhension de la nature des sciences chez les élèves de 13 et de 16 ans. Cette étude utilise les données des questionnaires du PIRS, administrés aux étudiants et enseignants, qui contiennent des informations sur les facteurs déterminants dans le processus d'apprentissage des sciences et de la formation des attitudes envers la science. C'est certainement décourageant de voir que, même si 85% des élèves considèrent que la science est utile pour la société, beaucoup d'entre eux ne sont pas intéressés à l'apprendre; en fait, moins de 40% d'entre eux s'attendent à utiliser la science dans leurs carrières futures. Pour adresser le problème du désintérêt des jeunes à l'égard de la science, cette étude examine le rôle des trois acteurs principaux dans le processus d'assimilation des connaissances scientifiques: les enseignants, les parents et les élèves eux-mêmes. Des études indiquent que la participation et le succès en mathématiques et en sciences, que ce soit au niveau général ou au niveau de la poursuite d'une carrière scientifique, nécessite l'acquisition de connaissances et d'habiletés, mais demeure aussi largement déterminée par une attitude positive envers les disciplines scientifiques pendant les années scolaires. Cette étude démontre l'aspect déterminant des caractéristiques des élèves sur leurs rendement et attitudes; le rôle des parents (par exemple leurs encouragements et attentes) dans la formation des attitudes des étudiants, aussi bien que celle d'enseignants (par exemple leurs qualifications et attitudes) dans l'amélioration des résultats aux tests. Les principaux facteurs déterminant les résultats sont l'attitude des élèves envers l'école, leur choix de filière universitaire, leur satisfaction envers les résultats obtenus dans les disciplines scientifiques à l'école et l'intérêt de travailler dans des domaines où les mathématiques et la science sont importants. Malgré le fait que de rendre la science plus attirante

pour les élèves soit un but qui doit être considéré par les enseignants, les demandes inhérentes dans le domaine de la science qui impose un accroissement continu des connaissances et capacités nécessitent que les élèves eux-mêmes adoptent des attitudes plus positives et plus responsables. Enfin, la culture scientifique et la culture des jeunes doivent être connectées.

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1. Introduction

The 2004 School Assessment Indicators Programme (SAIP) developed by the Council of Ministers of Education Canada (CMEC, 2005) offers empirical data to describe the status of science literacy of Canadian students and the most important related factors. The design of SAIP was based on the premise that, for the largest part of the student population, science literacy reflects their understanding of science in the context of real-life situations (i.e., the manner in which students interpret science within their familiar context is more relevant than simple recall of information). What SAIP aims to capture is the level of general knowledge of science concepts, ability to apply science to everyday situations, and understanding of the nature of science. However, using science in real-life situations cannot occur without understanding its main concepts. Therefore, the stages of formal and informal learning in which science literacy is acquired are the same as the stages by which science knowledge and skills are enhanced for those interested in pursuing a science-related career. This study is based on the assumption that science literacy constitutes the ground from which scientific talent grows, because without a large pool of science literate people it is not likely to expect that scientific talent will come into sight and properly serve, in the future, the common interests of the entire population.

This study builds on previous research which indicates that success in mathematics and science, either at the level of literacy or further pursuit of related careers, involves not only skills and knowledge, but is largely determined by positive attitudes toward these disciplines during school years. Literature reviews on science education illustrate how the learning of science occurs in formal and informal settings, and how the roles of family and school intertwine in supporting students during the learning process and further educational planning. Moreover, these factors contribute to improve students' self-confidence in their math and science abilities, to instil values about the importance of these subjects, and to encourage their performance. This study will use the Science SAIP data to identify the specific ways in which student, family, school, and teacher related factors contribute to high achievement and positive attitudes toward science for 13- and 16-year-old Canadian students.

2. Literature review

2.1 The context of science learning

Goals of science (scientific) literacy

The latest funding initiative of the Natural Sciences and Engineering Research Council (NSERC), the CRYSTAL pilot program, aims at supporting research on the teaching and learning of mathematics and science (K-12) and developing practical solutions to promote science literacy and numeracy (NSERC, 2005). The new Centres for Research in Youth, Science Teaching and Learning (CRYSTAL) are expected to lead the national dialogue about science education and to make immediate impacts which include changing young children's attitudes towards science and mathematics schoolwork as well as towards careers in these areas. On one hand, it is recognized that science literacy and numeracy are vital skills in today's innovation-based economy. On the other hand, it is expected that improving science literacy among all students will help increase the supply of students qualified for and interested in science, mathematics, and engineering programs at the university level. Science literacy of young Canadians is therefore outlined as a major goal for teachers, students and parents, school boards, school and post-secondary institutions, science promotion groups, policy makers, curriculum developers, and text book publishers. I will further review some approaches to the concept of science literacy.

What is science literacy? Researchers portray science literacy as a concept that has defied any precise definition, perhaps because the term has encompassed many educational themes over time (DeBoer, 2000). Historically, science provided intellectual training for the inductive process of observing natural phenomena. The learning and practice of the scientific method, through carrying out independent inquiries and/or lab experiments, led to a way of thinking that enabled individuals to act independently. Science education has increasingly been seen as an aid to making informed judgments about the benefits and risks associated with science and technology, and to gain appreciation for the contributions of scientists. DeBoer shows that in the late 1960s, since the gap between science achievements and science literacy became of concern for American scientists and science educators, more focus was placed on content knowledge in a broad range of science fields. "The main goals of the science community were the preparation of future scientists and a general public that would be knowledgeable enough to be sympathetic to the work of scientist" (p. 588). However, by the 1970s, science educators started to support the idea that science literacy should focus on understanding science in its social context, and that science-related social issues, not disciplinary content, should be used to organizing curriculum. Although the importance of technology was recognized, it was not clear how technology was relevant for science education. Building individual or class projects related to particular scientific themes have provided a useful context for "learning science," but it was never reported that this was accompanied by learning specific scientific ideas (Cajas, 2001).

In 1995, National Science Education Standards were established for all American students. DeBoer (2000) reviews the controversies around the standards-based reform that established norms as measurable outcomes for science literacy. He concedes that standards can be useful guideposts, or a basis on which science educators can compare their ideas. DeBoer elaborates that "scientific literacy defines what the public should know about science in order to live more effectively with respect to the natural world" (p. 594). Although acknowledging that it is not easy to prescribe the best route to achieve this goal, DeBoer suggests that a broad and open-ended approach to scientific literacy would free teachers and students from rigid guidelines and would let them pursue science teaching and learning more closely aligned to their particular situations. However, the DeBoer approach faces the reality of school resources and teacher competency – raising issues of equity regarding good quality science education for all students.

In the race for improved science literacy, it is remarkable that scientists have embraced the goal of scientific education for all students, not just for the best and brightest. Lopez and Schultz (2001) identify two revolutions in the American K-8 science education: The first is a revolution in the goals of science education and the second is a revolution in the methods used to teach science. Both have been supported by the scientific community since the 1960s. For instance, an idea promoted by teacher-scientist alliance programs established in many school districts was that science education is expected to cultivate in students a comprehensive set of intellectual habits and attitudes which can be acquired through active learning (i.e., "hands-on" science). The authors identified five points of success that allowed a number of school districts to replace the traditional, didactic, just-the-facts approach and sustain exemplary kit-based programs based on:

(1) using the best available materials, (2) establishing science material centres, (3) providing ongoing professional development for teachers, (4) developing assessment tools for hands-on science, and (5) offering sustained administrative support. These points suggest that more innovative teachers and schools were likely to support a systemic reform of science education, at least from kindergarten to grade eight.

Means of achieving science literacy. In addition to research that looks at science literacy from the perspective of outputs and external resources, there is some research interest directed toward the means used by students to engage with and construct science understandings. Yore and Treagust (2006) restate that the level of science literacy is associated to the following components:

> 1. The meaningful understanding of knowledge about the big ideas or unifying concepts/themes of science like the nature of science, scientific inquiry, and major conceptual themes in the biological, earth-space, and physical sciences.
> 2. A literacy component that stresses the cognitive abilities, critical thinking, habits of mind, and information communication technology (ICT) to understand the big ideas of science; to inform and persuade others about these ideas; and to participate more fully in the public debate about STSE (science, technology, society, environment) issues. (p. 293)

The role of language in science literacy was the focus of the 2002 Island Conference organized on Vancouver Island, Canada (Hand, Alvermann, Gee, Guzettti, Norris, Phillips, Prain, & Yore, 2003). The "Island Group" emphasizes "the need to bridge the gap between literacy practices, teaching and learning of science in school classrooms, and between research-based claims and educational policies, instructional decisions, and teaching and assessment practices" (p. 608). It is pointed out that research looks separately at various aspects of literacy, giving little recognition of commonalities across disciplines. The authors acknowledge that communications of oral and written science are multidimensional, involving "language, physical gestures, mathematical symbols, graphic representations, and visual adjuncts" (p. 609). It is also acknowledged that science can be learned in formal and informal contexts (e.g., Internet, hiking). By making use of informal science literacy skills and multiple abilities to deal with scientific information, we can encourage students to see themselves as autonomous learners.

Hand and Prain (2006) have expanded the Island Group's view by recently observing that the issue of science literacy development requires diverse perspectives that include contributions from the pedagogical, scientific, linguistic, psychological, philosophical, and socio-cultural fields. They posit that the understanding of science is a complex process that involves not only crossing literacy boundaries and functional use of language, but also building intelligent habits of mind. This concept refers to the ability to think and construct knowledge scientifically by developing a state of mind that allows individuals to move from simple repetition of learned actions to thinking and understanding practices. Building habits of mind would also impact one's ability to make use of science literacy skills in everyday life in new contexts. The "habits of mind" concept has also been associated previously with emotional dispositions that include "values and attitudes, a willingness to seek solutions and solve problems" (p. 105). This notion is a reminder of Bourdieu's *habitus*, defined as "systems of durable, transposable dispositions," that are built within a particular type of environment and are useful in generating and structuring various practices and representations (Bourdieu, 1977). In other words, by aiming to develop scientific habits of mind, we empower students to think analytically and critically, to transfer knowledge and skills effectively across subjects and into everyday life, to build confidence in their abilities and develop positive attitudes toward the learning and practice of science and, ultimately, to *like science* for unveiling to us the wonders of nature.

Family environment

Do parents matter? There is a vast amount of research that illustrates the relation between family background and students' educational attainment, from early childhood learning to completion of post-secondary education. Theory, policy, and practice account for the increasing role that parents are expected to play in modern educational systems in order to support their children through school and college, either independently or by partnering with the school and community. Parental support is likely to include, in varying amounts, home-school learning, help with homework, participation in school events, hiring tutors, etc. Even when parental involvement is not explicit, the family is still instrumental in transferring to children values, traditions, and beliefs about and dispositions toward education that foster key strategies of success in school and career. This cultural inheritance passed on to children is embodied in their cultural capital (Bourdieu, 1997), which is accumulated starting from early childhood.

Bourdieu and Passeron (1977) argue that schools are the places where the cultural capital of the middle and upper classes is reified and rewarded. By use of pedagogic authority, the educational system ensures the reproduction of the dominant culture, and contributes to the reproduction of the social structures, reinforcing privileges, and maintaining social inequities. Many studies have documented that parents matter in the educational success of children, success measured by their ability to go along the school trajectory, achieve well in various subjects, plan, enrol in and complete post-secondary education, and finally obtain rewarding positions in the labour market (Andres & Grayson, 2005).

Within this broad picture of schooling, students' motivation to engage in and ability to cope with mathematics and science is the centre of attention due to the relevance of these fields for modern economies. This focus reflects the general belief that all individuals should be literate in these areas and the specific goal that well-qualified human capital should understand science and technology. To do well in science courses and accumulate scientific knowledge and skills, the student has to manifest interest in the subject and possess a strong disposition for learning. Research validates that parental involvement is exerted on at least two fronts. First, family can contribute to students' educational practice by offering direct help in school activities, stimulating their interest in school and motivation to learn, shaping up their expectations for further education (Jacobs & Harvey, 2005; Reay, 2004; Zady & Portes, 2001), and instilling love for intellectual endeavours. Second, parents may influence students' choices of subject courses in senior high school (i.e., science or non-science paths) and post-secondary orientations (Crosnoe, 2001; David, Ball, Davies & Reay, 2003; Dick & Rallis, 1991; Dryler, 1998; Jacobs & Bleeker, 2004; Solomon, 2003), specifically targeting science-related educational and career paths.

Parental involvement in children's schooling. Cultural and economic capital resources of parents, which affect their time availability, access to information, and extent of social network, affect the level of parental involvement. Reay (2004) associates mothers' efficacy in helping children with school to social class and family circumstances. For instance, working-class single mothers feel unequipped to engage in homework, are less confident in relating to school and teachers, and lack the financial resources to hire tutors. Middle-class married mothers have the resources and disposition to engage their children in extra-school activities that support their learning. The author points out that the power of cultural capital (e.g., parental education) is also visible in the choice of schools and programs, such as gifted and talented, that parents make for their children. In reproducing educational advantage, cultural capital can often be effective, even when families have access to little economic capital, through educational dispositions passed to children. Since working-class families have to rely entirely on schools throughout their formal education, the author calls for “educational policies [that] can counteract the strategies of the middle classes to ensure continuing advantage” (p. 83).

Parental involvement is related to children’s achievement. By following a sample of students in nine Californian high schools over three years of study, Crosnoe (2001) illustrates how parents adjust their engagement in relation to the curricular tracks in which children are enrolled. Although parental involvement (e.g., help with homework, attendance at activities, course selection) was less common for students in lower ranking tracks (e.g., remedial level), parents were less likely to disengage over time since their children continued to need support. On the other hand, for the higher achievers enrolled in college preparatory tracks, parental involvement was dynamic at the start of high school, yet more likely to drop over time. Rather than a signal of disengagement, this withdrawal is interpreted as parents’ turning their attention to the next level of their children’s education. Therefore, all parents showed interest in their children’s schooling, but in different ways.

Socio-economic status (SES) disadvantage may become overwhelming for parents when they are expected to help their children with math and sciences. Zady and Portes (2001) observed child-parent interactions while completing homework-like science tasks for a group of seventh-grade students. Although all parents in the study manifested interest in this research experiment that was designed to support their children’s learning, low SES mothers of low achiever students struggled with the printed instructions, pointing at the directions to help their children, and being continuously stressed by the unfamiliarity with the task. Even if both parent and child showed willingness and motivation to complete the science tasks, lack of parental literacy was a barrier. Low student achievement and low SES were usually associated. In the case of high achievers, mothers admitted having joined their children in science activities at home and intentionally treated the tasks as game-like situations. The study concludes that literacy problems inherited from students' home environments could forever close the door to school science for at-risk children. The lack of motivation or interest, used to explain low achievement for some students, may often serve as only a cover for students' frustration with unfamiliar tasks.

In a study by Jacobs and Harvey (2005), parents of higher achieving students exhibited different attitudes toward achievement and their (child's) school, when compared to those of lower achieving students. Schools were ranked based on their students' achievement in the final year of secondary school and a variety of school improvement indicators. Parents of children at the top-rated schools approved of schools pushing students toward high achievement, but still expressed the lowest satisfaction with the level of education in the last year of secondary school. This reflected their own academic backgrounds and high aspirations and expectations for the post-secondary paths of their children, attitudes built over a long period of time (e.g., since child was born). Parents of children from lower-ranked schools were aware of the lack of school academic 'push' for their children. However, they showed satisfaction with the level of education, and indicated that personal growth and character-building are also relevant outcomes of school success. Since 'pushing' students toward high achievement is quite beneficial in relation to science education, which requires a constant learning effort, it is likely that students who are not 'pushed' will be less inclined to tackle the subject.

Parents also play a role in instilling in their children an interest toward science learning. Jacobs and Bleeker (2004) demonstrate that parents convey their attitudes and values about math and sciences to their children. They examined the relations between parents' math-promotive behaviours, beliefs about science, toy purchases, playing chess or math-related games, and children's later achievement and interest in math and science subjects. Although there is no doubt that parental practices have some effects on children, the authors inquire: "Exactly what matters and under what conditions? When will math-promotive behaviours backfire, and when will they produce long-term interest in the topic?" (p. 18). The authors found that parental practices in promoting math and science learning to their children remain "gendered". Regardless of a child's grade in school, parents were more likely to purchase math and science items for sons, while being more involved in daughters' math and science activities. It was surmised that either parents perceive that girls need more help in these areas or that girls adopt more collaborative learning strategies and share their academic pursuits and curiosities with parents.

How do parents, who might themselves know little about science, support their children's learning? In a study of primary school students, Solomon (2003) described how out-of-school science activities were carried out at home. First, the majority of parents were willing to help their children regardless of how confident they were about their science knowledge or what feelings they had about school science. Depending on their own experience with science learning, parents adopted different 'pedagogical' strategies: making models, explaining how things worked, or buying encyclopaedias and books to search for answers. Second, children behaved differently at home, showing more interest and participation in performing science activities, which is interpreted as a result of reinforcing natural bonding. Third, take-home science activities produced positive results in terms of enjoyment and attitude building. Yet, almost no link was found with in-school achievement. This suggests that home learning of science might help to develop positive attitudes toward science through parental encouragement and building of common interests, rather than advancing students' science achievement.

Parental involvement in educational planning. Planning for post-secondary education is a major part of the inherited educational capital that motivates students toward learning. David, Ball, Davies, and Reay (2003) examined how parents are directly involved in the planning process for both their daughters and sons, making obvious the increasing role of education in keeping pace with changes in the labour market. Middle-class parents admitted having invested heavily in their children and, fathers particularly, having tried to control the post-secondary choice process. Parents disclosed they always had high aspirations for their children's education: "Oh, it's been on my mind all along that he's going [to university]" (p. 30). Girls tended to be more willing to accept the participation of their parents in educational planning. In contrast, boys showed more resistance, seeing involvement as "intrusive or irrelevant". In fact, since the 1990s, the growing participation of women in post-secondary education has brought the 'boy's turn' concern to the education research agenda (Weaver-Hightower, 2003).

Parental background (i.e., education and employment) plays a major role in encouraging girls to go into male-traditional fields. Dryler (1998) demonstrated that Swedish girls and boys made gender differentiated choices of upper secondary school courses. Students were more likely to choose similar educational and occupational fields as their parents (i.e., the “same-sector” effect). However, parents working in the service sector or parents with higher levels of education were more willing to support their children to choose gender-atypical fields of study (e.g., girls studying sciences and engineering or boys studying nursing). Parental encouragement has a tremendous effect on children in various educational situations, be it school learning, choice of school subjects, or planning for higher education. Young women and men who plan science-related careers report higher levels of parental encouragement. Dick and Rallis (1991) argue that the mother’s level of education, as well as employment history, usually manifest a role-model effect on daughters, while the father's encouragement helps boost their self-confidence. These factors support young women in engaging and succeeding in male-traditional disciplines such as science because they contribute to shape up positive attitudes toward school in general and science in particular.

Formal and informal learning of science

School and the structured learning of science. It is hard to distinguish between contributions brought by various factors in enhancing students’ attitudes to and achievement in science. Each individual will have a different story about how family and school, the most likely factors, have influenced their educational paths (Jacobs & Harvey, 2005; Ma, 2004). In general, family influence (if any) encompasses early orientation toward science, availability of resources and knowledge, encouragement and recognition of achievements, and instillation of career aspirations. Schools should ideally build the foundation of skills, competence, and level of science literacy for all students within environments that foster structured learning of science and eradicate the feeling of alienation that students experience in science classes. Schools are also expected to compensate for unequal cultural capital (Jacobs & Bleeker, 2004; Reay, 2004).

How to make science education more efficient and attractive to the young generation has become a worldwide challenge. It is accepted that good teachers can make a difference, and that science educators should possess both the capacity to understand natural phenomena in a broad context and the talent to effectively communicate their knowledge, while engaging students in a stimulating endeavour of discovery. If a society wants students to be science literate, a high priority should be given to the quality of science teaching. Chin (2005) investigates the level of science literacy demonstrated by first-year pre-service teachers (i.e., entering the program directly from high school) educated in Taiwanese colleges. The study compared those who completed advanced school science courses before starting the teacher program, expected to be science education majors, with those coming from non-science tracks, expected to be elementary education majors. Both groups were required to possess good levels of science literacy, since elementary school teachers could be assigned at any time to teach science. Scientific literacy was assessed with respect to four areas: (1) science content, (2) interactions among science, technology, and society, (3) the nature of science, and (4) attitudes toward science. Science education majors relied extensively on science content and demonstrated positive attitudes toward science, which suggests that attitudes and structured knowledge support each other in building science literacy. However, not supported by solid science backgrounds, the elementary education majors showed more orientation toward general aspects like science and technology or the nature of science. This raises the question whether a generalist approach is sufficient for science teaching.

Mulholland and Wallace (2005) describe the journey of a young elementary science teacher over ten years of teaching in an Australian school. It is interesting to note that overcoming the negative memories about science accumulated in high school advanced chemistry classes was the biggest challenge faced by the future science teacher during her university studies. In analyzing the pedagogical content knowledge of her classes, the authors identified three stages with the focus shifting from science content to general and interactive knowledge. In the beginning, being less certain about her understanding of science content, the teacher attempted to teach information-based lessons that allowed her to remain in control of the classroom. When she gained enough confidence in her own scientific understanding to address inquiries for which she was unprepared, she gradually adopted a more interactive teaching style that stimulated students to discover the subject-matter knowledge. At that point, the general and interactive teaching bases grew up naturally, in parallel with the science content knowledge. Accumulation of teaching experience appears to be a complex process in which confidence in the subject matter is the only way to foster diverse and enriched methodology.

Informal science education. Informal education appears to be beneficial for stirring and maintaining young people's interest in science. Museums, science promotion events, or outreach programs help spark scientific curiosity in young minds by making science more relevant to everyday life and more exciting at school. Out-of-school activities help students to find out that science, although complicated, is fascinating and can make the learning of science 'fun.'

Jarvis and Pell (2005) explored the attitudinal changes toward science of 300 children, aged 10-11 years before, immediately after, and 4-5 months after visiting the UK National Space Centre. Although the overall science enthusiasm and even the interest in space science decreased over this 5 months period, the level of awareness of the role of science increased over time, especially for boys. As a result of the visit, all students, and especially boys, improved their views about science and becoming scientists in the future. One result of the visit was that students were inspired to read science books at home and watch science programs on TV. Family members in science-related fields were found to act as role models for some students, a factor essential in creating and maintaining these interests. The authors also note possible cultural effects, since the highest science enthusiasm was scored by a suburban school with a large Asian population. However, closer analysis of school differences showed that the attitudes of teachers in preparing the visit and maintaining/enhancing the level of interest afterward made the biggest difference. For students who came unprepared for the visit, the enthusiasm and interest, although high immediately after the visit, disappeared over time. However, the visit had a lasting effect and helped enable the bridging of formal and informal science education for those students who received prior background information. This experiment suggests that stirring children's interest in science is not sufficient; what really matters in achieving long-term results is continuity and persistence in maintaining this interest and relating the 'fun science' with school science.

Equity and science education. In democratic educational systems, there is hope that science education will address the academic needs of all students, not only the brightest. How teachers embrace the goal of science literacy for everyone is reflected in their attitudes towards and beliefs about ability grouping. Hallam and Ireson (2003) presented findings of a study based on a sample of 1500 secondary school teachers from UK schools that operated with mixed-ability or ability-setting classes. Teachers' responses were clearly associated with the type of school they taught in; those in "tracked" schools were likely to support the benefit of "tracking," arguing that able children could maximise their attainment; those in mixed-ability schools leaned toward an equitable view saying that discipline, disaffection, and self-esteem issues are better resolved in mixed-ability classes. Student benefits were also perceived differently for various subjects, teachers generally believing that mathematics and modern foreign languages would require grouping based on ability and attainment, while humanities were more appropriate for mixed-ability teaching. Beliefs about ability grouping in the teaching of general sciences were situated in the middle, although one science teacher from a mixed-ability school expressed reservations about mixed-ability teaching "because the higher ability pupils are not stretched to their full potential." The teacher continued: "however, we do very well with the lower ability in the classroom" (p. 347), which indicates that a stimulating science class environment is beneficial for students of all abilities. Preference for ability grouping in subjects like mathematics and advanced sciences may have at least two reasons: (1) learning in these subjects is gradually built on prior knowledge, and (2) learning is enhanced by prior success in addition to effort. From a different perspective, science literacy involves, to a large extent, positive attitudes that are nurtured within inclusive class environments such as may be found in functional mixed-ability classes.

Another major concern regarding unequal education opportunity for students is related to the low participation of girls in advanced school science courses (Catsambis, 1995; Mendick, 2005; Young & Fraser, 1994). Reasons for girls' low participation rate in science subjects can be attributed to a variety of socialization and cultural factors (e.g., parents buying gender-specific toys or being more sympathetic of girls' interest in humanities; girls' beliefs that they cannot succeed in science; and societal expectations for gendered occupations). Regardless of antecedents, schools develop, in a more structured way, students' interests, values, beliefs, and attitudes. Teachers, counsellors, peers, curricula, extra-curricular activities and types of school programs may either distance some students from science or attract them to it. Schools can have a significant impact on girls' self-confidence and attitudes toward science (Brutsaert, 1992).

While program content is essential in stimulating girls' interest in science, the science classroom environment is relevant in that it often mirrors a "real-world" science climate. Feminist researchers argue that as long as curriculum, school programs, and class atmosphere will be male-dominated, there is a strong chance that girls will be turned away from science (Kahle, 1996).

Numerous studies focus on the beliefs and attitudes that science teachers have toward the issue of gender and science because teachers are expected to adjust behaviours and practices of science classes to create a gender inclusive environment. It is extensively documented that during the senior high school stage, female students are more oriented toward life sciences and male students toward physical sciences courses, which some interpret as preferential interest or individual inclination. However, it is also documented that girls opt out of some science classes, like physics, in a greater proportion than male students drop out of biology classes, and this happens after they experience the environment of these classes (Adamuti-Trache, 2004). Causes that lead to girls dropping out of hard science classes are not always considered seriously by teachers. Zohar and Bronshtein (2005) have found that most of the interviewed physics teachers in urban schools in Israel underestimated the issue, did not consider it a problem, or at best, did not know how it could be solved. Most explanations were related to individual student factors (e.g., ability and interest), parental influence, and teacher's guidance (or lack thereof) regarding career choices. Socialization factors like the masculine image of physics, girls' peer group pressure, or pedagogical and curriculum issues were not mentioned. The authors conclude that it is apparent that some teachers hold gender-stereotyped beliefs regarding girls' abilities and access to some occupations and, hence, do not view themselves responsible in any way for girls' low participation in advanced physics classes.

Lack of participation in advanced math and science classes is likely to create disadvantages in relation to careers for girls, students with low SES, or other unprivileged groups (Adamuti-Trache & Andres, in press; Mendick, 2005). Science is a major and engaging discipline, and it is hard to believe that students can so suddenly lose their interest in science or disregard its importance once they have the opportunity to make elective course choices. It is more likely that, in the elementary and junior high school years, a process of alienation from science begins to occur. School is the first major arena where young women and men start accumulating social capital on their own by exploiting the cultural capital inherited from their families, by acquiring skills, competence and credentials, and by developing a social network. If school fails to compensate for inherent social disadvantages, it is likely that some students will lose momentum and miss the opportunity to reach their academic potential. This situation is even more critical for science-based pathways that demand early orientation, constant preparation, and guidance.

2.2 Student attributes

Eagerness to learn science is grounded in cognitive and affective motivations that allow the individual to move from "the familiar to the unfamiliar" places of the scientific landscape (Alsop & Watts, 2003). Interest, values, beliefs, attitudes, and self-confidence are individual attributes that support achievement and success in any practice, be it science, sports, or writing. Depending on one's aspirations, the growing of scientific aptitudes follows a continuous path determined by individual and contextual factors. Some individual attributes relevant to science learning are reviewed in this section.

Curiosity and talent

Most studies explore students' scientific interests in the context of school curricula and some report that mathematics and science subjects are perceived as less interesting by students. Baram-Tsabari and Yarden (2005) used a more naturalistic approach to demonstrate that children manifest spontaneous interests in science and technology that span a variety of fields by analyzing the questions Israeli children submitted to a series of television programmes. Girls and boys in the later years of elementary school and early years of junior high school sent questions that covered various fields of interest (e.g., biology, astrophysics, technology), motivation (e.g., applicative and non-applicative), and level of science literacy (e.g., factual, methodological, explanatory). It was found that the 8-13 year-old students showed more interest in biology, technology, astrophysics, and earth sciences, rather than physics, a field that may be less familiar to students because parents and teachers are less prepared to present it (Osborne, Simon & Collins, 2003). Many older children asked questions relating science to everyday life. Girls showed interest in technology, but mostly in relation to the history of technology, an area that helps to place events in a socio-cultural context. Other authors (Jones, Howe & Rue, 2000) also found gender differences among sixth-grade students, boys being more interested in planes, cars, atomic bombs, or computers and girls in rainbows, weather, communication, or health. Baram-Tsabari and Yarden acknowledge that the variety of science interests manifested by children make it difficult to develop an inclusive curriculum. Without implying that the structured learning of science should be abandoned, they advocate that skilful teachers could have more freedom to promote a wider range of science activities. Above all, they argue that school science has to gratify the genuine curiosity of children through relevant knowledge and experiences.

Indeed, curiosity is the most significant attribute that keeps alive the interest in science. It is encouraging to find out that Einstein asserted “I have no special talent. I am only passionately curious,” but there is no doubt that ability plays an essential role in the understanding of science. However, ability grows with time by exercising one’s capacity to observe and reflect on phenomena, by developing inquiry skills, and persistently asking questions and searching for answers. Schools measure ability in an indirect way by assessing students’ skills in performing specific tasks. Depending on the organization of the educational system, students may be assigned to classes or programs by ability level (Hallam & Ireson, 2003; Reay, 2004). Teachers and parents hold mixed opinions regarding the utility and equity of such policies, although research findings show that in math, sciences, and foreign languages most capable students are challenged to do better in high ability classes.

Classroom environment has an effect on students’ perception of their own ability. Dreves and Jovanovic (1998) explored the ability perceptions of fifth- through eighth-grade students and found that participation in hands-on science activities during the academic year increased boys’ sense of mastery in doing science, although it had no effect on girls. The most active girls were those who came into the classroom with a sense of confidence and assumed leadership in the small group activities. Due to the type of activities, male dominance was not even visible in the classroom. However, evaluative feedback from teachers was missed, especially by girls. Other studies have confirmed that to boost their confidence, girls are more sensitive to evaluative teacher-student interactions, rather than feedback received from peers. Since confidence in one’s ability enhances active participation and leads to further achievements, teachers and parents need to find appropriate ways to recognize and reward students’ effort and performance. Without continuous and active exposure to math and science, literacy goals and gender balance in science-related occupations are futile. Linver and Davis-Kean (2005) reiterate that research does not demonstrate gender differences in math ability and that math performance in standardized tests is systemically comparable for boys and girls. However, gender differences in self concept regarding math and science ability, not school grades differences, should become a reason of concern for teachers and parents. Similarly, Jacobs and Bleeker (2004) found that children's interest and involvement in math and science activities were related to parents' perceptions of children's abilities, as well as parents' attitudes toward math and science.

Self-confidence and values

There is a large amount of research addressing issues of students' self confidence and self esteem in relation to academic success. Branden (1992) described self-esteem as "the experience of being competent to cope with the basic challenges of life and of being worthy of happiness" (p. 18). Self-esteem is built upon the experience of success and is achieved and strengthened over time by the reinforcement of specific practices. Therefore, if students became confident in their ability to do well in math or science, they would feel empowered to face new challenges. Individual achievement leads to further growth of self-confidence and self-esteem, shaped within the family and school environment.

Walz and Bleuer (1992) have edited a comprehensive monograph that addresses a broad range of issues related to students' self-esteem. It contains a blend of theory, research findings, and useful ideas for building self-esteem in elementary and high school students in relation to academic performance and career development. For instance, in a study of career development and self-esteem for boys and girls, Chiu (1992) demonstrates that career choices are linked to self esteem. Adolescents who obtained good self-esteem scores also had clearly defined career goals. However, girls tended to score lower than boys on their self-report tests, though receiving higher ratings from their teachers. Encouragement from teachers tended to boost their confidence, especially for those planning to prepare for male-dominated fields such as science. On the other hand, boys appeared to be equally confident about performing well in both traditional and non-traditional careers (Haring & Beyard-Tyler, 1992). Interestingly, both boys and girls with high self-esteem were likely to prefer traditionally male careers, including science.

Age is an important factor influencing the level of students' self-esteem. Brutsaert (1992) shows that during early adolescence (junior high school) girls' self-esteem is highly dependent on parental support, while boys' self-esteem depends on their sense of mastery. However, at the middle adolescent stage (senior high school) boys and girls react similarly and their self-esteem becomes highly dependent on their academic achievements. This dependence is stronger for girls, who show a higher level of confidence if they are enrolled in a more rigorous study curriculum. This fact suggests that girls adjust better to a more demanding school context and may be more likely to benefit from structured academic instruction.

To preserve their self-esteem, those unskilled in a specific area tend to grant it little value. Simpkins and Davis-Kean (2005) followed 180 students from kindergarten or first grade to grade 12, comparing groups of students clustered by their ninth-grade values and self-concepts in math and science. They found that adolescents tended to value a subject such as science only when they felt they were good at it. Although it might be expected that a combination of high value and high self-concept would determine the choice of advanced math and science courses, this study showed that only high self-concept was determinant of students' choices. Still, the value placed on a domain remains a significant factor in making career decisions. It then becomes apparent that since more boys than girls possess high self-concept and place a high value on math and science, this results in gender differences in science-related career choices.

Achievement and educational choices

Achievement in science is usually measured by testing students' knowledge of science curriculum. Research has looked at how achievement is related to other educational outcomes (e.g., course selection, educational planning, or access to post-secondary education) and how it can be predicted by various factors (e.g., individual characteristics, family background, prior knowledge, or classroom practices). Socio-economic status remains a significant determinant of students' educational achievement. Ma's (2004) analysis of New Brunswick Grade 6 students' achievement in math, science, reading, and writing showed that within-school socio-economic gaps were wider in math and science compared to other subjects, especially in schools where parental involvement was more pronounced. In general, high SES families are more involved in their children's schooling and they become even more aggressive in ensuring their children's academic needs are met when their children are enrolled in schools with a wide SES range. There is no evidence that involvement of high SES parents in school affairs benefits all students, as suggested by Reay (2004) or, on the contrary, contributes to social inequity by gaining benefits for only their children.

There is a common belief that students with educated parents have a net advantage in school because parents can support them in various school activities. A study of Dutch students in the last year of elementary school (Driessen, Smit, & Sleegers, 2005) looked for direct relations between parent-initiated forms of involvement (e.g., help with homework, choice of secondary school, parents informed about school matters, school-supportive home climate) and various student outcomes (e.g., self-confidence, language and math achievement). When controlling for school effects (e.g., school size, ethnic composition, SES), little evidence of correlations were found. For instance, helping with homework sometimes had a negative effect on students' mathematics achievement. This may show that when students experience math difficulties, parental help with homework is not sufficient. It also confirms what Zady and Portes (2001) reported about the hard struggle and minimal success of less educated parents in helping their children with science homework. Although social class has a generally positive impact on students' academic achievement, this does not hold true for direct help with homework. Help with math and science homework requires specialized knowledge, particularly for upper grades, that not all parents, even educated ones, possess. It is more likely that the relationship between high achievement and parental education resides in a family environment that encourages academic work and cultivates high academic and career aspirations for children (Jacobs & Harvey, 2005). What may influence high achievement more directly are school and classroom climate, good teaching, and student effort.

Academic achievement has an impact on students' choices of advanced math and science classes. Opting for science courses indicates a high level of science literacy, a good mathematical background, and perhaps an interest in pursuing science-related educational and career paths. These choices are supported by a strong self-concept in math and science ability and also reflect ambitious plans for higher education since admission in many academic programs requires a background in math and sciences (Adamuti-Trache, 2004; Ayalon, 2005). The role of sustained preparation in math is essential. Watt (2005) demonstrates that participation and performance in higher levels of math courses is determined by prior achievement, higher math-related intrinsic value, and high self-perceptions of math talent. The gender comparison in his study points to the likely determinants of math achievement and further participation. Although boys' and girls' prior knowledge was comparable, the author notes that success expectancy by boys was higher and, although not always realistic, translated into higher levels of participation and achievement in advanced courses. The implication is that even moderate levels of achievement may promote access to higher math level courses for boys. However, if success expectancy and self-concept of ability is lower – more likely the case for girls – the likelihood to persist in math and science is decreased regardless of achievement.

The Expectancy Value Model of Achievement-Related Choices developed by Eccles and her collaborators in 1983 (Eccles, 2005) hypothesized that educational, vocational, and avocational choices are related to individuals' expectations of success and the value attached to those options and that these expectations are shaped over time by positive experiences, including good achievement. Therefore, achievement is not only an outcome but also a generator of further choices and performance. In the case of school math and sciences, a lack of prospects regarding expectations of success or usefulness of learning, perhaps combined with lack of appreciation for scientific skills, may predispose students to make less effort in persisting in these more challenging subjects. Unfortunately, this also contributes to reduced level of science literacy and negative attitudes toward science. Based on Eccles' notions of expectancy and value, Barnes, McInerney, and Marsh (2005) analyzed the enrolment in science courses of Australian students in New South Wales high schools. Similar to the secondary school system in most Canadian jurisdictions, after completing general science courses Australian students may select a number of subjects that lead to graduation. The authors show that enrolment decisions are gendered and that differences in enrolment behaviour are determined by divergence in the perceived career value of courses, subject interest, and expected course performance. Prior achievement constitutes a basis for self-perception of ability. While females tend to be more intrinsically motivated, males are more likely to pursue what will provide achievement advantage.

Cleaves (2005) explored the science choices of higher achievers in secondary schools. As evidence of the high expectancy value attached to the subject, students incorporated science in their educational planning essentially because they were aware of the wide range of career opportunities supported by a scientific background. The author noted that students with clear science career projections and those with flexible plans that incorporated science appeared to benefit from parental advice that placed emphasis on the traditional ‘educational capital’ (Bourdieu & Passeron, 1977) of some school subjects. For instance, these parents described mathematics as a ‘solid subject’, physics as ‘fundamental’ or biology as a ‘definite science.’ For those who decided against taking science past the age of 16, the lack of knowledge about science occupations and low self-perceptions of their ability were determinant causes. A correspondence between parental education and course choice in the last year of high school is found by Adamuti-Trache and Andres (in press) who demonstrated that students with university-educated parents were more likely to select mathematics and physical science courses, selections that propel them onto a university track.

Attitudes and habitus

Mattern and Schau (2002) argued that a better understanding of attainment and persistence in science can result from investigating the relationship between attitudes toward science and achievement. In defining attitudes, the authors include several dimensions such as interest, enjoyment, motivation, value, and self-concept, all which are assumed to be part of the equation leading to achievement. They developed a structural equation model of attitudes-achievement measured at two times in the academic year (beginning and end) on a sample of seventh- and eighth-grade students in New Mexico. The main result for all students was the validity of a cross-effect model in which achievement and attitudes at the earlier time affected outcomes at the later time. For girls, a unilateral relation between pre- and post-outcomes was exhibited, in which attitudes and achievement developed independently. But, for boys, initial achievement was more important because it showed an additional effect on attitudes, not only on achievement, at the end of the year.

Osborne, Simon, and Collins (2003) argued that the decline in the numbers of students choosing to study science has to do with students’ worsening attitudes toward science. The ‘swing away from science' appears to have been over the past 20 years common to many countries, leading to shortages of teachers, scientists, and engineers. Since national economic performances are proportional with the number of scientists and engineers (e.g. in Japan and the United States), it is likely that educating more children in mathematics and science would be beneficial for the economic development and general well-being of society and would promote more positive attitudes toward science. As others noted, positive attitudes can range from an appreciation of science and scientists and acceptance of scientific inquiry as a way of thought to the development of an interest in pursuing science-related careers. The authors indicated that science is viewed as a 'love-hate' subject, rated important by large proportions of students but also perceived as difficult or boring by many. Osborne, Simon, and Collins also made the following observations: science preference may reflect students' perception that they are good at the subject; interest in science should not be confused with interest in school science; and the erosion of science interest during high school, especially for girls, may be related to environmental factors (i.e., structural variables like socio-economic class, peers and friends, classroom/teacher factors, curriculum variables, perceived difficulty of science, and enhanced subject choices). The authors also noted cultural differences in attitudes towards the study of science. For instance, Asian families, who tend to favour long-term career advantages, steer their children's choice of careers toward medicine, engineering, or mathematics. Osborne, Simon, and Collins concluded that science educators have to recognize the distinction between individual/intrinsic interest and situational/extrinsic interest, the latter being stimulated by contextual factors such as good teaching. They quote Claude Bernard, the nineteenth-century French physiologist, who stated that science is a "superb and dazzling hall, but one which may be reached only by passing though a long and ghastly kitchen," indicating that the road toward scientific literacy is not easy. Educators should enhance the 'task value' associated with learning science (i.e., interest in, importance, and utility of science) in order to motivate students toward sciences (Barnes, McInerney, & Marsh, 2005; Eccles, 2005).

In a comparative British-Australian study based on TIMSS (Trends in International Mathematics and Science Study) data, Miller, Lietz, and Kotte (2002) demonstrated that the desire to obtain a job in science is more strongly determined by attitudes toward science than by achievement, thus repeating the message that schools and parents should foster the development of positive attitudes and appreciation for science. No direct effect of gender was found on attitudes (e.g., enjoying or liking science, subject difficulty) and attributions (e.g., need of natural ability, good luck, hard work, memorization), although some gender effects were manifested in interest toward science-related careers. The authors identified how students are affected by the importance attributed to science learning by their mothers. A mother's attitude influences the value that a student assigns to his/her success in school science and to science in general, which in turn affects occupational preference. Therefore, attitudes toward math and science are implicitly rooted within family traditions and values (Bourdieu, 1997).

Habitus is another concept introduced by Bourdieu that plays a role in understanding students' success in school and beyond. Dumais (2002) argues that habitus is the orientation one has toward using cultural capital resources, which children inherit from their parents (e.g., books, familiarity and interest in culture, educational guidance, parental role models). Habitus is created over the years through socialization within the family and through the continuous exposure to values, traditions, and behaviours associated to specific practices. The school system is viewed as a field of practices, such as doing homework, attempting to get good grades, studying hard, and having educational expectations. Student dispositions to accomplish specific tasks by taking actions constitute his/her habitus; dispositions are accordingly developed toward the practice of science, mathematics (Adamuti-Trache & Zaher-Mazawi, 2005), or other school subjects. Because it is determined by the opportunity structure available to students, educational habitus is gendered and dependent on social class. For instance, being aware of having little cultural capital, students from low socio-economic families self-select themselves for non-university education; knowing that engineering is a male-traditional field, women choose to go into arts and humanities. Dumais (2002) applies the concepts of cultural capital and habitus to analyze students' cultural participation and whether this participation has some effect on school grades. In Dumais' study, habitus is operationalized by students' occupational expectations and is found significant in predicting school success. Lareau and Horvat (1999) have extended the use of cultural capital and habitus to include race and class in analyzing family-school relationships. They argue that possession of cultural capital and the assumption that it is passed automatically from family to child is not entirely true because institutions can also play a role in accepting or declining the activation of capital through inclusion or exclusion of students in specific tracks.

The habitus of parents, who may know how to turn the relationship with school into an advantage for their child, is relevant.

Habitus can be a useful concept in understanding other aspects of schooling such as making choices of elective subjects, planning for post-secondary education, or participating in science learning. The importance that parents place on math and science, their own involvement with these fields, stories about science and scientists, interest in visiting science museums or planetariums, instructional games and toys bought for children, attention paid to developing early numeracy skills to children, pushing children to choose science courses in high school, and planning for science-related careers are only some of the many ways parents can contribute to transferring capital and helping children to create the habitus of practice and success in science. Since early development of scientific skills is not as critical as developing reading and numeracy skills, dispositions toward science (habitus) are mostly shaped during school years. However, if parents value school science preparation, they will also interact with teachers or select schools, programs, and activities to ensure good math and science instruction for their children. Meanwhile, the continuous exposure to a climate that values science is likely to instil interest in science and motivate children to develop positive, or at least neutral, attitudes toward science.

2.3 The learning and liking of science

If it is true that structured learning of science plays a significant role in achieving science literacy, it is hard to believe that the liking of science arises when the liking of school is missing or deficient. As Ireson and Hallam noted (2005) in their study of grade seven to nine students, liking of school occurs when students feel supported by their teachers and other students, and it is further maintained by good achievement and academic motivation. The authors found liking of school to be highly correlated to students' perception of good teaching. For instance, students perceived that English teachers listened to them and explained more than math and science teachers, a result that may be associated to the nature of English classes where students can draw on their experiences and engage in discussions. Others found that academic orientation (e.g., interest in school, views of teachers' expectations, usefulness of school) declines over the course of high school, although students in higher tracks maintained more positive attitudes (Crosnoe, 2001). A decline in academic orientation definitely affects preparation in demanding subjects such as math and science, which require constant involvement by students. If students often complain that "teachers keep going over the same old thing" (p. 215), secondary education should search for ways of making school subjects relevant and more attractive to students. This section will review literature on students' experience with school science by looking at gender and age effects.

Gender effects

For the past 30 years, gender differences in science participation have received considerable attention by researchers, educators, and policy makers, reflecting the social concern regarding persistent occupational segregation in science and engineering. Feminist pedagogy focuses on science achievement, evaluation, curriculum and classroom interactions, and promotes collaborative rather than competitive styles of science classes, likely to create a friendlier environment for girls' learning (Davis, Ginorio, Hollenshead, Lazarus, Rayman & Associates, 1999; Kelly, 1987). Reunifying cognitive and affective approaches to science and eliminating stereotypes in science materials represent steps toward science classroom inclusion of less privileged groups, not only girls. However, other feminist models such as those viewing science as a "philosophy of wisdom" rather than a "philosophy of knowledge," granting subjectivity a leading role in science methodology, or loosening the requirements of scientific rigour and consistency are perceived to be in conflict with the essence of modern science and are unlikely to be accepted without supporting evidence.

The role of societal stereotypes in influencing female students is a major concern in feminist pedagogy. Gender-role stereotypes gradually shape students' perceptions of their own potentials, dreams, and roles in society. School exposure to gender-role differentiation confirms and deepens children's earlier experiences regarding family and work gender-roles, thus shaping students' conceptions about gender and career. Gender-role stereotypes develop as social constructs observed at the level of elementary school years, but more obviously become manifest at the beginning of junior high school. The important role that school and teachers could play in changing societal stereotypes and instilling in students appropriate attitudes regarding gender and science is discussed in the literature (Murphy, 1996; Tolmie & Howe, 1993). Since it is unrealistic to believe that substantial change could occur as a result of individual practice, action on a global scale is recommended, including specialized instruction on gender equity offered to educators.

Various issues of gender differentiation in schools are presented by Streitmatter (1994), starting with girls' and boys' preferences across curriculum areas. Boys as a group dominate higher-level math and science classes, whereas girls prefer biology classes. It appears that female students feel more comfortable and empowered while working within a discipline that features humanistic content to which they can relate. Debacker and Nelson (2000) identified gender differences in the motivation of students towards learning science (e.g., interests, goals, commitment, values, work habits). Perceptions about science classes, science careers, and scientists are usually dominated by stereotypical beliefs that also shape students' career options. Research on gender stereotyping regarding educational and career paths emphasizes that boys may feel more comfortable and entitled to engage in science and plan a science-related career than girls (Walz & Bleuer, 1992). Other authors explained the differential persistence of men vs. women in math and science courses as the result of pressure to fill gender roles and to live up to teachers' and parents' expectations (Blickenstaff, 2005). Since mathematics, physical sciences, and engineering are portrayed as symbols of 'masculinity,' these fields are likely to create a safe and honourable battlefield for young men who are expected to continue to play dominant roles in these traditional fields (Mendick, 2005).

In Canada, as in Britain or the United States, curricular differentiation in senior high school is the result of students' course selection reflecting their interests, abilities, previous experiences, general knowledge about school subjects, and planned educational paths. Choices of math and science courses in senior high school depend on students' understanding of the benefits of scientific instruction and of scientific careers. Research demonstrates that these choices are gendered. For instance, in Watt's study (2005), large proportions of girls indicated interest towards a course about "Maths in Society," while only boys selected a course about "Maths in Practice." Also, disappointment with school science (e.g., lack of knowledge about science work, lack of self-confidence) led to female students' inhibitions with respect to studying advanced science (Adamuti-Trache, 2004; Andres, 2002; Cleaves, 2005). Barnes, McInerney, and Marsh

(2005) found substantial sex differences in perceived career value, interest, and performance expectations triggering the post-17 science course choices. The content of selected curriculum for science courses plays an important role. Physical sciences in particular were presented from a ‘career preparation’ perspective, insisting on ‘practical’ topics such as mechanics and electricity, with less emphasis on broader interest topics such as astronomy. Especially at the upper levels of high school, girls distance themselves from physical sciences, opting out of “hard” science courses such as physics (Adamuti-Trache, 2002), a phenomenon which may be caused by the choice of subject matter included in these courses.

Many authors argue that females place higher value on the people-oriented aspects of their careers; reasons why they go into social sciences and humanities. If there is some interest in science, they prefer to direct it toward health careers and make high school choices to ensure access to these fields (Miller, Slawinski Blessing, & Schwartz, 2006; Simpkins & Davis-Kean, 2005). It follows that females’ rejection of science is not related to perceiving science “hard” or as not fitting female gender roles, but in not finding science relevant to their life goals. This suggests that school science needs to focus more specifically on the applications of science in everyday life, to explain what scientists do, to introduce students to broader science content, and to better identify and develop individual scientific abilities.

Age effects

Examination of the effect of age on science achievement and attitudes requires longitudinal research. One attempt is found in the work of Mattern and Schau (2002) who developed measurement models of achievement and attitudes for seventh- and eighth-grade students in New Mexico schools based on data collected at the beginning and again at the end of the 1995-1996 school year. Their models reinforce the strong and complex relation between science attitudes and achievement, which differs by gender as discussed earlier. However, the models show that instructional strategies need to target both attitudes and achievement; educational outcomes that reinforce each other over time.

Many studies report the appearance of a middle school gap in achievement and attitudes to science. Simpson and Oliver (1990) pointed to the decline in science attitudes and motivation for both sexes from Grades 6 to 10. A similar decline was noted by Linver and Davis-Kean (2005) for math achievement from Grades 7 to 11, with the largest drop at the transition from middle to high school. Research finds the middle school gender gap in science to be primarily a decline in girls' self-concept and attitude toward science (Catsambis, 1995). It follows that middle school constitutes a critical point in one's educational career that can lead to an attitudinal change with respect to math and science. One can argue that interest in science and positive attitudes toward the discipline are difficult to maintain over time if structured learning or evidence of some utility value is not offered to students. For instance, in Jarvis and Pell's study (2005), although students visiting the UK National Space Centre showed increased enthusiasm for science and interest in space science immediately after the visit, a long-term effect (5 months later) was not observed.

Age effects are also observed in the study by Baram-Tsabari and Yarden (2005) who looked at the spontaneous interest in science content shown by children. With age, students shift their interest from zoology to human biology or from biology to astrophysics and technology. The relative popularity of physics questions among young children compared to the drop in interest for older children may be related to the increased inaccessibility of the physics content, which suggests that interest in science cannot be supported without knowledge. However, interest in technology is reflected in the increased number of applicative questions asked by older students. The authors comment that this result may indicate a shift from interests in the "wonder of science" (i.e., non-applicative questions) to interest in the "utility of science" (i.e., applicative questions).

Summing up

This literature review presents an extremely small number of studies on science education, with focus on the last 10-15 years. The interest in this topic reflects a widespread belief that science is important for the welfare and progress of modern societies and that the young generation is expected to be prepared to carry on science and technology development. Research covers various topics from the context (e.g., school policies, classroom practices, teachers' beliefs and attitudes, parental involvement) and content of science learning (e.g., curriculum, access to informal science) to students' response in engaging with the math and science disciplines (e.g., interest, motivation, attitudes, choice). This review points toward the relation between students' achievement in and attitude toward science demonstrated by many studies.

Less is written in particular about science literacy -- the very general level of science education that technological societies expect from the whole population, not just those engaged in science-related activities. As the basic level of science education, literacy is built up through formal and informal learning. Many say that what we expect from a science-literate person is at minimum a positive attitude toward science and a basic knowledge about how science and technology affect everyday life. A positive attitude toward science is often mentioned as a desirable student outcome, as it is needed to enhance learning and further achievement. Positive attitudes toward science are generally proof that students *like science*, or have at least some appreciation for this discipline, which is a goal of science literacy.

By using the School Assessment Indicators Programme (SAIP) database, this study aims to analyze the relation between attitudes to science, test achievement, school science achievement, and various student, family, and teacher characteristics. Since the SAIP testing contains invaluable information on the level of students' science literacy, this study is expected to produce new evidence on the current state of science education in Canadian schools.

3. Methodology

Purpose of the study and research questions

This study aims to analyze aspects of student attitudes toward science in relation to student characteristics (age, gender, school science achievement, planning for post-secondary education), student SAIP test achievement, attitudes toward school, and various family and teacher characteristics. The analysis will be developed comparatively for the two age groups of students who participated in the SAIP programme. At the time of SAIP testing, they were enrolled at educational levels which correspond within most Canadian provinces to the end of Grade 7, marking the transition to high school (i.e., 13-year-olds) and to the end of Grade 10, marking the entrance in senior secondary schooling (i.e., 16-year-olds). Three major research questions will guide the analysis:

1. How are student attitudes toward science related to their science achievement and their attitudes toward school? Are there differences by age and gender?
2. How does the interplay of major influencing factors (i.e., student, parent, teacher) determine their achievement in SAIP testing and shape students' attitudes towards science?
3. What are the profiles of students who do well in science (i.e., score well on SAIP testing) and who believe science can fit into their educational pathways? Why do they "like science?"

Data

For the purpose of this research we will use the 2004 Science School Achievement Indicator Program (SAIP) data and target specifically students' attitudes toward science in relation to test achievement and other individual, parent, and teacher factors. The Student survey data contain overall achievement test scores and information on students' achievement in science courses, as well as a variety of variables regarding students' background and attitudes toward science. This dataset also contains information on students' perception about parental involvement in their science preparation, as well as data on parents' education. Students also expressed their opinions about the involvement, encouragement, and expectations of their science teachers. In addition, the SAIP Teacher survey data contain information on the qualifications, teaching experience, and specific views of classroom science teachers. The two datasets are merged by student unique identifiers. Rescaled weights are computed from the survey weights to preserve the counts in the SAIP sample while estimating correct proportions in the population.

There are several issues related to missing data. First, although SAIP test results are available for all students, about 10% of the records are systemically missing student survey data. Second, teacher data are missing for about 28% of the records in the merged file, in part because students, mainly some 16-year-olds, were not enrolled in science courses in 2004. Third, there could be some random missing values for various survey items. Therefore, the analysis will be initially based on a research sample of about 23,200 student records that contain both test results and student survey data. This sample shows similar test performance profiles compared to the original sample that is representative of the whole pan-Canadian student population. However, only about 18,500 student records are linked to teacher data, and this student subsample is less representative of the whole student population. It contains higher achievers and low proportions of students who declared not taking science courses during the current academic year. Since this subsample will be employed in modelling attitudes toward science and achievement in the SAIP test, it is expected that results will represent a best scenario. In the public report published by CMEC (2005), it is noted that there is not enough information about how representative the teacher sample was of the whole pan-Canadian population of science teachers.

Variables

Survey questions associated to variables used in this study are presented in Table A1 (see Appendix section). In this section, we conceptualize the variables used in the analysis.

Achievement. SAIP achievement is measured by a 2-category variable that indicates whether the student achieved below or above criterion in his/her age group. To offer a more complete picture of student performance in science, we will present some data on achievement in science courses during the current school year. This variable is described by 6 achievement groups based on students' grades. It will not be used in the modelling section.

Attitudes toward science. Twenty-one survey items measured on a 4-point Likert scale (i.e., 1=strongly disagree to 4=strongly agree) have been selected to construct measurement scales of student attitudes toward science. Some items reflect general views about science and its place in society, or science as a school subject, students' interest in science, and understanding of its utility value. Other items indicate how students position their achievement in science courses with respect to contextual factors.

Principal component analysis led to an aggregation of variables into two factors. One factor polarized those items that reflected a broad understanding of the utility value of science, the need for hard work and study in coping with the subject, and interest in science. This factor is likely to describe students' positive attitudes toward science, shaped over time through school experience and knowledge about the place occupied by science in society. This attitude scale points toward the active engagement that the student has with the discipline. Most items target the broad understanding of the importance of the field, and high scores reflect students' abilities to make judgements independent of occasional circumstances. For instance, some items that refer to science course marks, included in this scale, describe a positive approach by the student who is capable of making critical judgements about his/her own work or the course (e.g., obtaining a high mark because the course was well taught or the student studied).

The second factor polarized those items that reflected a narrow view of science directed toward immediate course-related results. This factor is likely to characterize students' negative attitudes toward science, based on the expectation that course difficulty could be overcome through good luck, natural ability, or easy marking. It also reflects a passive reaction to the subject that is viewed only in terms of the immediate task to obtain school grades. We use this factor in the descriptive and comparative analysis to explore to what extent students reduce their idea of science to the issue of school course grading.

The positive and negative attitude scales were analyzed for inter-item reliability, which led to medium values of Cronbach's alpha coefficients. Items included in the two attitudes scales are:

- Positive attitudes (11 items: STQ16B to STQ16F, STQ17B, STQ17F, STQ17K, STQ17O, STQ18D, STQ18E) → $\alpha = 0.71$
- Negative attitudes (10 items: STQ16A, STQ17A, STQ17C, STQ17G to STQ17J, STQ17L to STQ17N) → $\alpha = 0.72$

As expected, the two attitude scales were negatively correlated ($r = -.256$, $p<.001$). Therefore, one can anticipate that modelling any of the attitude scales will reveal similar relationships among variables. For the purpose of this study, the second factor that characterizes students' negative attitudes toward science will be dropped from the modelling section.

Attitudes toward school. Attitudes toward school are hypothesized to be relevant to understanding how and why students are doing better and have more positive attitudes toward a challenging subject like science. School engagement and enjoyment, fair treatment by teachers, and good relations with peers, as well as the ability to cope with school work may contribute to an enhanced love for learning and trust in the school institution that in turn can affect both achievement and attitudes toward challenging school subjects. This scale contains fifteen variables (Appendix Table A1) and has a large value of Cronbach's alpha coefficient, α = 0.82.

Parental factors. Mothers' and fathers' level of education are defined by 2-category variables that indicate whether the parent has or does not have a university degree. Parental expectations, encouragement, and involvement variables are measured on 4-point Likert scales.

Teacher factors. SAIP data contains information on students' perceptions of encouragement, academic help, and expectations from teachers, which are ordinal variables measured on a 4-point Likert scale. Data on teacher qualifications are used to construct a 2-category variable that indicates whether the teacher has a background in science (i.e., Bachelor or Masters degree in Science). Gender is also used in the analysis. In addition, teachers' views about the relation between achievement and student ability and his/her hard work in doing science are considered. Four variables related to student ability are available. The scale shows a medium reliability, with Cronbach's alpha coefficient, α = 0.56.

Other student factors. Individual characteristics are age and gender, which will be the two design variables that will structure the analysis. Students' satisfaction with science course achievement and the importance they assign to these results are described on 4-category Likert scales. Planning for post-secondary education is described as a 3-category variable indicating: university and college plans, technical and institute plans, and no defined plans yet. Another 3-category variable indicates whether or not students intend to work in fields related to science or are undecided. However, the research sample will also be presented with some details regarding which science-related fields are envisaged by students. Further research may consider how these detailed career plans relate to performance and attitudes toward science during the school stage.

Method

The analysis is based on various methods that include:

- Descriptive statistics (e.g., cross-tabulations of various single variables by age-gender groups, graphing).

- Principal component analysis and reliability analysis (e.g., aggregate variables into scales, verify reliability of scales, obtain composite scores).
- Multivariate comparative analysis (e.g., ANOVA) to compare composite scores of attitudes toward science by age-gender groups.
- Regression models to predict attitudes toward science and logistic regression models to predict student SAIP performance by various parent, teacher, and student factors.

4. Findings

4.1 Research sample and student profiles

Table 1 describes the research sample by the two design variables: age and gender. In addition, we summarize some variables that describe student profiles with respect to their science school achievement, satisfaction with school science achievement in the current year, importance students assign to these results, SAIP test results, plans for post-secondary education, and intended science-related career plans, including envisaged areas. This sequential description situates student achievement within a broader perspective of performance and aspirations with respect to science and future education.

The most striking age effect that is noticeable when analyzing the distribution of students across school science achievement categories are the large proportions of 16-year-old students who did not take any science courses during the current year. Some of these students could be at the senior high school level when science courses are no longer mandatory, but if 25% of boys and 19% of girls choose to end their exposure to science this early it might be of concern for practitioners and policy makers with respect to any school mandate to increase science literacy. Table 1 shows gender differences in school science achievement, supporting that, at least during elementary and middle school years, girls obtain better results than boys in science courses. However, students are not satisfied with their school results which are situated below the average of 2.5. Their level of satisfaction grows with age, in part because older students give less importance to school science performance. Although girls obtain higher grades in school, boys obtain better results in the SAIP science tests, especially for the 13-year-olds. Performance in SAIP tests declines with age quite visibly, showing that only 24% of boys and 22% of girls in the 16-year-old group achieved above criterion.

Table 1: Student profiles by age and gender				
Age	***Age: 13-year-old***		***Age: 16-year-old***	
Gender	**Male (n=5728)**	**Female (n=5642)**	**Male (n=5826)**	**Female (n=6004)**
Average mark in science courses (%)				
Above 90	9	11	6	7
Between 80-89	25	31	15	24
Between 70-79	30	27	21	22
Between 60-609	18	16	14	14
Between 50-59	9	6	11	7
Below 50	3	2	4	3
Don't know	5	6	3	3
Do not take science courses	1	1	25	19
Satisfaction with school science results				
Mean (SD)	2.1 (.7)	2.1 (.7)	2.3 (.9)	2.3 (.8)
Importance of school science results				
Mean (SD)	3.2 (.7)	3.3 (.7)	3.0 (.9)	3.1 (.9)
SAIP achievement of criterion (%)				
Below	57	61	76	78
Above	43	39	24	22
Post-secondary plans (%)				
Technical/Other	20	11	25	11
Don't know	19	18	8	6
University/College	61	72	67	83
Expect to work in a field related to science (%)				
No	23	26	32	38
Don't know	38	40	27	24
Yes	39	33	41	38
Most likely career choice areas (% of those who expect to work in science-related fields)				
Sciences	9	17	11	15
Engineering	30	4	25	4
Health sciences	14	42	17	56
Computer sciences	18	6	18	4
Math or science teaching	2	5	2	4
Other science/technology areas	8	6	8	5
Don't know	20	21	19	12

We notice that the proportion of students planning to attend university increases with age, just as the disparity between women and men increases. Among the 16-year-old female students, 83% plan to pursue university or college education as compared to 67% of male students. Large proportions of the older students have post-secondary plans and only 6% of women and 8% of men do not know yet. More male students plan to continue studies in post-secondary institutions other than university or college, and this proportion increases with age from 20% to 25%.

The proportion of those who expect to use science in further studies and career is slightly increased for the older students from 39% to 41% for boys, and 33% to 38% for girls. However, the proportion of those who do not expect to use science in further studies is increased even more when we compare the two age groups, from 23% to 32% for boys, and from 26% to 38% for girls. As noticed, at both ages, higher proportions of boys than girls intend to use science in further studies or career. However, the distribution of students across science-related areas is dependent on both age and gender. When comparing the two male age groups, it is interesting to notice that only about 80% express clear plans at both ages, and the only minor shift is noticed from engineering toward sciences and health sciences. The two female age groups are more dynamic. If 21% of the younger girls did not know which science-related area would be of interest, the proportion decreased to 12% for the older group. There is a clear shift in interest toward health sciences, with more than half of the 16-year-old female students selecting this field as the most likely career choice.

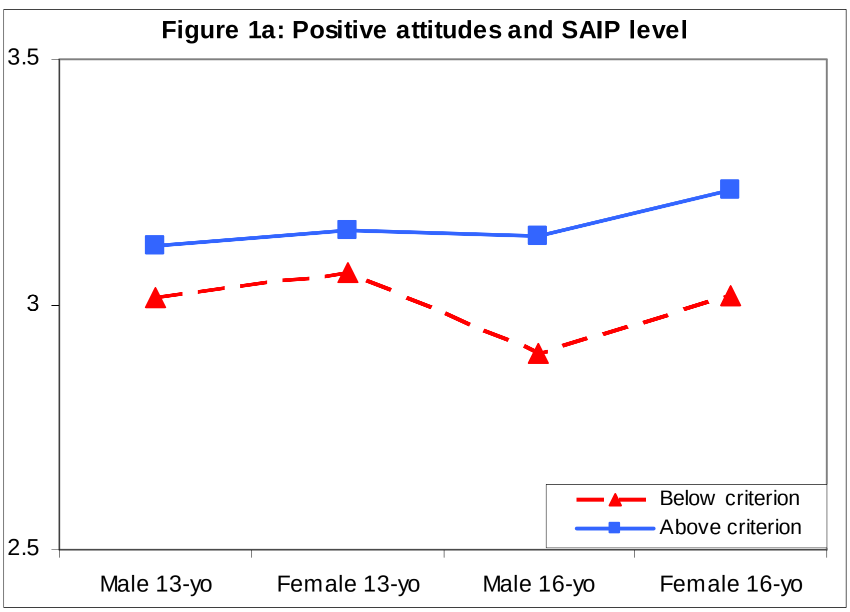
This preliminary descriptive analysis suggests that age and gender are relevant demographic characteristics in studying how students position themselves with respect to science. If age rather than gender seems to differentiate students with respect to school science outcomes (e.g., average science course grade and satisfaction with school science results, importance given to doing well in science, SAIP test achievement), both age and gender are determinant factors in planning for further education and science-related careers.

4.2 Attitudes toward science

This section contains comparisons of composite scores describing attitudes toward science by age-gender groups, and in relation to achievement (i.e., SAIP and school) and attitudes toward school. Table A2 (see Appendix) contains some details regarding students' responses to different attitude items by indicating the proportion of students who agree and strongly agree on each statement. Age and gender differences are visible across the table. For instance, surprisingly fewer older students agree that interest in science and that studying science are important to getting good jobs. On the other hand, older students are more likely to believe that natural ability is needed for doing well in science, which is regarded as more difficult than other subjects. Female students are more likely to consider that hard work and study lead to getting good results in science, in relation to their view that science is more difficult than other subjects. Boys are more likely than girls to relate good/bad luck, easy/tough marking and natural ability to their grades, while girls relate their results to course difficulty, the way it was taught, and the general difficulty of the subject. Age and gender differences are visible across both types of attitude items, either related to general views or course-related.

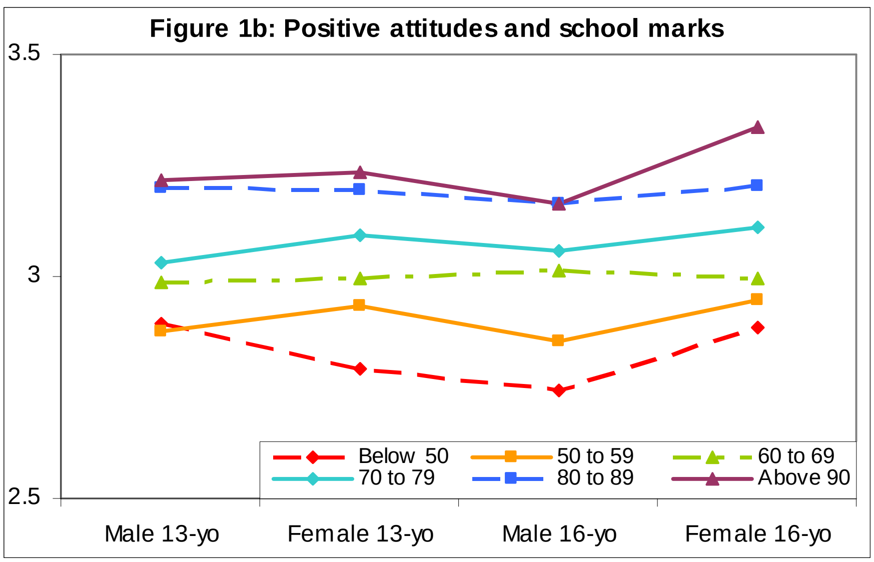
Attitudes and achievement

For both attitude scales, differences among groups are tested with a factorial ANOVA design, in which age, gender, and achievement are independent factors. Two measures of achievement are separately considered: SAIP test achievement (i.e., below and above criterion) and average mark in science courses (i.e., six achievement groups). ANOVA analysis results are shown graphically in this section (Figures 1a, 1b, 2a, 2b) and presented in Tables A3 and A4 (see Appendix).



Attitude-achievement patterns show that higher achievers, as identified by performance in SAIP testing (Figure 1a) or in school science courses (Figure 1b), have more positive views toward science. Gender and age are also relevant factors as confirmed by significant main effects

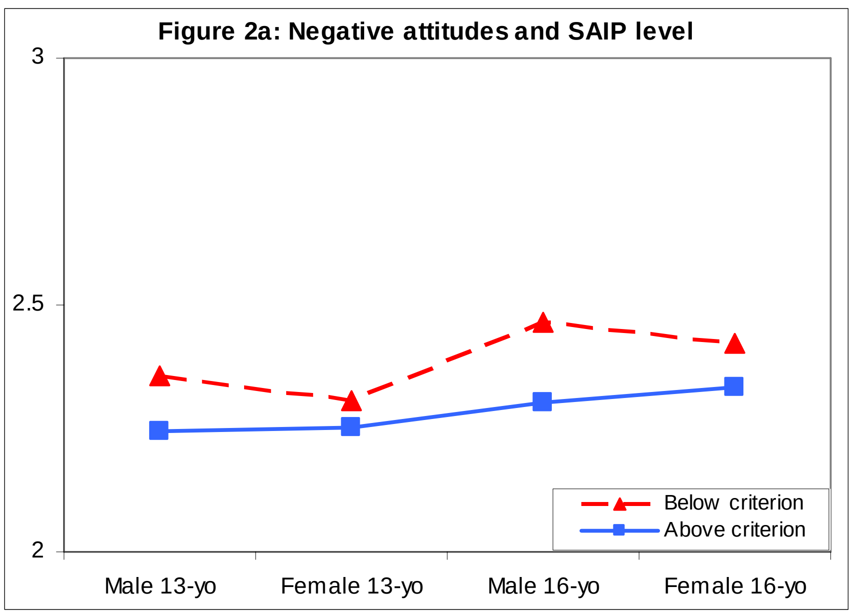
(Appendix Table A3). The level of achievement in SAIP appears to interact with age, showing lower attitudes for older students who achieve below criterion as compared to younger students of the same level. This suggests that with age, poor students are more likely to disengage with challenging subjects like sciences. For each of the two levels of achievement, female students hold more positive attitudes in terms of active engagement with science. Figure 1a shows that although all age-gender groups hold positive attitudes toward science above the average of 2.5, there is more variability among low-achiever groups. The 16-year-old male students who score below criterion are the most likely to disengage with science. It is important to note that with age, the attitude gap between low and high achievers is enhanced.



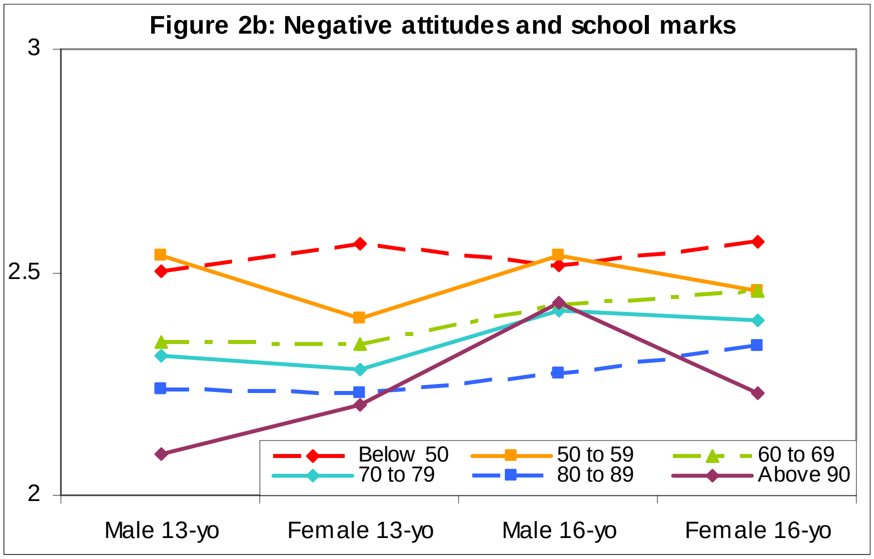
However, when comparing students' positive attitudes with school science results, differences by gender are more pronounced. The 13-year-old girls and 16-year-old boys who are low achievers are placed lower on this scale. Differences are also visible in Figure 1b that displays the average scores by age-gender groups and achievement. It shows that high-achiever girls score clearly high on the attitude scale, and especially the 16-year-old girls who obtain above 90 in science.

If we compare patterns describing students' negative attitudes toward science, the most significant differences are also related to achievement rather than age and gender (Appendix Table A4). For instance, those students who scored below criterion in the SAIP test are more likely to hold negative attitudes, blaming course difficulty and teachers for their results. This effect is more pronounced for boys than for girls and is enhanced with age. Similarly, when the six school achievement groups are compared, one can notice a clear tendency that those students who obtained lower average grades in science courses were more likely to blame external factors for their lack of success. Patterns are quite similar by gender, but age differences are pronounced, with older students more likely to search for explanations of their low achievement in outside causes.

Figure 2a reflects the patterns observed in Figure 1a in the opposite direction, and confirms that attitudes toward science, whether positive or negative, become more differentiated by achievement level for older students. Both graphs show that male and female students who score above criterion exhibit quite similar attitudes. However, the pattern line(s) that correspond to those who score below criterion show that the 16-year-old male group is the most problematic.



For the school science achievement groups, the pattern lines showing negative attitudes become more erratic (Figure 2b) compared to those describing positive attitudes (Figure 2a). In Figure 2b, if the younger male achievement groups exhibit a fairly large variation in attitude scores, as do both female groups, the older male group appears to be more homogeneous, most achievement groups showing similar attitude scores. Even the16-year-old males with marks above 90 in science seem to believe that external causes are responsible for their results.



With small exceptions, the two attitude scales show consistent opposite patterns: Students who have high positive views about science and demonstrate active engagement with the discipline are likely to disregard external causes affecting their performance. In contrast, those who are less motivated and interested in the subject and regard science as a difficult subject and a burden tend to look for outside reasons to justify their achievement. In the following analysis, we will use the positive attitude scale (hereafter called attitude scale) only. The content of this attitude scale that describes whether an active engagement with science is established is also related to concepts introduced in the literature review such as interest in science, utility value of science, self-concept, and persistence. Since in relation to attitudes toward science, SAIP achievement mirrors closely school science achievement, the second measure becomes redundant.

Attitudes and the school environment

Science courses are challenging subjects that confront students with knowledge and tasks that are perceived as difficult by about 50% of students in our sample. As reflected in the responses included in the positive attitude toward science scale (Appendix Table A2), over 70% of students assert that when faced with difficulties in science they would keep trying to solve the problem, and over 90% agree that doing well in science requires hard work. However, students are not alone in their struggle to cope with science, and family, school, and sometimes friends are typical resources. The question is whether or not students perceive these resources to be available, and to what extent the school environment contributes to building positive attitudes toward science that are essential determinants of performance.

Some of the factors that are expected to support students in school, and especially in coping with challenging subjects like science, are described in Table A5 (see Appendix). Although many students agree that parents' and teachers' encouragement is important for them to do well in science, age, gender, and achievement level differences are noticeable. For instance, girls are more reliant on parent and teacher encouragement. However, for support with difficult science problems, parents are the least expected to help, and students rely on teachers and friends. While 67% of 13-year-old boys and 69% of 13-year-old girls agree or strongly agree they would ask parents for help with science, these proportions are reduced to 36% and 41%, respectively, in the case of 16-year-olds. However, up to 87% of 16-year-old females would ask teachers or friends for help with science.

Figure 3: Students' perception of supporting factors

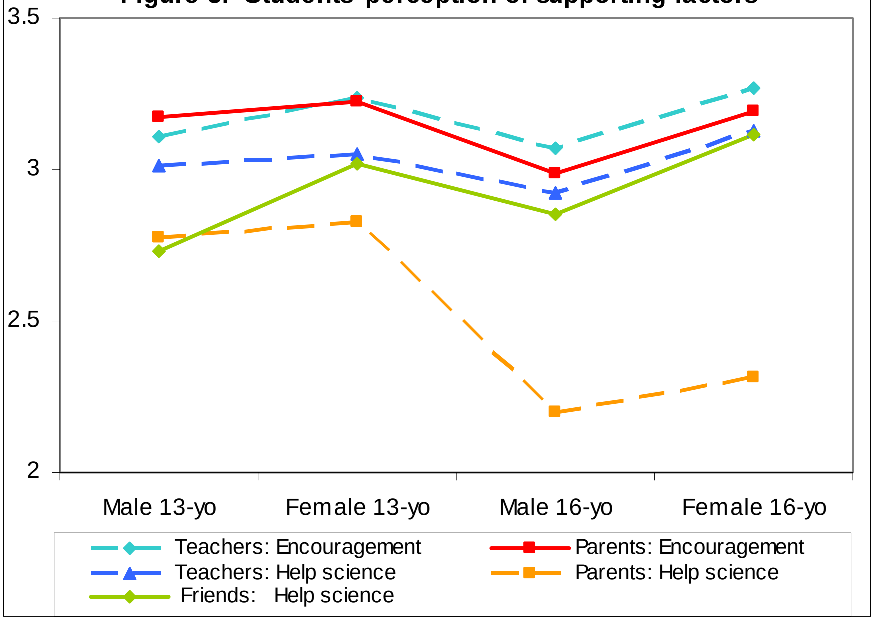


Figure 3 shows the mean scores describing students' perception of support from teachers, parents, and friends across the age-gender groups. The graph confirms the observation reinforced in the literature that although parents' encouragement is perceived by students as important in doing well in science, their ability to help the child when confronted with difficulties in science may become problematic. Especially when the child is in the upper grades and the content of science courses is increasing in difficulty, parents may not possess adequate knowledge to provide help. Therefore, it is likely that many students have to rely on teachers and friends. Thus, their ability to establish supportive relationships within the school environment becomes essential.

Table A6 (see Appendix) details the responses to the fifteen school attitude items by age, gender, and SAIP achievement level. It is impressive to find that over 90% of students like to learn new things, though not necessarily in school, because a significant number, especially boys, do not enjoy going to school (e.g., 49% of low-achiever 13-year-old boys). Only about half of boys and two-thirds of girls agree or strongly agree that going to school is enjoyable, and higher achievers are more likely to be in this category. Enjoyment to attend school is related to students' view that there is something interesting to do in school, and girls score better on this item. At the extremes, up to 75% of high-achiever 16-year-old girls as compared to 48% of low-achiever 16-year-old boys believe that school offers interesting things to do. Almost half of the students object that they are bored in school, over 90% declare they have lots of friends there, and over 80% feel respected in school. Interest in school work is more acknowledged by girls, and large differences by achievement become very pronounced for the older students, varying from 35% for the low-achiever boys to 76% for the high-achiever girls. However, over 80% of students feel they know how to cope with school work, although fewer low achievers admit they feel good about their results. Overall, students believe they are treated fairly by teachers.

Strong correlations between students' attitudes toward school and their attitudes toward science ($r = .473$, $p < .001$), their achievement in science courses ($r = .282$, $p < .001$), and even their SAIP achievement ($r = .079$, $p < .001$) reinforce the salutary role of the school environment in supporting learning and contributing to student engagement with challenging subjects like science.

4.3 Modelling achievement in and attitudes toward science

The focal variables of this study are:

- achievement in the SAIP science test used as a measure of science literacy level;
- attitudes toward science used as a measure of student engagement with the subject.

These variables will be analyzed separately as outcomes predicted by contextual and individual factors. Separate regression models will be developed for each age group to identify explanatory variables of outcomes for two significant educational transitions: middle school to high school (i.e., 13-year-olds) and junior to senior secondary school level (i.e., 16-year-olds). Logistic regression models will be applied for predicting the likelihood that students perform below or above criterion in SAIP science testing, and OLS regression models will be developed to predict the attitudes toward science. The following sets of variables are introduced sequentially by developing 3-step models:

- parent-related factors (mothers' and fathers' education, students' perception of parental expectations, encouragement, and support for science courses);
- teacher-related factors[1] (gender, number of years teaching science, qualification for teaching science, teachers' views about factors ensuring student success in science, and students' perceptions of teacher expectations, encouragement, and support for the course);
- student-related factors (gender, attitudes toward school, post-secondary education plans, intention to work in fields related to science, and satisfaction with achievement in science).

The 3-step models show minor differences in the contributions brought by each predictor in explaining the outcomes. Since the interplay of factors rather than the predominance of specific factors is of interest, only the regression coefficients for the full model will be shown, comparing the 13- and 16-year-old groups. However, we will comment on the model summaries for each step. By running separate regression analyses by age, we expect to identify sets of factors that are specific to each developmental stage. Although separate analyses by gender may reveal notable differences, previous research shows that these are likely to be captured through more elaborated analysis, like structural equation modelling (e.g., Mattern & Schau, 2002), which is beyond the scope of this study.

SAIP achievement models

Table 2 shows the results of the full models, which predict the likelihood of achievement above criterion in SAIP science test by age. The tests of the full models with all predictors against a constant-only model are statistically significant, as were the intermediary models controlling for various sets of variables. For the 13-year-old models, the first step (i.e., parent factors) explained 4% of the variance in the outcome and the second step (i.e., parent and teacher factors) did not bring any significant increase. In the final step, when all factors were introduced, the model reaches 11% in explaining the likelihood of achieving above criterion. The classification table shows that overall 63% of respondents were correctly classified by the logistic regression model, which indicates a modest model performance. Similar results are obtained for the 16-year-old group. The contribution of teacher factors was more pronounced as the models explained sequentially 4% of variance in the first step (i.e., parent factors) and 7% in the second step (i.e., parent and teacher factors). The test of the full model with all predictors against a constant-only model was statistically significant leading to 15% of the variance in outcome explained and 67% of respondents correctly classified by the model. For both ages, the achievement models show a significant but weak association between SAIP performance and predictor variables.

Parents' education has a positive effect on student achievement, enhancing by a factor of 1.4 the likelihood of achievement above criterion in the SAIP test for both ages. However, there is no significant relationship between student achievement and their perceptions of parental support with difficult science problems. For the 16-year-olds, there is tendency, although not significant, to increase the likelihood of good achievement in the SAIP test due to parental expectations. It is important to note that students who achieve well are not likely to perceive parental support with difficult science problems as a resource. As shown in the previous section, when confronted with difficulties in science, students rely on resources outside the family (e.g., teachers and friends). The contribution of teacher factors shows similarity for the two age groups. It is likely that having a male science teacher leads to better achievement in science, especially for the older students. This is an intriguing effect that requires further investigation. Frequencies show that this effect occurs for all 16-year-old students, regardless gender. Indeed, 32% of boys and 28% of girls who have a male science teacher, as compared to 25% of boys and 20% of girls who have a female science teacher, achieve above criterion[1].

Table 2: Student SAIP achievement model -
Odds ratios for the full model (achieving below/above criterion =0/1)

Variables in the equation	13-year-old	16-year-old
Parent-related factors		
Univ educated Mother (No=0; Yes=1)	1.394 **	1.360 **
Univ educated Father (No=0; Yes=1)	1.350 **	1.293 **
Student: Parents want me to do well in science	.882	1.025
Student: Encouragement from my parents is important	.779 **	.895
Student: I receive support with difficult science problems	.948	.876 **
Teacher-related factors		
Gender (M=0; F=1)	.992	.737 **
Science qualification (No=0; Yes=1)	1.216 **	1.116
Teacher: Students need ability to do well in science	1.057	1.388 **
Teacher: Hard work is required to do well in science	1.034	1.068
Student: Teacher want me to do well in science	1.090	1.138 *
Student: Encouragement from my teacher is important	1.118	.820 *
Student: I receive support with difficult science problems	.903 *	1.108 *
Individual factors		
Gender (M=0; F=1)	.863 *	.647 **
Attitudes toward school	1.007	1.332 *
Post-secondary plans: (Tech/Other =0)		
Don't know=1	1.325 *	1.759 **
Univ/college=2	1.350**	2.018 **
Work in a field requiring science education (No=0)		
Don't know=1	1.212 *	1.533 **
Yes=2	1.994 **	2.668 **
Satisfaction with results in science course	1.781 **	1.244 **
(Constant)	.184 **	.020 **
Model Chi-Square	**486.6****	**569.9****
% Correct Predictions	**63%**	**67%**
Nagelkerke R square	**0.11**	**0.15**

* $p < .05$ **$p < .01$

For the younger group, the most significant factors are teachers' background in science and students' perception of teacher encouragement and expectation of good results. For the older students, these factors have similar contributions, although qualification does not appear to be significant. For the 13-year-old group, the effect of teacher qualification is more pronounced, likely because not all elementary school teachers possess science degrees, while it is likely that most high school teachers who teach science have a science background. For both groups, but especially the 16-year-olds, the teachers' belief that student ability is important to do well in science increases the likelihood of a student achieving above criterion in SAIP testing. Although not significant, teachers' view that students must work hard to do well in science has positive effects on achievement. While encouragement by teachers has some relevancy for the 13-year-olds, teachers' support with difficult science problems is significant for the 16-year-old students.

Individual factors brought the most significant contribution to explaining the outcome. Gender strongly affects achievement, girls being less likely than boys to achieve above criterion for both ages. Student attitudes toward school bring a significant contribution to the model for the 16-year-olds and have a positive effect on achievement for the 13-year-olds. There is also a strong positive relationship between achievement and post-secondary planning, especially for the 16-year-old students: Better achievement in SAIP science testing is likely related to having university or college post-secondary plans. Those who intend to continue their studies based on science education are twice as likely to perform better on the test compared to those who are certain they will not use science in their future studies, or are not yet decided. Those who report high levels of satisfaction with results in science courses are almost twice as likely to achieve above criterion in the case of 13-year-olds, and about 1.2 times as likely in the case of 16-year-olds.

Overall, factors that exert a positive effect on SAIP test achievement are parents' education, most teacher factors (e.g., male teacher, science qualification, teachers' belief in the impact of hard work and student ability, and teachers' expectations), and student factors (e.g., gender, attitudes toward school, planning for university or college education, and satisfaction with science course results). The strong effect of student factors on test achievement is an important result because it suggests directions in which parents and teachers should work to support students' performance.

Attitudes toward science models

The linear regression models predict attitudes toward science by the same sets of parent, teacher, and student factors introduced in three sequential steps. We will show the results of all the model summaries but will present regression coefficients only for the final model (Table 3). All intermediary models controlling for various sets of variables were statistically significant. For the 13-year-old group, the first step that accounts for parent variables has led to a model that explains up to 19% of the variability in outcome. The proportion of the variance explained increases to 29% when both parent and teacher factors are included, and reaches 44% in the final model. For the older age group, variables introduced in the first step account for 11% of the variance explained, which is increased to 21% in the second step, and 42% for the full model.

Although in the first step model, mother's education was a significant predictor of positive attitudes for the older students, the effect disappeared when controlling for teacher and individual factors. In the final model, only fathers' education appears to be somehow important for the younger students. For both age groups, the most important factors are parental expectations and encouragement from parents followed by parents' support with difficult science problems; although the latter factor is statistically relevant only for the younger students.

Teacher variables also bring a significant contribution to the model. Among the most relevant are teacher qualification in science, teacher support with difficult science problems, and encouragement received from teachers. In the full model, teachers' expectations lose their importance for 13-year-olds, but represent a strong positive factor for the older students. A teacher's belief that students need ability to succeed in science has a negative effect on the younger students who may be discouraged if they are not up to ability expectations; it has a positive effect on the older students who may feel rewarded for their talent. An opposite effect is observed when considering teachers' belief that hard work is important in student success: It impacts positively on 13-year-olds' attitudes, but leads to a negative reaction on the 16-year-olds'. If teachers' gender was significant for predicting students' achievement, it does not play any role in influencing their attitudes.

Table 3: Student attitudes toward science model –
Regression coefficients for the full model (unstandardized coefficients & std errors)

Variables in the equation	13-year-old	16-year-old
(Constant)	.911** [058]	1.053** [058]
Parent-related factors		
Univ educated Mother (No=0; Yes=1)	.012 [.010]	.010 [.010]
Univ educated Father (No=0; Yes=1)	.030** [.010]	-.005 [.010]
Student: Parents want me to do well in science	.068** [.011]	.071** [.009]
Student: Encouragement from my parents is important	.048** [.007]	.042** [.008]
Student: I receive support with difficult science problems	.038** [.005]	.008 [.005]
Teacher-related factors		
Gender (M=0; F=1)	.000 [.008]	.002 [.008]
Science qualification (No=0; Yes=1)	.070** [.008]	.048** [.014]
Teacher: Students need ability to do well in science	-.027* [.009]	.015 [.019]
Teacher: Hard work is required to do well in science	.011 [.006]	-.020** [.007]
Student: Teacher want me to do well in science	.004 [.007]	.038** [.007]
Student: Encouragement from my teacher is important	.054** [.008]	.042** [.008]
Student: I receive support with difficult science problems	.115** [.006]	.075** [.006]
Individual factors		
Gender (M=0; F=1)	.006 [.008]	-.011 [.008]
Attitudes toward school	.326** [.012]	.303** [.013]
Post-secondary plans (Tech/Other=0; Don't know=1; Univ/College=2)	.009 [.006]	.053** [.006]
Work in a field requiring science education (No=0; Don't know=1; Yes=2)	.107 [.005]	.145** [.005]
Satisfaction with results in science course	.014* [.005]	-.002 [.005]
Model summaries & ANOVA tests	**$R^2_{adj} = 0.44$** **F= 254.8****	**$R^2_{adj} = 0.42$** **F= 216.2****

* $p < .05$ **$p < .01$

Student variables are determinant in predicting attitudes toward science. Although gender differences are not significant, a negative contribution to the attitude score is noticed for the older students, which suggests a deterioration of girls' attitudes toward science in high school. The most significant determinant of attitudes toward science is the factor describing students' attitudes about school. For the 16-year-old students, the model also shows strong relationships between attitudes toward science and planning to pursue university or college education, and working in a field requiring science education. The directionality of these relationships cannot be determined by this analysis. Students may engage with school science because they have post-secondary plans that can be achieved through science education. Another possibility may be that the likelihood of planning for university is increased if students develop positive attitudes toward science. Regardless of which comes first, it is important to point out that attitudes toward science are part of the equation when the 16-year-old students make their post-secondary plans. Even the 13-year-old students, who may not have clear understanding of post-secondary planning, show an enhanced appreciation of science learning if they can relate science to interesting jobs. Although students' satisfaction with results in science course plays a significant role in SAIP achievement for all students, a minimal positive effect on attitudes is observed only for the younger students.

In summary, the above models portray how contextual and individual factors contribute to determine students' attitudes toward science. Individual determinants that reside in student's own desire to succeed, satisfaction with school results, long term motivation for learning science, and defined plans for post-secondary education also play a significant role in building students' positive attitudes. Even if we introduced them as independent factors, it is likely that they become instrumental through the interaction with contextual factors created within family and classroom environments. Understanding of the value of academic coursework is the result of dispositions created within the family and the accumulation of cultural capital (Bourdieu, 1986), as is the ability to plan for future education and access to resources about work and occupational requirements. Parental expectations are significantly important in shaping students' attitudes. Less understood is whether and how teachers would help students to create forms of academic capital embedded in satisfaction with academic results, the desire to be rewarded for better school results, and the disposition to compete academically.

5. Conclusion

The purpose of this study was to explore the question: “who likes science and why?” There is no doubt that “liking science” is a major characteristic of a young generation that loves Star Trek, computers, and technological wizardry. It originates in children’s “genuine curiosity” and “spontaneous interest” as pointed out by other researchers (Baram-Tsabari & Yarde, 2005; Jones, Howe & Rue, 2000; Osborne, Simon & Collins, 2003). The findings of this study show that almost 90% of students affirm that they learn new things in science classes, over 85% of students agree that science is not harmful and brings good things to the world, and over 65% are interested in science subjects. This suggests that scientific topics appeal to students’ curiosity and desire to understand the surrounding world, and students also believe in resourceful scientific methods. Yet, if some young people see science subjects as being boring, uninteresting, distant, and above all, ‘uncool,’ causes should be sought in the school’s ability to reach out to students who decline involvement with science by the end of elementary school. This situation turns the question into: “What goes wrong in the process of engagement with science or, more specifically, why do students manifest what appears to be a sudden rejection of science?” In responding to the problem of student disengagement, this study has examined the role of three principal actors in the process of acquiring scientific literacy: teachers, parents, and the students themselves.

Teachers

Young people attribute their lack of interest in science courses to the way science is taught in schools, the complexity of these subjects, and an apparent shortage of attractive careers. The latter issue signals that students’ motivation toward sciences resides in the ‘task value’ associated with learning science (Barnes, McInerney & Marsh, 2005; Cleaves, 2005; Eccles, 2005). Indeed, our study findings show that 63% of students believe science is among the most important subjects in school. However, while about 65% of the younger students think science is useful in order to get jobs, this percent falls to 46% of the older students. Addressing students’ concerns about the accessibility of school science and its task value would require reworking the science curriculum to make it more relevant to young people’s experiences and expectations, highlighting the bright prospects that science and technology offer intellectually and financially, as well as the important role it plays in solving the major challenges of our modern life. The role of school and science teachers is essential to effectively implementing instructional changes (Chin, 2005; Jarvis & Pell, 2005) and developing appropriate learning tools. Teacher qualifications and their passionate involvement with science are essential in reaching these goals. As shown in the models developed in this study, when teachers possess science backgrounds, it is more likely that students of both age groups manifest positive attitudes and obtain good test achievement. *More research has to be oriented toward understanding how student outcomes in science relate to teacher knowledge, teaching ability, and passion for the subject.*

The study findings clearly show that teachers, not parents, are perceived by students as providing support when they encounter difficulties with science problems, a trend which increases with age. Other studies also attest that parental assistance becomes problematic with challenging subjects like math and science (Solomon, 2003; Zady & Portes, 2001). Although parents continue to have a large influence on children's schooling (Bourdieu, 1997; Crosnoe, 2001; Jacobs & Harvey, 2005), students turn toward teachers and friends when challenged with difficult school work. Tutoring is another major factor in ensuring students' academic success, but it is not discussed in this study. Study findings suggest that parents and teachers bring complementary contributions to student attitudes toward science because parental expectations balance teacher support. In the meantime, encouragement provided by both parents and teachers matter by boosting student self-esteem, as accounted for by other authors (Chiu, 1992; Dick & Rallis, 1991; Haring & Beyard-Tyler, 1992; Ma, 2004). In the case of older students, teachers' expectations and support were both found to lead to more positive attitudes. However, the same factors have a less pronounced effect on achievement. For instance, teacher expectations and support positively affect the 16-year-olds' achievement, while some influence on the 13-year-olds is attributed to teacher expectations and encouragement. *Surprisingly, little effort is assigned to developing a theoretical framework that relates student outcomes to socio-educational, attitudinal, and behavioural factors associated to teachers.*

Parents

While emphasizing the importance of teachers and classrooms in the development of student competence and interest in science, parents also play a role. Sometimes parental effects are directly observed and sometimes they interact with or complement those of teachers.

The research focused on the impact of family background on children's schooling and on parents' involvement with math and science activities is framed within the cultural capital theory that uses parental education, social class, and family resources to explain the bad and the good in one's educational career (Bourdieu & Passeron, 1977; Dumais, 2001; Reay, 2004). It is demonstrated that inherited cultural capital is instrumental at various educational stages that include senior high school and post-secondary education (Adamuti-Trache & Andres, in press; Ayalon, 2005; Dryler, 1998). Findings from this study are in agreement with previous research by confirming a relationship between parental education and students' achievement in and attitudes toward science. *Although a relationship between cultural capital and educational attainment is well supported theoretically, how this relationship is structured in the case of math and science attainments, as a direct effect or mediated by other factors, is not fully understood.*

The strong correlation we found between the 16-year-old students' school attitudes and their attitudes toward science and achievement suggests that students' outcomes in science emerge from an overall school success pattern (Crosnoe, 2001; Ireson & Hallam, 2005). Indeed, many studies demonstrate that high achievers in math and science obtain overall good school results. This connection reveals how family background impacts on students' science performance, even when parents know little about science. If educated parents contribute to instilling love and interest for academic work, raise high expectations for post-secondary plans, and even act as resources providing information about careers, they exert a direct influence in shaping children's positive attitudes toward school. If attitudes toward school are a necessary condition for good outcomes in math and science, parents indirectly contribute to enhancing attitudes and achievement in challenging subjects like math and science. While a large number of parents can support their children in enhancing their reading and even numeracy skills, science knowledge is more specific and less accessible to most adults. For many students, science teachers, and sometimes friends, are better resources to enhance competencies in this area. *Since family support may be in many ways subjective, or unavailable in families with low resources, better understanding of the role of school and teachers to create a uniform culture for all students is desirable and forms an area of needed research.*

Students

The above argument suggests that by strengthening school science learning we can offer all students equal access to math and science study. However, individual student characteristics play their role in making this opportunity viable for everyone. Students come to science class with different levels of ability and different academic inclinations that shape their future plans. For those who do not expect to work in a science-related field (i.e., about 30% of the SAIP research sample), science is just one of many school subjects, though this does not imply they do not want to learn interesting things in science classes (90% of students agreed on this statement). Science literacy that satisfies students' curiosity about the natural world and that leads to an acquaintance with the scientific method are the minimum requirements for a generation that aspires to live in and contribute to a knowledge-based economy. The 25-30% of students in the SAIP sample who do not know if they want to work in science-related careers might need to access resources that will assist them in their educational planning, while keeping up some math and science skills. Unfortunately, too many students end school without an appropriate level of science literacy and/or sufficient math and science skills to allow them to engage in further studies at a later time. If students adopt the "science is not for me" attitude, this would likely block their capability to discover the richness and utility of scientific knowledge. Science should be made available to everybody by ensuring that all students acquire in school a basic understanding of the role that science plays in one's life. *Research should focus on issues related to the process of 'knowledge transfer' – the relevance of scientific knowledge in the 'real world' – to find not only how science is applied to daily problems but also how science becomes part of an individual's 'world view'.*

However, science literacy, which is a goal of science education for everyone, represents only a good start in stimulating the interest and motivation of some 35-40% of students who expect to work in fields related to science, as estimated by the SAIP research sample. I argue that students with specific science goals perform better and have more positive attitudes toward science. Many studies attest that ability for math and science are significant factors in the ease and joy some students have in dealing with these subjects, and many support the idea that students should be assigned to classes or programs by ability level (Hallam & Ireson, 2003; Reay, 2004). Others argue that streaming and tracking that differentiate by ability affect students' liking of school because the values attached to different tracks act on students' self-esteem. In our study, about

45% of the 13-year-olds and over 60% of the 16-year-olds believe in natural ability. Teachers' belief that students need ability to do well in science is also correlated to better achievement in SAIP testing and positive attitudes of the older students. However, an opposite effect is observed on the 13-tear-old students, who may indeed become discouraged or pressured sensing that teachers differentiate them by ability. As others have noted, classroom environment has indeed an effect on students' perception of their own abilities, and girls are sometimes more dependent on teachers' recognition (Dreves & Jovanovic, 1998; Linver & Davis-Kean; 2005). *When student ability is recognized, rewarded, and challenged in difficult subjects like science, students feel empowered and become more responsible for their study – a relationship that needs to be better researched for its consequences for policy and practice.*

Gender differences were not of major concern in this study. Although girls tend to achieve below criterion in SAIP testing, they are doing better in science courses. Girls are slightly less likely to expect to be working in science related fields, although this proportion is improved for the 16-year-olds. However, with respect to attitudes toward science, there are gender differences noticed on some attitude items. More girls considered science a difficult subject, but in their attributions for success they believe less in ability, and more in hard work. Previous research suggests that girls' instruction requires specific teaching strategies that target separately achievement and attitudes (Mattern & Schau, 2002). In the case of boys, instructional strategies targeting achievement would be successful in reaching both ends. About 50% of the SAIP sample agrees that science is more difficult than other subjects and over 95% admit that to do well in science one needs hard work. It is difficult to interpret whether this is a positive or negative result because science is indeed difficult and requires, if not hard, at least sustained study. If not properly acquired, strongly consolidated, and continuously used, math and science knowledge and skills can be easily wasted. Teachers also believe that hard work is required to do well in science, and this attitude tends to favour better SAIP results for students and is likely to improve the attitudes of 13-year-olds. However, the attitudes of 16-year-olds are worsened when teachers support the idea that students need to work hard. Our data show that girls seem to be more responsible in understanding the role of study and work in obtaining good results in science, which leads to a visible impact on their school grades. On the other hand, by relying on good/bad luck, boys may take more chances with tests by going outside the box of classroom knowledge and obtain better SAIP test results. *The emerging debate on gender and school disengagement suggests that research needs to be undertaken that specifically deals with male and female adolescents' engagement patterns in science.*

Prospectus

This study offers an account of some factors that contribute to success in school science and supports the viewpoint that science education should be structured in ways that offer opportunity and a positive learning climate for all students. Ongoing progress requires a science literate population from which top research talent can grow. If this goal is not reached, there may be serious consequences for the development of our modern societies that base their prosperity and well-being on continuous scientific and technological progress. If more young people do not join the scientific community, or if potential scientific talent (e.g., women, individuals with low SES, immigrants, ethnic groups) is wasted because of artificial barriers imposed in sciences classes, this shortfall will become even greater. Although making science more attractive for students is a goal that needs to be considered and addressed by educators, there are inherent constraints related to this discipline that require students themselves to adopt a certain orientation and build basic scientific knowledge. In short, science culture and youth culture have to be connected.

Notes

[1] Only 72% of the original student sample (about 25,700 cases) could be linked to the available teacher data (about 18,700 cases). A representative student sample that contains test and survey data was used to produce the descriptive and comparative analyses to ensure comparability of findings with previous reports. However, due to missing data in the teacher sample, the modeling analysis is based on a sample that consists of about 18,700 cases. Frequencies based on this sample show some discrepancies compared to results presented in preceding sections or SAIP reports published previously (CMEC, 2005).

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Appendix

Table A1: Variable Specifications

Quest #	Survey question
Student SAIP achievement	
DLEVEL	Achievement of criterion (Below/Above)
Student individual characteristics and dispositions toward science	
AGE	Student age group
STQ01	Are you female or male?
STQ09/10	After you finish high school, do you expect to continue your education? What form of education do you intend to take?
STQ11/12	Do you expect to eventually work in a field that requires education in science or technology? Which comes closest to the area in which you would most like to work?
STQ08	How satisfied are you with how well you are doing in your science courses this year? **(4-category scale *)**
STQ14E	How important do you think it is for you to do well in SCIENCE? **(4-category scale *)**
Student attitudes toward science & school science (4-category agreement scale *)	
STQ16A	Science is more difficult than other subjects
STQ16B**	I am not interested in science subjects
STQ16C	I learn many new things in my science classes
STQ16D**	Science brings more harm than good to the world
STQ16E	Science is one of the most important subjects in school
STQ16F	Studying science is important to be able to get a good job
STQ17A	To do well in science you need natural ability
STQ17B	To do well in science you need hard work
STQ17C	To do well in science you need good luck
STQ17F	Low mark: I did not study hard enough
STQ17G	Low mark: the teacher marked too hard
STQ17H	Low mark: bad luck
STQ17I	Low mark: the course was difficult
STQ17J	Low mark: the course was not well taught
STQ17K	High mark: I studied a lot
STQ17L	High mark: the teacher was easy in marking
STQ17M	High mark: good luck
STQ17N	High mark: the course was easy
STQ17O	High mark: the course was well taught
STQ18D	If I were faced with difficulties in science I would be keep trying until I am satisfied
STQ18E**	If I were faced with difficulties in science I would be likely give up and not try to overcome the difficulty
Student attitudes toward school (4-category agreement scale *)	
STQ19A	I like to learn new things
STQ19B	I have lots of friends in school
STQ19C	I feel good about school
STQ19D**	I am bossed around too much in school
STQ19E	I know how to cope with school work

STQ19F	I am genuinely interested in school work
STQ19G	I get along with most students in my school
STQ19H	I know that people respect me in school
STQ19I**	I am usually bored in school
STQ19J	My teachers treat me fairly
STQ19K	I enjoy going to school
STQ19L	I feel good about my school work
STQ19M**	There is not much interesting to do in school
STQ19N	I feel important in school
STQ19O	I get the marks I deserve
Parents' education	
STQ25A	What level of education did your mother achieve?
STQ25B	What level of education did your father achieve?
Parental involvement as perceived by student (4-category scales *)	
STQ17E	To do well in science you need encouragement from parents
STQ14A	How important do your parents think it is for you to do well in SCIENCE?
STQ18C	If I were faced with difficulties in science, I would be likely ask my parents for help
Teachers' characteristics	
TCQ24	Are you female or male?
TCQ27B	Which of the following degrees or diplomas do you hold? B Sc or equivalent
TCQ27F	Which of the following degrees or diplomas do you hold? Master of science degree
TCQ28A-28G	If you hold a B Sc degree or higher in SCIENCE: which major or concentration? Biology; Chemistry or Biochemistry; Computer Sciences; Earth Sciences; Mathematics; Physics; Others
Teacher support as perceived by student (4-category scales *)	
STQ14C	How important do your science teachers think it is for you to do well in SCIENCE?
STQ17D	To do well in science you need encouragement from teachers
STQ18A	If I were faced with difficulties in science, I would be likely to ask the teacher for help
Teachers' views: factors influencing students' achievement in science (4-category agreement scale **)	
TCQ13H	Some students have a natural talent for science and some do not
TCQ13J	Students need natural talent to do well in science courses
TCQ13K	Students need to work hard to do well in science courses
TCQ13T	There are limits to what a teacher can accomplish because student ability has a large influence on achievement
TCQ13V	High school students should be streamed into different programs based on their abilities

* 4-category scales (e.g., agreement: 1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree)
** recoded 4-category scale

Table A2: Attitudes toward science scales – Percentage of students who agree and strongly agree

Survey question	**Percentage of students who agree & strongly agree (%)**			
	Age: 13-year-old		***Age: 16-year-old***	
	Male	**Female**	**Male**	**Female**
Positive attitudes				
I AM interested in science subjects	73	69	66	66
I learn many new things in my science classes	89	91	85	90
Science DOES NOT bring more harm than good to the world	81	88	86	91
Science is one of the most important subjects in school	62	63	62	64
Studying science is important to be able to get a good job	68	63	48	45
To do well in science you need hard work	95	97	93	98
Low mark: I did not study hard enough	81	86	82	81
High mark: I studied a lot	78	89	74	92
High mark: the course was well taught	90	91	87	92
If I were faced with difficulties in science I would be keep trying until I am satisfied	76	78	73	80
If I were faced with difficulties in science I would be likely NOT give up and WOULD try to overcome the difficulty	85	90	78	86
Negative attitudes				
Science is more difficult than other subjects	42	53	54	65
To do well in science you need natural ability	48	43	63	62
To do well in science you need good luck	27	21	28	21
Low mark: the teacher marked too hard	28	25	37	33
Low mark: bad luck	22	13	22	14
Low mark: the course was difficult	70	80	71	82
Low mark: the course was not well taught	35	36	47	50
High mark: the teacher was easy in marking	38	30	42	34
High mark: good luck	33	22	35	24
High mark: the course was easy	69	72	63	63

Table A3:
Adjusted means (standard errors in brackets) for the positive attitude scale by achievement

	Age: 13-year-old		*Age:16-year-old*	
Achievement	**Male**	**Female**	**Male**	**Female**
SAIP test:				
Above criterion	3.1 (.008)	3.2 (.009)	3.1 (.010)	3.2 (.011)
Below criterion	3.0 (.007)	3.1 (.007)	2.9 (.006)	3.0 (.006)
Main effects	**Age:**	**F(1,20358) = 5.99 (p < 05)**		
	Gender:	**F(1,20358) = 163.76 (p < .001)**		
	Achievement level:	**F(1,20358) = 794.49 (p < 001)**		
Average science school grade				
Above 90	3.2 (.0180	3.2 (.017)	3.2 (.020)	3.3 (.018)
Between 80-89	3.2 (.011)	3.2 (.010)	3.2 (.013)	3.2 (.010)
Between 70-79	3.0 (.009)	3.2 (.010)	3.1 (.011)	3.1 (.011)
Between 60-69	3.0 (.012)	3.0 (.013)	3.0 (.013)	3.0 (.013)
Between 50-59	2.9 (.017)	2.9 (.020)	2.9 (.015)	2.9 (.019)
Below 50	2.9 (.033)	2.8 (.037)	2.7 (.024)	2.9 (.030)
Main effects	**Age:**	**F(1,16848) = 0.032 (p > .05)**		
	Gender:	**F(1,16848) = 34.97 (p < .001)**		
	Achievement group:	**F(1,16848) = 305.98 (p < 001)**		

Table A4:
Adjusted means (standard errors in brackets) of the negative attitude scale by achievement

Achievement	*Age: 13-year-old*		*Age:16-year-old*	
	Male	**Female**	**Male**	**Female**
SAIP test:				
Above criterion	2.2 (.009)	2.3 (.010)	2.3 (.012)	2.3 (.012)
Below criterion	2.4 (.008)	2.3 (.008)	2.5 (.007)	2.4 (.007)
Main effects	**Age:**	**$F(1,20350) = 193.57$ ($p < .001$)**		
	Gender:	**$F(1,20350) = 4.64$ ($p < .05$)**		
	Achievement level:	**$F(1,20350) = 248.28$ ($p < .001$)**		
Average science school grade				
Above 90	2.1 (.021)	2.2 (.020)	2.4 (.023)	2.2 (.021)
Between 80-89	2.2 (.012)	2.2 (.011)	2.3 (.015)	2.3 (.012)
Between 70-79	2.3 (.011)	2.3 (.011)	2.4 (.013)	2.4 (.012)
Between 60-69	2.3 (.014)	2.3 (.015)	2.4 (.016)	2.5 (.015)
Between 50-59	2.5 (.020)	2.4 (.024)	2.5 (.017)	2.5 (.022)
Below 50	2.5 (.038)	2.6 (.044)	2.5 (.029)	2.6 (.035)
Main effects	**Age:**	**$F(1,16843) = 89.22$ ($p < .001$)**		
	Gender:	**$F(1,16843) = 2.70$ ($p > .05$)**		
	Achievement group:	**$F(1,16843) = 114.95$ ($p < .001$)**		

Table A5: Supporting factors – Percentage of students who agree and strongly agree

Survey question	Percentage of students who agree & strongly agree (%)			
	Age: 13-year-old		*Age: 16-year-old*	
	Male	Female	Male	Female
If I were faced with difficulties in science, I would be likely to ask the teacher for help	82	85	79	87
If I were faced with difficulties in science, I would be likely to ask a friend for help	68	83	75	87
If I were faced with difficulties in science, I would be likely to ask my parents for help	67	69	36	41
To do well in science you need encouragement from teachers	85	91	85	92
To do well in science you need encouragement from parents	86	89	79	87

Table A6: Attitudes toward school – Percentage of students who agree and strongly agree

Survey question	Percentage of students who agree & strongly agree (%)							
	Age: 13-year-old				*Age: 16-year-old*			
	Male		Female		Male		Female	
Level of SAIP achievement	*Below*	*Above*	*Below*	*Above*	*Below*	*Above*	*Below*	*Above*
I like to learn new things	93	96	96	99	96	98	98	100
I have lots of friends in school	92	91	94	93	92	89	93	94
I feel good about school	68	70	76	80	68	74	77	81
I am NOT bossed around too much in school	68	73	76	77	75	79	83	84
I know how to cope with school work	82	85	85	89	77	83	82	86
I am genuinely interested in school work	43	47	56	60	35	49	58	76
I get along with most students in my school	90	92	92	91	93	93	92	96
I know that people respect me in school	81	82	86	81	88	86	88	89
I am NOT usually bored in school	38	41	51	53	35	39	51	56
My teachers treat me fairly	80	82	86	88	84	89	85	92
I enjoy going to school	51	54	62	67	54	56	63	73
I feel good about my school work	71	80	76	86	63	77	73	84
There is SOMETHING interesting to do in school	57	59	67	71	48	55	63	75
I feel important in school	53	53	58	55	52	54	55	62
I get the marks I deserve	80	88	86	92	80	82	81	91