Academic engagement and science achievement: A gendered relationship?

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Executive Summary

Given attempts to involve more girls in science and science-related careers, it is important to better understand gender differences reported in a recent test of science literacy administered to a national sample of Canadian 13 and 16 year-old youth. Results of the 2002 School Achievement Indicators Program Science (SAIP-SCIENCE) survey indicate adolescent girls perform significantly below boys in the application of scientific knowledge to applied, ‘everyday’ problems. Girls do, however, receive higher teacher-assigned grades than boys in their science classes. Since both assessment formats are important to establishing interest in and commitment to this field of study we examined the basis for gender differences in literacy scores and their relationship to teacher-assigned grades.

Much of the superior performance of girls in science classrooms may be attributed to teachers’ marking practices which incorporate not only cognitive achievement information but also social behaviours and compliance with demands for academic engagement – particularly, the completion of homework assignments. Homework then is correlated with teacher-assigned grades. However, because the latter are associated with objective test performance -- at least to the extent knowledge acquired in classrooms is transferable -- one would expect the study efforts of girls to be reflected not only in high teacher-assigned grades but also in higher literacy scores.

In this study we address the question: **Why do girls’ greater investments in homework not result in higher literacy scores**? We first establish the degree of difference between male and female scores on teacher-assigned grades in science and on the SAEP-SCIENCE literacy test. We next examine the effects on literacy achievement of a range of beliefs and behaviours suggested in the literature as predictive of achievement in science. These include PSE aspirations and parental expectations ‘to do well in science’, both of which may be assumed to encourage dispositions to study. We focus particularly on adolescent beliefs about the positive relationship between study effort and achievement. We also examine the effects on achievement of students’ homework behaviours – their actual investments of time in doing science homework. Taking dispositions, beliefs, and behaviours into account we next examine the effects of grades on literacy test performance. We find that all these factors are positively related to science literacy but that each also increases gender differences in literacy test scores.

With the qualification that science literacy scores of males and females are not widely discrepant, the pattern of gender differences in teacher-assigned grades and literacy scores found in the SAIP-SCIENCE data are important to the extent they discourage girls’ further involvement in science and science-related activities. Despite calls for better alignment of assessment indicators, it is unlikely that gender differences in teacher-assigned science grades and science literacy scores will be remedied by assigning girls more homework or persuading more girls to do homework. An effective initial response would be to recognize the variability in

science achievement among female science students. Many girls respond well to the current curriculum. Others do not and for these students curricular change may help. This requires an acknowledgement that science needs to be presented in more engaging ways, or even that girls may 'do' science differently. Similarly, it may be that boys performed well on the literacy test because their leisure time activities offer more opportunity to explore and apply science-related activities located in the community rather than the school. To the extent such informal learning is situated and experiential it too suggests alternative approaches to science instruction in the more formal setting of the school.

Introduction

Gender differences in achievement have been observed in teacher grades and in standardized tests for many years (Connelly, 2008; Downey & Yuan, 2005; Entwhistle, Alexander & Olson, 1997). Girls generally receive higher classroom grades while boys outperform girls on standardized tests. Several reasons have been offered for these differences. For example, teachers often consider student classroom behaviour in their grading and boys are generally more disruptive (or at least less compliant) than girls. And teachers deliberately reward effort – such as homework commitment and completion -- in addition to achievement in their marking in order to encourage student interest and involvement (Kelly, 2008). In standardized testing situations, individual differences in knowledge or skill are more directly assessed. Perhaps of even greater importance is the transfer of knowledge to different situations. The ability to solve novel problems is an instance of 'high-road' transfer that represents an understanding and application of basic scientific principles rather than their mere recitation (Salomon & Perkins, 1988).

The 2004 School Achievement Indicators Program Science (SAIP–SCIENCE) survey gathered data on the classroom achievement (grades) in science and objective test scores of scientific literacy from a nationally-representative sample of 13 and 16-year-olds. The literacy test assumes that students have acquired essential science concepts and principles in the classroom and are able to transfer this knowledge to a set of science literacy tasks. Consistent with the general evaluation literature, girls received higher science grades from classroom teachers and boys received higher standardized test scores on the SAIP-SCIENCE problem solving tasks (CMEC, 2004). What accounts for this gendered pattern of performance in science? And what are its implications for improving the participation of girls in science?

Since both assessment formats shape students' interest in and commitment to science as a field of study and possible employment, it is important to better understand the 'misalignment' in teacher-assigned grades and adolescents' performance on the SAIP-SCIENCE literacy test.

One student attribute that is highly regarded by teachers is academic engagement or, more specifically, behavioural engagement (Fredricks, Blumenfeld & Paris, 2004). The most obvious expression of the latter is 'time devoted to homework'. The value of investing time in homework is nevertheless controversial. While it is a feature of most teachers' instructional plans -- and generally supported by parents -- the academic merit of assigning homework is not favourably regarded by many researchers (Kohn, 2006; Kralovec & Buell, 2000). There is, however, evidence that homework time correlates with achievement in most middle and high-school subject areas, including science (Cooper et al, 2007). One of the reasons homework endures is that, in addition to being connected with achievement gains (better marks), it has social value. A belief in the relationship between effort and reward (effort-outcome covariation) is fundamental to both individual achievement and effective group behaviour – whether in the classroom, home, or workplace. Among adolescents, the ability to manage a homework schedule is evidence of the move to greater self-regulation. The ability to control impulses and so regulate one's study behaviour is an essential aspect of personal autonomy – a developmental imperative that emerges during early adolescence.

To the extent homework socializes adolescents to the role of student and affects their acquisition of transferable knowledge and skill, it may help explain the pattern of gender differences found in science achievement assessed by grades and standardized test scores. Homework is correlated with teacher-assigned grades and the latter are associated with objective test performance -- at least, to the extent knowledge acquired in classrooms is transferable. In the case of the SAIP-SCIENCE data, one would then expect the study efforts of girls to be reflected not only in high teacher-assigned grades but also in higher literacy scores.

In this study we address the specific question: **Why do girls' greater investments in homework not result in higher literacy scores**? We first establish the degree of difference between male and female scores on teacher-assigned grades in science and on the SAEP-SCIENCE literacy test. We next examine the effects on literacy achievement of a range of beliefs and behaviours suggested in the literature as predictive of achievement in science. These include PSE aspirations and parental expectations 'to do well in science', both of which may be assumed to encourage dispositions to study. We focus particularly on adolescent beliefs about the positive relationship between study effort and achievement. We also examine the effects on achievement of students' homework behaviours – their actual investments of time in doing science homework. Taking dispositions, beliefs, and behaviours into account we next examine the effects of grades on literacy test performance to gauge the degree of transfer from classroom to literacy test setting.

Background

Gender differences (and similarities) in achievement have been noted in several international assessments of high-school science, math and reading (McMullen, 2004). Differences have also been noted in associations between achievement (grades) and students' post-secondary education (PSE) aspirations, and other self-beliefs (Looker & Thiessen, 2004). This study examines gender in relation to adolescent achievement and selected factors that previous research suggests are relevant antecedents and correlates. These include: science achievement indicators, stated short and long-term goals, beliefs about effort as a value and as a cause of personal achievement, and the degree of commitment to homework.

Achievement Indicators

The literature on assessment in education emphasizes two relationships. The first concerns discrepancies between teacher-assigned grades and standardized test scores while the second involves the link between students' knowledge acquisition and their ability to solve applied problems (Ross & Gray, 2008).

Recent research on discrepancies in students' classroom performance and the results of formal testing has focussed on the intentions and behaviours of teachers. Kelly (2008), for example, argues that teachers reward non-cognitive behaviours such as responding to questions in class and completing homework assignments in order to encourage student engagement rather than ensure classroom discipline or the smooth operation of lesson presentation. Grades incorporate these behaviours directly while their benefits are only indirectly seen in standardized testing and in transfer tasks.

Students' ability to utilize their formal learning in applied settings involves transfer processes. Many standardized tests make few demands on students understanding in that they require recitation and surface reproduction of learned material. Of greater concern is the application of knowledge to practical problem solving tasks (Gredler & Shields, 2008). These problems comprise different structures. Some form recognizable patterns, are clearly defined and readily solved with the use of an algorithm. Others are less well-defined and require use of some heuristic (such as metaphor) to first identify the nature of the problem that then provides the insights necessary for a solution. Both types, however, involve understanding of important elements, dimensions, and causal relationships in the problem situation or setting.

The socio-historical perspective introduces the notion of situated learning in which problems have, additionally, a cultural overlay (Lave & Wenger, 1991). This perspective suggests the necessity of drawing on a more general awareness of the social setting in which scientific problems occur. To the extent awareness of context is important to problem solving it is likely that children with a wider experience of the world will possess some advantage. The problems presented in the SAIP-SCIENCE survey attempt to replicate problems arising in 'everyday life' that are solvable with the application of scientific principles learned in school, aided by relevant social and cultural understanding.

Parental Expectations

Parents' aspirations and expectations play a critical role in shaping the child's goals and dispositions (Sweet & Anisef, 2005). How these are communicated to children varies across families. Parents interact with their children in ways that promote self-regulation and emotional autonomy or, conversely, act to constrain development of these attributes (Dumais, 2005; Lareau & Weininger (2003). Male and female children appear to react differently to these home influences and boys in particular express their resistance (Sweet, Mandell, Anisef & Adamuti-Trache, 2007). This lack of compliance is also seen in the classroom, at least in the view of teachers. Farkas (2003), for example, suggests that teachers rate girls as being better 'citizens' in the classroom. That is, they are more responsive, cooperative, and attentive than boys. Using US survey data, Downey and Yuan (2005) related these classroom social behaviours to gender differences in adolescent school performance. While consistent with Farkas' work, an important qualification to their study was the need to consider specific subject areas such as math, science, and language when interpreting gender differences in outcome measures.

Self-beliefs and Academic Engagement

During the teen years adolescents begin to consider their future educational and career possibilities. Many of the beliefs formed at this time, as well as the behaviours they engage in, have important long-term effects. Clausen's (1991a; 1991b) notion of 'planful competence' includes a set of beliefs, dispositions, and behaviours that are associated with adolescent decision-making with consequences for their PSE and occupational futures. Planful competence describes individuals who: 1) feel confident in their capabilities; 2) can exercise a degree of self-regulation; and 3) are engaged in their studies.

Efficacy Beliefs Research on the relationship between students' belief in their own efficacy or competence and its effects on achievement have been reviewed by Eccles (2005), by Valentine, DuBois, and Cooper (2004) and, more recently, by Guerra & Bradshaw (2008). In general, studies in this area deal less with broad constructs such as 'achievement motivation' than with more specific factors associated with perceived ability or competence to perform tasks in a defined domain of study such as math, music, or science.

Such constructs as self-concept of ability (SCA) are typically based on implicit notions of intelligence or IQ. Self-assessments of efficacy are then made in relation to 'potential' or made relative to the perceived performance of classmates. Research by Marsh et al (2005) in Germany indicated that measures of self-efficacy are more closely associated with school grades than standardized tests. Their study also suggested beliefs about academic ability displayed few, if any, gender differences among German adolescents.

Other research has looked at the effects of attributions to effort rather than ability. Weiner (1986) and others argue that students gain a greater sense of personal control or 'agency' when attributions for academic success are made to effort. Equally, when faced with failure, effort rather than ability attributions are less likely to result in viewing oneself as a 'victim' or 'pawn'. Lloyd, Walsh, and Yailagh (2005) examined gender differences in a sample of BC adolescents' mathematics attributions and found girls consistently made attributions to effort for their mathematics success. In general, girls' attributions were more self-enhancing (agentic) than boys.

Self-Regulation Attending, concentrating and persisting are generally recognized as dispositions that are needed for learning. Children's possession of these is influenced by social structures such as gender, ethnicity, or social class because they are assumed constructed primarily within the family (Dumais, 2005). Parents play a primary role in developing these dispositions in their children. This is accomplished through the promotion of attitudes, beliefs, and values that parallel and complement those found in school classrooms (Lareau, 2003).

Although variously expressed across settings such as the classroom and home, these dispositions indicate the possession of self-regulating skills (Greene & Azevedo, 2007). The acquisition of such skills is, in part, developmental. As children mature they are better able to assume the responsibilities of the student role, underlying which is the ability to control impulses (Clausen, 1991b). The capacity to initiate and complete homework assignments is one such instance of children exercising volitional control over their studies. Sweet & Mandell (2005), for example, found that parental supervision of homework declined rapidly when children moved from elementary to middle or junior-high school and assumed responsibility for their homework assignments. In this way, adolescents gain a measure of autonomy in their relations with parents and teachers (Morrow, 1999; Clausen, 1991b).

Engagement School engagement is a form of investment students make in their studies. Fredricks et al (2004) describe several forms of school engagement and their relationship to achievement. Their review of the literature indicates the difficulties in empirically distinguishing among the various types. Homework is an example of academic engagement yet it also reflects social conventions and (frequently) emotional stress (Kralovec & Buell, 2000).

The comprehensive review of research on homework and its relationship to achievement conducted by Cooper, Robinson, and Patall (2006) provides evidence that homework <u>time</u> is associated with adolescent academic achievement. This assertion is questioned by Kohn (2006) who views homework as an impediment to learning and an imposition on students' leisure time. Other research by Trautwein & Koller (2003) suggests the association between the homework assignment and grades or test score performance is mediated by situational and contextual factors – located both in the classroom and the home.

While the 'homework debate' continues in the public domain, Canadian high-schools and their students maintain the practice. Recent evidence from the Youth in Transition Survey (YITS) indicates some significant gender differences both in terms of achievement and academic engagement. McMullen (2004), for example, found that among 15 year-old Canadians, girls' achievement in reading far exceeds that of boys while their scores are generally similar in Math and Science. Girls' homework completion rates and time invested in study were, however, significantly higher than those of boys across all subject areas. Also, establishing a homework routine appears to have long-term consequences. Shaienks, Gluszynsi and Bayard (2008) noted that PSE degree or diploma completion was significantly related to whether the student did three or more hours per week of homework in high school.

Summary

Our principal concern in this study is the role of academic engagement (homework) in adolescent boys' and girls' acquisition of scientific knowledge and its application to solving practical science problems. In this regard, the literature suggests we can expect:

1. Gender differences in science literacy scores that favour boys and differences in classroom grades that favour girls.

2. Girls to spend more time on science homework.

3. The importance parents attach to their children's performance in science class may contribute to gender differences in achievement, if girls are less resistant than boys to their parents' expectations for academic excellence.

4. Gender differences in children's post-secondary aspirations, efficacy beliefs, and attributional patterns are likely to affect achievement.

5. Children's classroom science grades will be positively associated with science literacy scores (as determined by standardized testing) but will enhance girls' ability to transfer acquired science knowledge in the solution of practical problems only if their grades accurately reflect acquired science knowledge.

Method

Data and Sample

For the purpose of this paper we used data obtained from the 2004 School Achievement Indicator Program survey of science literacy (SAIP-SCIENCE). The SAIP-SCIENCE survey was administered by the Council of Ministers of Education Canada (CMEC) to assess science literacy in each province [(Note 1)]. Literacy in this test asked students to "relate their understanding of science to real-life situations that were familiar to them" (CMEC, 2004, p.5). The literacy tests and student survey were administered to some 13,900 13-year-olds and 11,800 16-year-olds. In addition to the literacy test items, the SAIP-SCIENCE survey gathered information on respondents' characteristics and views. These included three groups – students, principals, and teachers. In this study only the student component of the survey was employed. This contains overall science test (literacy) scores, information on students' achievement in science courses (grades), as well as several variables regarding students' beliefs and behaviours toward school work in general and their science course in particular. This dataset also contains information on students' perceptions of parental expectations of their science performance.

There are several issues related to missing data. First, although SAIP test results are available for all students, about 10% of the records are systematically missing student survey data (Adamuti-Trache, 2007). These records were eliminated from the analysis leaving a research sample of 23,205 students. Second, there are some (random) missing values for various survey items. None of the variables included in the analysis has more than 3% missing data which suggests that the size of the research sample is relatively stable, and results are representative of the 13- and 16-year-old Canadian student population. Fifty-one percent of students are 16 years of age and 49% are 13 years of age. The sample contains 50.2% female students, with equal gender proportions within the younger age group and 51% female students in the older age group. Rescaled weights are computed from the survey weights to preserve the counts in the SAIP sample while estimating correct proportions in the population

Variables

The variables selected for use in the study are contained in the Appendix. Gender is the design variable. Age is included as a control variable and in this analysis is not of substantive interest although obvious differences exist in the school situations and performances of 13 and 16-year-olds.

Science literacy scores are dichotomous, indicating attainment (or not) of a 'literacy criterion'. For 13 year olds this was level 2 and for 16 year-olds it was level 3 on a scale containing 6 levels[(Note 2)]. Grades were reported by students. These would correspond to the report card grades assigned by their science teachers. As reported in the Appendix, teacher-assigned grades are represented on a scale ranging from 0 (failure or a lack of knowledge) to 6 (first class standing or above 89%). In defining the Grades variable, we included cases that did not take a science course 'this year'. This involved only 16 year-olds who had dropped out of a science course or who opted not to include science in their high school program. These were coded zero as being *relatively* less knowledgeable than any one currently enrolled in science.

Parents' influence on their children's school performance is indicated by students' perceptions of their parents' emphasis on the value of doing well in science. This is not intended to be a measure of socio-economic status (SES) as rising PSE aspirations and expectations characterizes parents' views across the SES spectrum. However, it is consistent with current critiques of parental involvement in children's education which assign different (social class-based) meanings to parents' expectations 'to do well' academically (Lareau & Weininger, 2003). Also, including students' understanding of their parents' wishes as an influence on their own notions accommodates the concern this paper has with children's construction of personal competence and autonomy.

Students' post-high school aspirations were included as indicators of student behavioural intentions. These are assumed to act as goals which direct the purposeful learning behaviour in students in the (science) classroom as well as other settings such as the home and community. While many students plan to move directly from school to work, most opt for some PSE pathway. Transition to the PSE system is consistent with the academic orientation of most Canadian high schools and so serves as a relevant motivator for students.

Student beliefs included statements endorsing the necessity of possessing 'natural ability' or 'hard work' if one is to be successful in science. These are essentially value statements reflecting both transferred family values and broad cultural norms.

In achievement situations of success or failure, causal attributions of ability and effort represent internal states. Unfortunately, the SAIP questionnaire did not include an attribution-to-ability question but rather asked for responses to the 'difficulty of the course' – an external attribution to task difficulty. However, one may infer the presence of one's internal state from the absence of the other. We therefore included only the effort attribution and interpreted a lack of endorsement to effort as a positive endorsement of ability.

Homework time was used as an indicator of academic engagement. The scale was the number of hours devoted to science homework in a week. Homework time was chosen as a behavioural expression of students' belief in the relationship between effort and achievement.

Results and Discussion

Description of gender profiles

This section examines gender differences across the variables used in the study. Table 1 shows the tests for the various proportions (i.e., chi-square statistics) or means (i.e., t-tests or non-parametric tests) of individual variables. A regression analysis follows in Table 2 that models the likelihood of meeting the SAIP achievement criterion.

In Table 1 some 34% of male students as compared to 31% of female students met the criterion on the SAIP test. While statistically significant, this is not a large difference. It is, in fact, similar to recent international assessments of 15 year-olds which show only small (and inconsistent) differences in science scores (McMullen, 2007). By contrast, teacher-assigned grades favoured girls who tend to have an average course mark closer to interval 70-79 as compared to boys who have an average mark closer to interval 60-69.

Table 1: Variables – descriptive statistics and tests of difference by gender

		Male (n=11555)	Female (n=11650)	Tests*
SAIP achievement: % who met the SAIP criterion		34%	31%	p<0.001
Grade received in science course (midpoint=3)		3.2	3.6	p<0.001
Belief in natural ability (midpoint=2.5)		2.6	2.5	p<0.001
Belief in hard work (midpoint=2.5)		3.3	3.4	p<0.001
Attribution to effort (midpoint=2.5)		3.0	3.2	p<0.001
Homework Time		2.2	2.5	p<0.001
Post-secondary plans	No plans	7%	4%	p<0.001
	PSE but DNK Program	14%	12%	
	Technical/Other	21%	10%	
	University/College	58%	74%	
Parental expectation to do well in science (midpoint=2.5)		3.2	3.2	ns

* We used chi-square tests to compare proportions, t-tests to compare means and a non-parametric test to compare ranks.

There are no significant gender differences between students' perception of how well parents expect them to do in science. Overall, students agree that parents want them to do well in science.

There are clear gender differences in students' plans for post-secondary education. Seventy-four percent of female students have academic plans as compared to 58% of male students. This corresponds to the increased female enrolments in university. It says nothing, however, about the pattern of participation at PSE. In fact, most still follow well-established, gendered pathways at university and college (Andres & Adamuti-Trache, 2008). Males are more attracted to vocational (technical) education (21%), perhaps reflecting not only preferred work orientation but the recent attempts to attract more young people to the apprenticed trades and other vocational or technical occupations. Interestingly, significant numbers of adolescents are undecided about their futures. The 13 and 16-year-old age groups are merged in these data. Nevertheless, one can observe that, among 13 year-old respondents, some indecision may be expected as they are not required to opt for a distinct academic or vocational stream at that age. Among16 year olds, however, indecision suggests a lack of planning for the impending school-work or school-PSE transition.

Significant gender differences exist in adolescents beliefs about the utility of effort and ability in relation to achievement. Overall, a belief in hard work is a more firmly held value than a belief in natural ability. However, boys are more inclined to believe in natural ability while girls tend to believe that hard work matters more in doing well in science.

Students were asked whether they attributed success (or failure) in a science test to effort. Their responses did not appear to reflect the apparent strength of their stated belief in the value of hard work and its contribution to achievement. There is an apparent contradiction between the beliefs expressed and the behaviours referred to in these causal attributions. However, this is observed somewhat less among girls than boys. To the extent effort is not a salient attribution in these situations, we may infer that a belief in natural ability is a more plausible explanation to these students. Such an attribution may support self-esteem when the student is successful but confers somewhat less security (sense of control and agency) when the student performs poorly, as some did on the science literacy test.

Gender differences also were apparent in the amount of time students devote to homework. For the science course specifically, the homework midpoint roughly corresponds to 1 hour (or less) of study per week. Both boys and girls, then, devote relatively little time to science homework.

Logistic regression models

In this section, we conduct four logistic regressions to examine the antecedents and correlates of students' performance on the SAIP literacy test. Specifically, we test which variables contribute to the prediction of SAIP performance and whether their entry in the equation reduces or enhances gender differences.

The first model (Model 1) establishes the impact of gender, controlling for the effect of age. The second accounts for student beliefs. In the third model we add homework time as an instance of behavioural engagement that may affect test performance (we assume it most directly affects grades). The final model displays the effect of school grades as an indicator of transfer effects. Table 2 presents the results of all four models using odds ratios.

Table 2: Logistic Regression Models (Below SAIP Criterion=0; Above SAIP criterion=1)

Variables	Reference Categories & Levels	Odds ratio			
		Model 1	Model 2	Model 3	Model 4
Individual					
Sex	Male=ref	.87**	.78**	.72**	.66**
Age	Age 13-year old=ref	.43**	.43**	.40**	.52**
Student beliefs					
Belief in natural ability	Scale variable		1.00	1.00	1.00
Belief in hard work	Scale variable		1.21**	1.15**	1.17**
Attribution to effort	Scale variable		.82**	.79**	.81**
Post-secondary plans	None=ref				
Planning (1)	Don’t know		2.23**	2.15**	1.99**
Planning (2)	Technical/Other		1.91**	1.82**	1.70**
Planning (3)	University/College		3.06**	2.78**	2.24**
Awareness of parental expectations	Scale variable		1.31**	1.18**	1.10*
Student behaviours					
Homework time	Scale variable			1.37**	1.12**
School achievement in science					
Grades	Scale variable				1.63**
Constant		.76**	.12**	.13*	.04**
Model Chi-Square		886	1437	1835	3804
Nagelkerke R^2		**5%**	**9%**	**11%**	**22%**

*p < 0.05 ; **p<0.001

In Model 1 we enter age (as a control) and gender to establish a baseline. Gender differences are not large although significant – the odds of females meeting the criterion are some 13% less than that of males.

Model 2 introduces indicators of students’ beliefs about what it takes to perform well in science (i.e., natural ability, hard work); their reaction to success/failure in the science course -- i.e., whether high marks are the result of study (effort) and low marks a result of a lack of study time; plans for post-secondary education (PSE) as a measure of student aspirations; and, finally, students’ awareness of the importance parents attribute to their success in science. The most significant effect is noticed for student PSE aspirations. As compared to students with no PSE plans, those planning for PSE are some 2 to 3 times more likely to meet the criterion. There is a relatively large and positive effect of student awareness of the importance that parents attribute to their success in science. Children of parents who expected them to do well in science were more likely to meet the science literacy criterion as compared to those who had no such expectations. A belief in the necessity of possessing natural ability to succeed in science is not significantly related to test performance. There is a positive effect on achievement due to students' beliefs that hard work leads to better results in science. However, the corresponding attribution (to effort) is negatively related to achievement on the literacy test. When controlling for these variables we notice an increased gender effect. The initial pattern of higher male achievement is further reinforced.

Model 3 introduces the behavioural engagement factor expressed as 'time spent on science homework'. Students who spend more time on science homework are more likely to meet the criterion. Holding this factor constant, however, increases gender differences. Despite girls' greater investment in homework, the likelihood of their meeting the criterion relative to boys decreases. Homework time also has an impact on the relationship between student beliefs and the likelihood of their meeting the SAIP criterion. For instance, it diminishes the perceived importance of parental expectations to do well in science; and its inclusion in the equation has a similar moderating effect on the effects of other student beliefs, with the exception of their belief in the efficacy of natural ability.

Finally, Model 4 includes grades in science courses to test the degree of transfer from classroom science learning to the literacy test situation. Grades are strongly associated with performance on the SAIP indicating effective transfer of classroom learning. However, controlling for grades further diminishes the SAIP performance of girls relative to that of boys. This suggests boys acquire a facility for solving applied science problems outside the classroom or are able to make better use of their classroom science knowledge – that is, they are better able to engage in 'high-road' transfer.

While students' beliefs, homework behaviours, and their grades are associated to varying degrees with attaining the SAIP criterion of achievement in science, the analysis indicates consistent gender differences. A comparison of the initial odds indicates that girls do less well than boys on the SAIP problem solving tasks -- and the addition of other factors merely serves to reinforce this disparity with odds ratios shifting from .87 to .66 as the model is completed.

Conclusion

This paper is an initial foray into the SAIP-SCIENCE data set. The larger project of which it is a part examines how adolescents' form educational and occupational plans that involve the pursuit or application science knowledge (Adamuti-Trache, 2007). Evidence of achievement is a key element in their planning and decision processes. In this study, we examined relationships between adolescents' beliefs about self, their study behaviours, prior classroom science grades, and performance on a science literacy task.

We first compared male and female adolescents on two forms of assessment – teacher-assigned grades and a standardized science literacy test. As suggested in the literature, there was a gendered pattern of performance on both assessments -- girls received higher teacher-assigned grades for their classroom work while boys performed better on the standardized test.

Our comparison of male and female literacy test performance assumed that both male and female students were motivated by short and long term goals. In this study these were represented by (parents') expectations to do well in science and by PSE aspirations, respectively. There were some differences in the level of PSE aspirations held by boys and girls – more boys preferred college than university -- but essentially the same proportions in both groups planned on continuing their education at the post-secondary level.

The further comparison of boys' and girls' belief and behaviour profiles indicated significant gender differences in the value of study effort, attributions to effort, and homework time. Girls more than boys endorsed the value of academic effort ('hard work'), made attributions to effort when explaining the reasons for academic success, and spent more time engaged in homework assignments.

The selected student beliefs and behaviours were then regressed on the SAIP-SCIENCE literacy test scores and produced the following findings which are summarized below:

1) Students' stated belief in the value of hard work was not supported by the negative relationship found between their test score performance and attributions to effort. This lack of congruence between effort beliefs and attributions suggest students view ability as more important than effort in determining academic success. Despite inconsistencies in effort beliefs and attributions, students do spend time on homework and these efforts are positively associated with higher test scores.

2. Grades also are positively associated with SAIP-SCIENCE test scores indicating the effective transfer of knowledge gained in the classroom.

3. The cumulative effect of both homework and grades on the relationship between gender and SAIP-SCIENCE performance is to further widen the initial gender difference in favour of boys. Girls lower levels of achievement compared to boys in the SAIP-SCIENCE literacy test suggests that acquisition of transferable classroom knowledge is not facilitated by girls' greater investment in homework. While in general the ability to solve the science literacy tasks involves knowledge transfer from classroom learning, it appears boys are better able to learn additional (or other) skills needed to do well on the SAIP-SCIENCE test. This advantage may derive from their involvement in related activities and situations outside the classroom. These may be more frequently undertaken or they may simply take different forms.

Students are encouraged to complete homework assignments and girls more than boys appear willing to do so. The literature suggests that teachers acknowledge this commitment by incorporating effort as well as achievement in their grading. For the most part, this is done with the intention of encouraging greater student engagement. However, our analysis of the SAIP-SCIENCE data indicates that boys spend less time studying science, receive lower grades than girls from their science teachers, yet they perform better than girls on a test of science literacy. It appears, then, that girls' greater academic engagement with the science curriculum does not improve knowledge transfer sufficient to offset boys' literacy test score advantage.

Implications

Many recommendations to more effectively engage students in science and reward acquired competence have been proposed, among them the need to better align grades and test scores. However, in relation to girls' involvement with science it is not clear that both subjective and objective indicators of science achievement should be more closely aligned. It may be preferable to present girls' with science materials and problem solving activities in ways that encourage different approaches to 'doing science' (Howes, 2002). This position is similar to those who question the culture of science as it operates in classrooms. Many critics of science teaching argue that science could be presented not as a discipline comprising a body of knowledge to be accessed only by applying set theoretical formulations and a complex array of 'rules' but rather as a narrative or set of stories to be critiqued (Gilbert, 2001).

Despite the durability of gender differences found in the literature -- and repeated here in relation to testing formats – there is a need to acknowledge the amount of variation within gender. The conceptual perspective suggested for this task concerns itself with development of a 'scientific identity' (Brotman & Moore, 2008). This approach would first acknowledge the variety of ways in which girls' engage with science. In fact, science does appeal to many girls who comfortably incorporate the practices of the scientific community into their own identity. Where this doesn't occur, science education needs to consider gender as only one of many factors in adolescent identity formation. Socio-economic status, ethnicity, and community features intersect with gender and need to be recognized in science programming (Roth and Tobin, 2007). This is especially the case in culturally diverse urban schools with high enrolments of immigrant students (Scantlebury & Baker, 2007).

Finally, the nature of informal science education needs to be considered. There may be important gender differences in students' reactions to the informal learning opportunities found in supplementary science programs, summer camps, and museum visits. At present most such programs enrol students who have already demonstrated an interest in science. How those girls (and boys), who are less engaged react, has not been adequately studied (Fadigan & Hammrich, 2004).

Gender differences in achievement are common across curricula and grades. Generally these differences are not large and concerns often expressed over relatively small differences may be somewhat misplaced (White, 2007). However, engagement and achievement have consequences for students' course choices and access to programs at the post-secondary level. For these reasons, further research is needed on the antecedents and correlates of girls' involvement with science in school and in community settings. The gendered pattern of achievement across types of assessment (grades versus standardized tests) examined in our study offers some insight as to students' general response to learning and applying science knowledge. It also reveals some of the difficulties and complexities that can be anticipated in further research on the topic.

Notes

1. The SAIP-SCIENCE literacy test assesses a range of science facts and concepts and requires these be applied to the solution of practical, ‘everyday’ problems. Examples of these problems may be seen on the CMEC website (www.cmec.ca)
2. The SAIP-SCIENCE literacy scores range from 0 to 5. The standard of performance or ‘criterion’ adopted for 13 year olds was set at ‘2’ and for 16 year-olds it was set at ‘3’. These levels were determined by a panel of experts as reflecting acceptable performance for those age groups.

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Appendix: Variable Specifications

Quest #	Survey question	*Variable categories / Derived variables*
	Student SAIP achievement	
DLEVEL	Achievement of criterion (Below/Above)	Below=0; Above=1
STQ07	Grade received in Science course	Recoded: 0= did not take science 1= <50 and DNK 2=50-59 3=60-69 4=70-79 5=80-89 6= >90
	Student individual characteristics	
AGE	Student age group	13-yo=0; 16-yo=1
STQ01	Are you female or male?	Male=0; Female=1 (recoded)
	Student Beliefs and Behaviours	
STQ14A	How important do your parents think it is for you to do well in SCIENCE?	4-category variable; 1=not important at all → 4=very important
STQ17A	To do well in science you need natural ability	4-category variable 1=strongly disagree → 4=strongly agree
STQ17B	To do well in science you need hard work	4-category variable 1=strongly disagree → 4=strongly agree
STQ17K	High mark: I studied a lot	4-category variable 1=strongly disagree → 4=strongly agree Derived variable as Mean of STQ17K and STQ17F
STQ17F	Low mark: I did not study hard enough	
STQ09/10	After you finish high school, do you expect to continue your education? What form of education do you intend to take?	Derived 4-category variable 0= No PSE plans 1=Don't know 2=Technical/Other 3=University/college
STQ15C	Homework Time (hours /week)	Derived variable: 1= no time 2=< 1 hr 3=1-2 hr 4=3-4 hr/5-6hr/6 hr and more