Science Engagement and Literacy:
A Retrospective Analysis for Students in Canada and Australia

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Abstract

Given international concerns about students' pursuit (or more correctly, non-pursuit) of courses and careers in science, technology, engineering and mathematics (STEM), this study is about achieving a better understanding of factors related to high school students' engagement in science. The study builds on previous secondary analyses of Programme for International Student Assessment (PISA) datasets for New Zealand and Australia. For the current study, we repeated these analyses to compare patterns of science engagement and science literacy for male and female students in Canada and Australia. The study's secondary analysis revealed that for all PISA measures included under the conceptual umbrella of *engagement in science* (i.e., interest, enjoyment, valuing, self-efficacy, self-concept, and motivation), 15-year-old students in Australia lagged their Canadian counterparts to varying, albeit modest, degrees. Our retrospective analysis further shows, however, that gender equity in science engagement and science literacy is evident in both Canadian and Australian contexts. Additionally, and consistent with previous findings for indigenous and non-indigenous students in New Zealand and Australia, we found that for male and female students in both countries, the factor most strongly associated with variations in engagement in science was the extent to which students participate in science activities outside of school. In contrast, and again for both Canadian and Australian students, the factors most strongly associated with science literacy were students' socioeconomic backgrounds, and the amount of formal time spent doing science. The implications of these results for science educators and researchers are discussed.

Introduction

Prompted by international concerns about school and post-school engagement and participation in science subjects, and by extension, students' pursuit of careers in science, technology, engineering and mathematics (STEM), this study's aim is an improved understanding of factors associated with school students' engagement in science. Science educators have long argued the case for universal scientific literacy as a central aim of science education policy and practice, and strong consensus exists that scientifically literate societies are essential in fuelling a nation's development. As well, beyond national economic development imperatives are the social benefits that accrue from a citizenry with strong science literacy, including citizens' decision making around issues of personal, social and ecological health and well-being (DeBoer, 2000; Goodrum, Hackling & Rennie, 2001; Hackling, Peers & Prain, 2007; Laugksch, 2000; Sadler & Zeidler, 2009; Symington & Tytler, 2004; Tytler, Osborne, Williams,

Tytler, Clark, Tomei, et al., 2008). However, while the benefits of science literacy for all are widely held and even heralded, the general decline of school and post-school engagement in science has also been acknowledged internationally, and a considerable body of evidence documents this drift (Bennet & Hogarth, 2009; Bybee & McRae, 2011; DeWitt, Osborne, Archer, Dillon, Willis, & Wong, 2011; Sjaastad, 2012; Tytler et al., 2008).

In Australia, emphasis has been placed on increasing the number of students taking science at the upper levels of secondary schooling (Department of Innovation, Industry, Science and Research, 2012). Internationally, public and political angst about falling enrolments in school science courses has resulted in frequent similar calls for more engaging science lessons, curriculum and teaching. In addition, coupled with a general decline in engagement and participation in school science is the continued under representation of women in physical science courses and careers (Hyde & Linn, 2006, Rennie, 2010). For example, data from the Relevance of Science Education (ROSE) study in Europe, that resulted from standardised surveys across 20 countries, showed that despite our aspirations, significant disparities still exist for females interested in school science and that, on average, girls report liking science less than boys (Schreiner & Sjøberg, 2004). This under representation of women in physical science courses and careers continues to preoccupy the science education community despite emphasis on gender-inclusive science over the past three decades (Aikenhead, 2011) and evidence that there is little difference in the abilities of males and females in doing science (Hyde & Linn, 2006; Sagebiel & Vázquez-Cupeiro, 2010). Given the internationally acknowledged importance of scientifically literate societies, and ongoing concerns about the lack of engagement in school and post-school science for girls and women, an improved empirical understanding of factors related to engagement in science is important.

The current study builds on previous secondary analyses of Programme for International Student Assessment (PISA) data for high school students in New Zealand and Australia that showed—quite differently from the factors associated with science literacy—that students' engagement in science is most strongly associated with science-related activities that students do outside of school. In contrast to science literacy, students' engagement in science was much less associated with students' socioeconomic status (SES), time spent doing formal science, or the nature of teaching (and learning) students report experiencing in their science classrooms (Author et al., 2011a; Author et al., 2011b). The current study builds on this work and comparatively examines factors associated with engagement in science and science literacy by investigating gender comparisons and a comparison of Australia and Canada. Canada is often cited as an appropriate comparator for Australia because of its geographical size, the size and diversity of its population, and similar cultural and political roots (e.g., member of the 'Commonwealth of Nations'). Furthermore, Canadian students have perennially performed well on PISA in comparison with other OECD countries (Bussière, Knighton, & Pennock, 2007), and the education system is generally regarded as highly equitable—from a socioeconomic standpoint—in both provision and educational outcomes (e.g., Bussière, Knighton, & Pennock, 2007; Perry & McConney, 2011). Therefore, through the application of our hierarchical analytical model to female and male 15-year-old students in Canada—a country very similar to Australia in geography and culture—this study builds on our understanding of factors potentially associated with students' science engagement and science literacy. The purpose of our study is to better understand the factors relating to student engagement in science and science literacy through a comparative examination of factors across Canada and Australia with a specific

emphasis on gender. In this retrospective analysis, therefore, we asked the following research questions:

1. How do female and male high school students in Canada and Australia compare in terms of their engagement in science and science literacy as measured by PISA 2006?
2. To what extent are patterns of association—among factors thought to explain engagement in science and science literacy—similar across the four groups, disaggregated by country and gender?

The answers to these questions will help us better understand the factors relating to student engagement in science and science literacy, and therefore help us to address international concerns regarding lack of engagement in school science and post-school participation in science, based on empirical analysis of an international science dataset.

Attitudes, Engagement and Participation in Science

Much research in science education has investigated the link between science attitudes and science achievement. Historically, underpinning calls for more engaging school science is an assumption that attitudes and achievement are closely related with positive attitudes directly (and positively) associated with better achievement in science. While this positive relationship finds considerable support in science education research (e.g., Singh, Granville & Dika, 2010; Swarat, Ortony & Revelle, 2012; Tran, 2011), a positive correlation is not always the case. For example, in their review of the literature on attitudes to science Osborne, Simon and Collins (2003) noted that many studies reported weak correlations between students' attitudes and achievement. More recently, a study of university students found no relationship between student interest and achievement in physics (Gungor, Eryilmaz, Fakioglu, 2007). Similarly, analyses of PISA (Bybee & McRae, 2011; Drechsel, Carstensen & Prenzel, 2011) and Trends in International Mathematics and Science (TIMSS) (Ogura, 2006) data demonstrate that positive attitudes towards science are not necessarily associated with high achievement in science For example, PISA 2006 findings for Finland, the gold standard for educational performance in cross-national comparisons, were among the lowest for interest in science whilst among the highest in science literacy (Bybee & McRae, 2011).

The variability evident in the empirical research literature therefore does not allow us to draw firm conclusions regarding the extent to which positive attitudes are associated with high achievement in science. At the same time, however, we contend that the strength of the correlation between these two constructs is not the most salient issue. Instead, we agree with Ainley and Ainley (2011) that along with "achievement an important educational outcome for today's young people is an attitude that gives participation in science an important place both in their current life and their future" (p. 52). Similarly, Fensham (2007) emphasised the importance of students' affect toward science, in addition to their cognition of science, as essential learning outcomes for all students. This emphasis on the affective component of students' interaction with, or response to science is not new. For example, more than two decades ago Head (1985) wrote *The Personal Response to Science* to highlight the importance of affect in science education. Twenty years later, Alsop (2005) published an edited book in which contributors explore the many aspects of affect in science education. One of the clear messages from these and other authors, across a 20-year span of science education research, is the importance of taking seriously student affect toward science, the non-cognitive aspects of science in students' lives.

Accordingly, it is evident that uni-dimensional affective constructs such as attitudes or interest in science (Osborne, Simon & Collins, 2003; Tytler & Osborne, 2010) have formed an important focus for science education research over the past two decades. More recent inquiry, however, has tended to focus on complex, multi-dimensional constructs such as students' engagement in science (Chang, Singh, & Mo, 2007; Lin, Lawrenz, Lin, & Hong, 2012). This shift raises the question of what is meant by 'engagement' in science. The research literature has depicted engagement as having three components (Fredricks, Blumenfeld & Paris, 2004). The first, *behavioural*, can be understood as participation in science or science-related activities (Lin, et al., 2012). The second, *emotional*, encompasses affective responses to science and includes constructs such as attitudes toward, or interest in science (Ainley & Ainley, 2011; Fredricks, Blumenfeld, & Paris, 2004; Osborne, Simon & Collins, 2003). The third component, *cognitive*, relates to the concept of investment in learning, or the extent to which students are willing to work to master science concepts and skills, drawing on previously studied constructs such as motivation and self-regulation of learning (Fredricks, Blumenfeld & Paris, 2004).

In this paper, engagement in science is anchored mainly to emotional and cognitive components, aligned with its description by Thomson and DeBortoli (2008) that emphasises students' attitudes towards science, responses to scientific issues, interest in learning science at school and beyond school, and their motivation to do well in science studies and to pursue a science-related career. More specifically, our conception of engagement in science depicts a multi-dimensional suite of affective variables including students' interest, enjoyment, valuing, self-efficacy, self-concept and motivation in science. Our use of these components was initially inspired by Professor Barry McGaw, former Director for Education in the Organisation for Economic Co-operation and Development (OECD) in his description of Australian students' performance across the first three rounds of PISA (McGaw, 2010).

As noted above, the *behavioural* components of engagement reflect activities that students do to participate in science both formally and informally. The formal aspect includes activities students are asked to do to participate in science lessons, including how much time they spend in lessons and homework and the types of activities in which they engage. On the other hand, informal participation refers to activities students do outside of their normal school program, including activities such as watching TV about science, reading books and magazine articles about science, attending science clubs and visiting science-related websites. In this paper therefore, our analytic model includes both affective and cognitive aspects of students' engagement in science, as well as behavioural aspects representing students' participation in both formal and informal science activities. In other words, the analytic model is designed to address our second research question, the extent to which students' affective and cognitive engagement in science and literacy are associated with various student and classroom factors. Our core interest is to examine the extent to which informal and formal activities are associated with students' emotional (affective) and cognitive engagement in science.

Method

This research provides a retrospective analysis of PISA 2006 datasets for Canada and Australia, focusing on students' engagement in science, and science literacy. Developed by the OECD, PISA is an international assessment of 15-year-old students' literacy in reading, mathematics, and science administered on a three-year repeating schedule. Each round of PISA assesses all three subjects and also focuses in considerable depth on one of the three; for 2006, that in depth focus was on science. The undergirding purpose of PISA is to provide large-scale,

high quality data that usefully support the development of member countries' educational systems toward students' attainment of the skills and knowledge necessary for personal and working life in countries with, or moving toward, 21st century globalized economies (OECD, 2004). Importantly, in attempting to achieve this purpose, PISA assessments differ from other international assessments in that they are intentionally decoupled from specific school curricula; rather, the assessments are designed to reflect holistic, authentic definitions of literacies in reading, mathematics and science.

Sample

For this secondary analysis, the 2006 datasets for Canada and Australia were collected from the PISA data housed at the Australian Council for Educational Research (ACER). Additionally, for the current study, we have extended previous analyses to also compare engagement in science (as measured by PISA) for female and male students, which allowed an assessment of equity across the two countries from the perspective of gender.

In PISA 2006, Australia's sample included 356 schools and 14,170 students, of whom 49% self-identified as female. The dataset for Canada included 896 schools and 22,646 students of whom 51% self-identified as female. In PISA, each country's sample is drawn to be representative of the number of students enrolled in different types of schools (e.g., non-government or government, college preparatory or vocational schools) and locations (e.g., metropolitan, provincial, or remote). However, PISA's two-stage sampling frame—by which schools are sampled first and then students sampled within schools—means that sampling weights are associated with each student because students and schools in a particular country may not have the same probability of selection. Additionally, some within-country groups are over-sampled to allow national reporting priorities to be met (OECD, 2009). This two-stage sampling frame has the potential to increase the standard errors of population estimates. Thus, in keeping with PISA's recommendation, descriptive and inferential statistics generated through secondary analysis of these data for Canada and Australia have taken account of the normalised final student weights included in the datasets, a procedure that allows realistic estimates of standard errors (OECD, 2009).

Variables

To answer this paper's research questions about female and male 15-year-old students' comparative engagement in science across the two countries, we examined PISA variables (interest, enjoyment, value, self-efficacy, self-concept and motivation) that have previously been associated with students' engagement in science (Author et al., 2011; Bussière, Knighton, & Pennock, 2007). As noted by Thompson and DeBortoli (2008), students' attitudes toward science in PISA 2006 included how they responded to scientific issues, the motivation they reported to excel in their science subjects(s), their interest in learning science at school and beyond school and their motivation to pursue a science related course or career. Thus, PISA 2006 took account of some of the pitfalls noted in previous reviews of the literature on measuring students' affect in science (Fensham, 2007; Nieswandt, 2008; Osborne, et al., 2003). Additionally, PISA's measurement of interest in science "gathered rich data on students' attitudes towards science not only by using the Student Questionnaire but also, for the first time, by embedding contextualised questions about student attitudes towards science in the actual test units" (Thomson & DeBortoli, 2008, p. 24). We therefore examined both PISA's measure of contextualised (subject-embedded) interest in science as well as students' general interest in science assessed by the Student Questionnaire.

Beyond students' subject-embedded and general interest, the variables linked to students' engagement in science included measures of students' (1) enjoyment of science; (2) personal value of science; (3) general value of science; (4) self-efficacy in science; (5) science self-concept; (6) instrumental motivation in science; and, (7) future-oriented science motivation. PISA's index of *enjoyment of science* was derived from students' level of agreement with statements like *I generally have fun when I am learning science topics* and *I am happy doing science problems*. A four-point scale with the response categories "strongly agree", "agree", "disagree" and "strongly disagree" was used. All items were inverted for scaling and positive values on this index indicated higher levels of enjoyment (OECD, 2007). PISA's index of *personal value of science* was derived from students' level of agreement with statements like: *I will use science in many ways when I am an adult*; and, *science is very relevant to me*. Positive values on this index indicated positive perceptions of the personal value of science. Similarly, PISA's measure of *general value of science* reflected levels of agreement with statements like: *advances in science and technology usually improve people's living conditions*; and, *science is valuable to society*. Again, positive values indicated positive perceptions of the general value of science in society (OECD, 2007).

PISA's index of *self-efficacy in science* reflected students' beliefs in their ability to accomplish science-related tasks on their own. These included students' assessment of their ability to recognise a science question underlying a newspaper report on a health issue; describing the role of antibiotics in the treatment of disease; and predicting how changes to an environment will affect the survival of certain species. A four-point scale with the response categories: *I could do this easily*, *I could do this with a bit of effort*, *I would struggle to do this on my own* and *I couldn't do this* was used, and positive values indicated higher levels of self-efficacy in science. Similarly, *self-concept in science* was derived from students' level of agreement with statements like: *learning advanced science topics would be easy for me*; *I learn science topics quickly*; and, *I can easily understand new ideas in science*. As with the other indices that make up engagement in science for this study, positive values reflect a positive self-concept in science (OECD, 2007).

We also included two variables that assessed students' motivation in science. The first, *instrumental motivation in science* reflects "external rewards that encourage students to learn, to choose subjects and to choose careers" (Thompson & DeBortoli, 2008, p. 128). Five items were used to assess instrumental motivation. Students were asked how much they agreed or disagreed on a four-point scale with statements like: *Making an effort in my science subject(s) is worth it because this will help me in the work I want to do later on*; and, *I study science because I know it is useful for me*. Similarly, "students' expectations about studying science subjects beyond secondary school and working in science-related careers are important aspects of student motivation to learn science" (Thompson & DeBortoli, 2008, p. 131). PISA therefore assessed *students' future-oriented science motivation* to take up a science-related career by asking students to indicate their level of agreement with items like: *I would like to work in a career involving science*; and, *I would like to work on science projects as an adult*.

Analyses

Analyses of students' *science literacy* were accomplished using comparisons across the four student groups organized by country and gender. Different to the suite of engagement in science variables, however, to achieve comparisons in literacy performance we used one (the first) of five plausible values for science literacy provided in the datasets, in keeping with suggestions from PISA and others (OECD, 2009; von Davier, Gonzalez, & Mislevy, 2009).

Plausible values are multiple estimates of literacy performance generated for each student in each subject. In large-scale assessment programs such as the National Assessment of Educational progress (NAEP), TIMSS and PISA, plausible values are used to: 1) alleviate concerns about bias in the estimation of population parameters when point estimates of achievement are used to estimate those parameters; 2) allow secondary analysis using standard techniques and tools to analyse data that contain measurement error; and 3) facilitate the computation of standard errors within complex sampling frames (von Davier, Gonzalez, & Mislevy, 2009; Wu, 2005).

In addition to comparatively describing differences in Canadian and Australian 15-year-old students' engagement in science and literacy performance, we were also committed to better understanding the relative strength of factors typically associated with variations in these constructs. Previously, we had described a four-step multivariate model for explaining variation in literacy and engagement for indigenous and non-indigenous students in Aotearoa New Zealand and Australia (Author et al., 2011). This four-step hierarchical regression model (Cohen & Cohen, 1983) included four potential explanatory variables: 1) student SES (Index of Economic, Social and Cultural Status [ESCS] in PISA); 2) informal science-related activities students do outside of school; 3) formal time students' spent studying science in and out of school; and, 4) the nature of science teaching students reported for their science classrooms.

The entry order of these potential explanatory variables for understanding engagement in science and science literacy was conceptualised according to guidelines provided by Cohen and Cohen (1983). Explanatory variables enter the regression model based on both timing and duration. Thus, the most fundamental of these variables would necessarily be student SES, as this describes the student's family background and/or circumstances, which would both precede (in time) the other explanatory variables and would likely have been of the longest duration. Using similar logic, and closely related to students' economic circumstances, the second variable to enter the hierarchical regression was the informal, outside of school science-related activities in which students engage (e.g., watch TV about science; read science books; visit science-related websites; etc.). This variable would arguably have been patterned or established well before the school year in which 15-year-olds were responding to PISA. Again, using similar logic of timing and duration, the amount of time students typically spent on their formal science activities including regular lessons, outside of class lessons and homework/studying would be the third variable to enter the hierarchical regression. Finally, because PISA surveys collect data reflective of 15-year-old students' preferences and experiences at one particular point in time, the student-reported characteristics of formal science classroom teaching would be the explanatory variable (relative to the other three in this model) of shortest duration, the most recently occurring in students' lives, and therefore the last variable to enter the regression model.

Findings

In this retrospective analysis of PISA 2006 we posed two interrelated research questions. The first sought a comparative understanding of female and male 15-year-old Canadian and Australian students' affective and cognitive engagement in science. Specifically, how do female and male high school students in Canada and Australia compare in terms of their interest, enjoyment, valuing, self-efficacy, self-concept and motivation in science? The first question also sought a stronger sense of the comparative patterning of female and male students' literacy performance in science. That is, how do female and male students in Canada and Australia compare in terms of science literacy as measured by PISA 2006? The second research question examined the degree to which variation in Australian and Canadian students' engagement and

science literacy could be explained using student and classroom (science teaching) data gathered through PISA. As well, the second question examined the consistency of explanations of engagement and literacy across country and gender.

Figure 1 and Tables 1 and 2 provide data regarding the comparative patterning of students' engagement in science. For all PISA measures included under the conceptual umbrella of *engagement in science* (i.e., interest, enjoyment, valuing, self-efficacy, self-concept, and motivation), 15-year-old students in Australia lagged their Canadian counterparts to varying degrees.

Figure 1 here

Additionally seen in Figure 1, Canadian males typically reported more positively than their female peers on 6 of the 8 engagement variables, the exceptions being *general interest in science* and *instrumental motivation toward science*. Similarly, Australian 15-year-old males reported more positively than their female counterparts on 7 of the 8 engagement in science variables shown in Figure 1, the one exception being *general interest in science* for which Australian females were slightly more positive.

Table 1 here

In answer to the science literacy performance component of the first question, and as shown in Table 1, Australian 15-year-olds slightly lag the science literacy performance of their Canadian counterparts by about 8 points. Further, shown in Table 2, the science literacy performance difference between female and male 15-year-old Canadian students is about 5 points, favouring males, and although statistically significant, can be considered very small at 0.05 standard deviation units (5% of one standard deviation). Tables 1 and 2 also show that for Australian students, there was no difference in science literacy between males and females.

Table 2 here

Table 2 also shows that many of the engagement in science male-female mean differences for students in both Canada and Australia are statistically significant at the 5% level. However, using widely accepted yardsticks for assessing the size of mean differences (e.g., Cohen, 1983; Kirk, 1996), most of these differences can be characterised as small or very small ranging between 0.02 and 0.27 standard deviation (SD) units (2 to 27% of one standard deviation). (We chose to use standard deviation units because they allow estimation and comparison of observed differences on a common scale.) Overall, in answer to the first question for this study, four patterns are notable: 1) Canadian students were consistently more positive about science than their Australian counterparts; 2) within each country, males are consistently, although only marginally, more positive than their female peers, with the exception of students' *general interest in science*; 3) in PISA 2006, Canadian students modestly outperformed their

Australian counterparts on science literacy; 4) within each country, male-female mean differences in science literacy are very small (non-existent for Australian students) indicating equitable performance from a gendered perspective in both countries.

Table 3 provides the proportions of variance uniquely contributed by each of the potential explanatory variables (or sets of variables) and addresses the second research question, the degree to which variation in Australian and Canadian students' engagement and science literacy can be explained using student and classroom (science teaching) data gathered through PISA. The explanatory variables are located along the top of the table for each of the four groups of students (Canadian and Australian female and male students) while the dependent variables of interest (nine engagement in science constructs and science literacy) are located along the left side. In order to illustrate patterns of explained variance, different shades of grey are used. Dark grey shading is used to signify proportions of explained variance that are 10% or greater; lighter grey shading is used to signify proportions of explained variance between 5 and 10%; and, no shading signifies proportions of explained variance less than 5%. The differential shading illustrates a pattern of factors that are associated with variations in science literacy and engagement in science.

Table 3 here

For Canadian students, the factors most strongly associated with variations in science literacy are students' SES (9% and 8% for female and male students, respectively) and time spent on science (9% and 11% for female and male students, respectively). Similarly, for science literacy in Australia, SES plays the strongest role (10 to 13%) with time spent in formal science lessons or science study a relatively close second (7% for both female and male students).

Again using the four-step hierarchical regression model described above, for the nine science engagement variables examined in this study, the patterns of explained variance portrayed in Table 3 are remarkably consistent. Quite starkly different from the findings for science literacy, the factor most closely associated with variations in all nine engagement in science variables is informal science activities (i.e., science-related activities students do outside of school), which contributed between 11 and 35 percent of explained variance across the four groups organised by country and gender. For each of the nine 'engagement in science' variables, the proportions of variance explained by the other 3 factors in the regression model (SES, time spent in formal science lessons or study, and the character of science teaching encountered in the classroom) pale in comparison. As depicted in Table 3, this is seen to be particularly so for time spent on science lessons and study (ranging from 0 to 6%), and somewhat surprisingly for science teaching (the features of science teaching and learning experienced by these students in their classrooms) which accounted for between 1 and 6% of explained variance. This patterning of the factors that contribute (relatively) most strongly to the explanation of variability in the nine engagement variables holds true for both Canada and Australia, and across female and male students, as shown in Table 3. The patterning of explained variance associated with each of the four explanatory variables is also highly consistent with the patterning we observed across indigenous and non-indigenous student groups in Aotearoa New Zealand and Australia (Author et.al, 2011).

Discussion

In this retrospective analysis of PISA 2006, our purpose in the first instance was to comparatively describe the cognitive and affective engagement in science, and science literacy performance, of male and female high school students in Australia and Canada. Our descriptive analysis shows that Canadian students were consistently more positive about science than their Australian counterparts across all nine measures of engagement in science, as well as having modestly higher science literacy. Our secondary analysis further shows, however, that little difference exists between male and female students in both countries in science engagement and literacy. Put another way, gender equity in engagement and science literacy seems to exist in both Canadian and Australian high school contexts. Overall, the evidence here suggests that females and males are much more similar than different, supporting the contention of Hyde and Linn (2006) that an emphasis on gender differences is perhaps counterproductive:

> To neutralize traditional stereotypes about girls' lack of ability and interest in mathematics and science, we need to increase awareness of gender similarities. Such awareness will help mentors and advisers avoid discouraging girls from entering these fields. Continued monitoring of the relative progress of boys and girls is essential so that neither group falls behind. Rather than focusing on gender differences, mathematics and science educators and researchers could more profitably examine ways to increase awareness of the similarities in performance and in ability to succeed. (p. 600).

These findings that support other empirical studies have implications for science teachers who can be optimistic about the abilities of females in the science classroom. It is also the case, however, that, in contrast with our findings, school science subject enrolments and post-school engagement both seem to reflect continued gender differences favouring males (Ceci, Williams, & Barnett, 2009; Cerinsek, Hribar, Glodez, & Dolinsek, 2012; Handelsman et al., 2005; Hazari, Sonnert, Sadler, & Shanahan, 2010; Miyake et al., 2010). It is likely that differences in these outcomes are associated with factors not examined by PISA. Further research on factors that influence high achieving females in secondary school science is warranted.

Second, our aim was to examine the extent to which various student and classroom factors are associated with students' affective and cognitive engagement in science and literacy. Consistent with previous findings for New Zealand and Australia, we found that for female and male students in both Canada and Australia, the factor most strongly associated with variations in engagement in science was the extent to which students participate in science activities outside of school. These out-of-school activities (watching TV about science, reading books and magazine articles about science, etc.) were most explanatory of the variation in the nine variables comprising the emotional and cognitive aspects of science engagement. In contrast, the proportions of variance in engagement in science associated with SES, time spent in science lessons/study and characteristics of classroom science activities are notably small by comparison. In contrast to the variables associated with engagement, the factors most strongly associated with science literacy are SES and the time students typically spend each week on science. Noteworthy here is that the nature of science teaching reported by students is not strongly associated with the nine engagement variables nor with science literacy, even though teachers have been shown to be important in facilitating students' science career interests (e.g., Hazari, Sonnert, Sadler, & Shanahan, 2010; Jones, Taylor & Forrester, 2010). What, then, is happening in these science classes?

One way to gain insights into what students are experiencing is to further examine students' self-reports of the characteristics of the science teaching they experience. The frequency distributions of science teaching activities provided in Figure 2 show that students in both Canada and Australia report that they experience remarkably similar frequencies of various types of classroom science teaching. Although Canadian students report being more engaged, there appears to be little variation in what Canadian and Australian students are actually doing in their science classes. Figure 2 also shows that the three teaching strategies that most strongly reflect student agency or autonomy in doing science (student investigations) are experienced least often. Specifically, when asked in the PISA questionnaire: *When learning <school science> topics at school, how often do the following activities occur?*, the three activities least experienced by students in both Canada and Australia are, *Students are allowed to design their own experiments* (Q 34h), *Students are given the chance to choose their own investigation* (Q 34k) and *Students are asked to do an investigation to test out their own ideas* (Q 34p). These three student-led inquiry oriented activities, when compared with the other listed activities, reflect the greatest opportunity for students to control how they formally engage with science content in their classrooms yet they are experienced least often. This is consistent with our previous analyses of PISA 2006 for New Zealand and Australia (Author et al., 2011).

The importance of student autonomy was highlighted in a US study that investigated and summarised relationships between classroom activities and student outcomes by looking at studies that used large-scale national surveys to measure the effectiveness of varying instructional strategies (Camburn & Han, 2011). Evidence compiled from six studies that specifically investigated the relationship between student autonomy and student outcomes in subjects such as math, English and science showed a positive relationship between student autonomy and learning outcomes. Further empirical support for the benefit of student autonomy includes a study that identified the opportunity to explore science independently as a major contributor to scientists' continued interests in science as a career (Jones, Taylor & Forrester, 2010). Additionally, Bulunuz and Jarrett (2010) showed that secondary school students with high interest in science also reported having more autonomy in their past middle school class experiences. This has clear implications for science teachers and their use of student-led science activities in their classes.

Despite numerous calls for more emphasis on inquiry learning in science teaching (e.g., Bell, Urhahne, Schanze, & Ploetzner, 2010; Swarat, Ortony, & Revelle, 2012; Tamir, Stavi & Ratner, 1998) and empirical evidence that this approach fosters student motivation and interest in science (e.g., Hazari, Sonnert, Sadler, & Shanahan, 2010; Jones, Taylor & Forrester, 2010), Canadian and Australian students in the 2006 round of PISA reported that they do not regularly experience student-led inquiry. We suggest therefore that an implication of this study is that further research be pursued to better understand the role of inquiry in students' engagement in science, with particular attention to student-led inquiry. In summary, these very similar portrayals of the science teaching students experience seem to confirm that country differences in engagement in science, favouring Canadian students, are not reflective of differences in their science classes.

Figure 2 here

While science classroom activities do not contribute much to explaining differences in variation for the nine variables comprising engagement in science, the factor most strongly associated with engagement was informal, out-of-school science-related activities. These results have held up in three different countries (Australia, Canada, New Zealand), across gender and across indigenous status. To gain insights into the factor(s) that *do* explain variations in science engagement we examined students' self-reports of their participation in out-of-school science activities. The frequency distributions presented in Figure 3 reveal that the absolute levels of participation in out-of-school activities is low for both Canadian and Australian students (less than 20% in all cases). However, several authors have noted the importance of these informal activities in relation to achieving broader engagement in science. For example, there may be potential for improving engagement in science if "students could be encouraged to take a broader view of science than just something you do at school" (OECD, 2007, p. 165). One avenue worth investigating may be the development of informal learning activities tailored for parents and guardians to ensure that the broader view of science is supported in the home environment (Jones et al., 2010), especially since studies support the critical role that family plays in facilitating student engagement in science (Archer, Dewitt, Osborne, Dillon, Willis, & Wong, 2012). One of the challenges therefore is to meaningfully link science learning activities in informal settings to those in more formal classroom settings (Bell, Lewenstein, Shouse, & Feder, 2009).

Figure 3 here

Despite overall modest participation in out-of-school activities for both Australian and Canadian students, two differences in their self-reported activities are notable. More Canadian students reported that they watch science on TV (Canadian 19.5%; Australian 16.4%) and read science magazines (Canadian 13.9%; Australian 9.9%). The nature of the data does not allow us to suggest a causal relationship between watching television or reading science magazines and increased engagement in science. Furthermore, a bi-directional relationship probably exists between out-of-school science activities (especially watching science television programs and reading science magazines) and the engagement variables we examined. However, since science affect is a strong predictor of middle school students' completing a bachelor's degree in the physical sciences (Hazari, Sonnert, Sadler, & Shanahan, 2010), further research and a better understanding of the contexts that spark engagement in science seems warranted.

In addition to the multiple implications listed above, a major challenge for science educators is how to create engaging activities within the science classroom that develop student engagement with science and *also* student scientific literacy. Our evidence suggests that student-directed approaches and ways to broaden the view of science beyond the science classroom, perhaps beginning at home, merit further attention.

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