INDIGENOUS AUSTRALIAN STUDENT SUCCESS IN SCIENCE

Amanda Woods-McConney, PhD
Andrew McConney, PhD

School of Education
Murdoch University
Perth, Western Australia

MURDOCH UNIVERSITY
DISCOVERERS WELCOME

October 2014

INDIGENOUS AUSTRALIAN STUDENT SUCCESS IN SCIENCE

INDIGENOUS AUSTRALIAN STUDENT SUCCESS IN SCIENCE

ABORIGINAL & TORRES STRAIT ISLANDER HIGHER EDUCATION ADVISORY COUNCIL (ATSIHEAC)

INDIGENOUS HIGHER EDUCATION POLICY, RESEARCH AND STRATEGY GROUP
DEPARTMENT OF EDUCATION, AUSTRALIAN GOVERNMENT

Dr Amanda Woods-McConney
Associate Professor Andrew McConney

School of Education
Murdoch University

Table of Contents

List of Tables

List of Figures

1. Executive Summary

Declining interest and engagement in science and science-related courses and careers has been well documented and widely noted across Australia and similar highly developed countries. For Australia to successfully navigate the transition from a mostly resource-dependant economy to one that is knowledge-based and competitive, every effort needs to be made to help *all* students engage in science at the secondary and tertiary level. For a variety of historical and social reasons, Indigenous Australians, while expert in traditional ecological knowledge, are arguably vulnerable with regard to school science, reflected by longstanding lower achievement in science compared to their non-Indigenous peers. At the same time, research has shown that Indigenous students have interest in science beyond their non-Indigenous peers. This documented interest in science for Indigenous students highlights the need for further understanding Indigenous students' literacy and engagement in science. In this research, we attempt to better understand factors associated with science literacy performance and engagement in science for high-performing Indigenous students. A further understanding of these factors and the relationships among them for high-performing Indigenous students can help us identify patterns or relationships that appear important to Indigenous students' success in science.

In this research, we build on our recent research by further analysing factors associated with science literacy performance and engagement in science as measured by the Organization of Economic Cooperation and Development's (OECD's) PISA 2006 science assessment. The research was commissioned by the Commonwealth of Australia as represented by the Indigenous Higher Education Policy, Research and Strategy Group, Department of Education, as a means of better understanding Indigenous students' success and engagement in science. Amanda Woods-McConney, senior lecturer and Andrew McConney, Associate Professor, at Murdoch University in Perth, Western Australia conducted the research. Both researchers have substantial experience with secondary analyses of PISA data and commitment to better understanding factors associated with marginalised students' success and engagement in science. This report is designed to provide analyses and answers to five questions in short form:

- What characterises the learning and teaching environments reported by high-performing Indigenous students in science as measured by PISA 2006?

- For Indigenous students in science, what relationships and co-relationships exist among non-school based experiences/ characteristics and performance in science?

- What characterises the learning and teaching environments reported by Indigenous students with high self-concept in science as measured by PISA 2006?

- What profiles of engagement in science are evident for high-performing Indigenous students in science, as measured by PISA 2006?

- For high-performing Indigenous students in science, what relationships and co-relationships exist among engagement in science variables and performance in science?

The PISA 2006 data set was used to better understand high-performing Indigenous students' engagement in science and their learning and teaching environments. PISA 2006 was used because it is the latest PISA assessment that includes the engagement variables and the learning and teaching environment information for this study. For the purpose of this study *high-performing* and *high self-concept* were determined with a cut-score criterion of students at or above the 75th percentile for each measure, and for each student group, Indigenous and non-Indigenous. The top 25% of Indigenous Australian students (279 students) had a mean science literacy performance score of 574 (OECD average = 500). The top 25% of non-Indigenous students (3,313 students) had an average of 644 in science literacy. This difference equates to about 1¾ years of schooling. Socio-economic status (SES) is an important consideration for both high-performing Indigenous and non-Indigenous students. For both groups, and to a relatively equal degree, higher SES is associated with higher performance in science.

In answer to the first question, there were interesting patterns for high-performing Indigenous students. For both high-performing Indigenous and non-Indigenous students only one of four teaching-related variables evidenced a positive association with science literacy performance, when student SES and outside-of-school activities are controlled. That variable (*Applications and models*) reflects a strong orientation to teacher-led science teaching and learning. Within Science teaching: Applications and models, the component item that showed the largest differentiation between all Indigenous and high-performing Indigenous students, was the student-reported frequency of teacher explanations about how science ideas can be applied to different phenomena. A greater proportion of high-performing Indigenous students experienced teacher explanations frequently.

Science-related activities that Indigenous and non-Indigenous students do outside of school play a strong role in science literacy. This was the focus of the second question. For each unit increase in the composite measure of science-related activities outside of school, science literacy on average improves by about 11 score points, or about one-quarter of a typical school year's learning, for both Indigenous and non-Indigenous high-performing students. High-performing Indigenous students, on average, report participating at higher levels in out-of-school science-related activities in comparison to all Indigenous students, and in comparison to all non-Indigenous students, It is also the case that high-performing Indigenous students had a substantially lower average for out-of-school science-related activities than their non-Indigenous high-performing peers. Quite similar percentages of high-performing Indigenous and non-Indigenous students reported frequently watching science-related TV and accessing science-related books. In comparison to high-performing non-Indigenous students, lower percentages of high-performing Indigenous students reported frequently accessing science-related web content or magazines. SES plays a substantial role in science literacy for both Indigenous and non-Indigenous students. It seems likely that this extends to placing barriers in the way of Indigenous students in terms of their ability to access key science-related activities and resources outside of school.

The top 25% of Indigenous Australian students in terms of self-concept in science (248 students) had a mean science literacy performance score of 476 (OECD average = 500). The top 25% of non-Indigenous students (3,356 students) had an average of 587 in science literacy. Both of these averages are substantially lower than the averages seen for high-performing Indigenous and non-Indigenous students. Indigenous students with high self-concept in science also had mean interest in

science (531) considerably higher than that for all Indigenous students (475), all Australian students (465) and importantly, considerably higher than the mean for non-Indigenous students with high self-concept in science (506). Socio-economic status (SES) is a very important factor for both Indigenous and non-Indigenous students with high self-concept in science. For both, higher SES is associated with substantially higher performance in science, and this is particularly so for Indigenous students. Science-related activities outside of school have a modest positive association with science literacy performance for non-Indigenous students with high science self-concept; this does not seem to be the case for Indigenous students with high self-concept in science. For Indigenous and non-Indigenous students with high self-concept, only one of four teaching-related composite variables evidenced a consistently positive association with science literacy performance, when student SES and outside-of-school activities are controlled. That variable (*Applications and models*) reflects a strong orientation to teacher-led science teaching and learning. For Indigenous and non-Indigenous students with high self-concept, one teaching-related composite variable evidenced a consistently negative association with science literacy performance, when student SES and outside-of-school activities are controlled. That variable (*Investigations*) reflects a teaching and learning orientation to science which is largely student-led (students design their own experiments, choose their own investigations, etc.)

Turning to the question of the engagement profile of Indigenous students, nine PISA variables together comprise a meta-construct representing students' engagement in science: content specific science interest, general interest in learning science, enjoyment, general and personal valuing of science, science self-efficacy, science self-concept, and instrumental and future-oriented motivations towards science. For all nine measures included under the conceptual umbrella of engagement in science, Indigenous students with high science literacy led their Indigenous reference population, to varying, often substantial degrees. High-performing Indigenous students, on average, were also more positive on all nine science engagement variables when compared to all non-Indigenous students, although to a lesser degree than when compared to all Indigenous students. High-performing Indigenous students evidenced, on average, levels of engagement in science greater than the mean for every measure except "general interest in science". High-performing Indigenous students were nevertheless, on average, less positive on nine science engagement variables in comparison to their high-performing non-Indigenous counterparts. The size of these differences between the two high performing groups varied, but in the majority of cases can be characterised as substantial.

On the key question of the relationships among engagement in science variables and science literacy performance, students' enjoyment of science plays a significant role in science literacy. This was the case for both Indigenous and non-Indigenous groups with high science literacy, once SES is accounted for, and in the context of several engagement in science variables. The association between enjoyment of science and science literacy is considerably stronger for Indigenous students than it is for non-Indigenous students (more than 50% of a school year of learning science versus about 15%). For both Indigenous and non-Indigenous groups with high science literacy, once SES is accounted for, and in the context of several other engagement in science variables, students' self-efficacy in science also plays a significant role in science literacy performance. The association between students' self-efficacy in science and science literacy is considerably stronger for Indigenous students than it is for non-Indigenous students (just under 50% of a school year of

learning science versus about 25%). High-performing non-Indigenous students also evidenced a significant relationship between self-concept in science and science literacy performance, once SES had been accounted for, and in the context of several other variables representing engagement in science. This was not evident for Indigenous students with high literacy performance in science. We emphasise that because of the modest size of the group of high-performing Indigenous students, and hence the relatively high standard errors associated with regression coefficients for this group, the observed associations between science literacy and engagement in science variables should be interpreted cautiously.

2. Acknowledgement

Out of respect, we wish to acknowledge that this project has been developed and composed on *Nyungar* land. We hereby acknowledge all past and present Traditional Owners, Elders and Custodians of these lands. We wish to acknowledge and respect their continuing culture and the contribution they make to the life of this city and this region.

We are deeply grateful to Professor Ian Anderson (ATSIHEAC Co-Chair) and the Aboriginal and Torres Strait Islander Higher Education Advisory Council for their review of this report. In the final report any unintended omission or misrepresentation remain the sole responsibility of the report's authors.

Amanda Woods-McConney and Andrew McConney

3. Project Rationale & Purpose

In recent years, numerous commentators and commissioned reports have noted an alarming decline in students' interest and engagement in science and science-related courses and careers. This well-documented phenomenon is not confined to Australia's students, but has been widely noted across similar highly-developed countries, based for example on Organization of Economic Cooperation and Development (OECD) data and analyses.

…despite a substantial difference in scientific literacy scores, analysis of PISA data demonstrated that Indigenous Australian students' interest in science led that of non-Indigenous students by 10 score points…

For Australia, however, the phenomenon holds particular significance. For Australia to successfully navigate the transition from a largely resource-dependant economy to one that is knowledge-based, competitive and sustainably diversified for the 21st Century, every effort needs to be made to help more students, not less, engage in science courses at secondary and tertiary school and to pursue science-related careers post-compulsory schooling. Additionally, beyond the economic imperative, there are many social benefits that accrue from a citizenry with strong science literacy and engagement, including citizens' decision making around issues of personal, social and ecological health and well-being.

Within the Australian community, and for a variety of historical and social reasons, Indigenous Australians, while expert in traditional ecological knowledge, are arguably vulnerable with regard to school science, reflected by lower achievement in science as compared to their non-Indigenous peers. Perennially, education outcomes for Indigenous Australian students have lagged far behind those of non-Indigenous Australians. In school science, the outcomes for Indigenous students are no different, and the gap between Indigenous and non-Indigenous attainment remains large. However, based on documented successes in other countries like Canada, we believe that science provides an avenue by which tertiary education engagement and attainment could be improved by better understanding Indigenous Australians' views and experiences of science in secondary schools (Aikenhead & Elliott, 2010; Aikenhead & Michell, 2011). In this research, we attempt to build on recent research (McConney, Oliver, Woods-McConney, & Schibeci, 2011; Woods-McConney, Oliver, McConney, Maor & Schibeci, 2013; Woods-McConney, Oliver, McConney, Schibeci & Maor, 2014), by further interrogating variables associated with science literacy and engagement in science as measured by the OECD's Programme for International Student Assessment (PISA).

Specifically, for example, our previous research (McConney et al., 2011) showed that despite a substantial and significant difference in mean scientific literacy performance scores, analysis of the 2006 PISA data in science demonstrated that Indigenous Australian students' interest in science led that of non-Indigenous students by 10 score points (0.1 standard deviation). In that study, regression modelling further showed that for Australian students, variation in student science literacy performance was associated with reading literacy (62 per cent) rather than contextualised interest in science (less than half a per cent). This is counter to the conventional view that student literacy in science is associated with interest in science. Instead observed variations in science literacy (the difference between those students who achieved well and those who did not achieve well) were associated with SES and literacy in reading and mathematics. Indigenous students' high interest in science was not associated with literacy in science revealing that the gap in science literacy performance between Indigenous and non-Indigenous 15-year-old students is not a function of differences in contextualised interest in science. These results are especially interesting because there is an "alarming lack of interest in science among students in the more developed countries" (Fensham, 2007, p. 3). The documented interest in science for Indigenous students highlights the need for further understanding Indigenous students' literacy and engagement in science.

In subsequent analyses, the factors that influenced literacy performance and engagement[1] in science for Indigenous and non-Indigenous students were compared (Woods-McConney, et al., 2013). This analysis suggested that variations in science engagement, for both Indigenous and non-Indigenous Australian students were most strongly associated with the extent to which students participated in science activities outside of formal schooling. In contrast, and somewhat surprisingly, students' engagement in science showed only weak relationships with learning and teaching activities in their science classrooms. Further, and in contrast with relationships observed for engagement in science, the analysis also suggested that most of the observed variation in science literacy was associated with students' socio-economic status (SES), time spent in science lessons and study, and the types of science learning and teaching students typically experienced in their science classrooms.

...this research aims to better understand those factors, both within and outside of school, that facilitate Indigenous students' literacy and engagement in science...

We cannot, however, assume that these findings hold true for all groups of Indigenous Australian students in school science. For example, we currently remain unsure about the degree to which these associations among PISA variables and constructs in science education hold true for Indigenous students with high literacy or high engagement in science. It would be helpful, therefore to better understand the extent to which these relationships also hold true for Indigenous Australian students who have been characterised as high-performing on PISA, and the extent to which they might differ from other Indigenous students or from non-Indigenous students also characterised as

---

[1]We have conceptualised *engagement in science* as a "meta-construct" that includes students' general interest in learning science, contextualised interest, enjoyment, general and personal valuing, science self-efficacy, science self-concept, and instrumental and future-oriented motivations in science. All of these component

high-performing in science. A better understanding of these factors and relationships among them for Indigenous students who are high-performing in science, can assist our general understanding about what factors appear important to Indigenous students' success in science, as well as factors that may provide significant barriers to Indigenous students succeeding in science. By extension, such an improved understanding could help us better design science education programs that are tailored to encouraging and supporting greater proportions of Indigenous students in moving into post-secondary science courses and science-related careers. This research project therefore aims to better understand those factors, both within school and outside of school, that facilitate Indigenous students' literacy and engagement in science.

4. Method and Measures

Why PISA?

The Programme for International Student Assessment (PISA) is an international standardized assessment of the performance of 15-year-old students in reading, mathematics, and science developed by OECD and administered on a 3-year cycle that began in 2000. The OECD's original intent for PISA was to measure "how well prepared in Science (along with Reading and Mathematics) 15-year-olds are for life in the 21st Century" (Fensham, 2009, p.885). An additional underlying intent of the assessments is to support the further development of member countries' educational systems toward students' attainment of the skills and knowledge necessary for personal and working life in developed (industrialized) countries in a 21st century globalized economy (OECD 2004, 2007). Thus, PISA surveys have made an important departure from other international assessments such as Trends in International Mathematics and Science Study (TIMMS) by purposely constructing assessment items on holistic descriptions of discipline-specific literacies rather than focussing on specific knowledge recall and students' mastery of content (Sadler & Zeidler, 2009). Furthermore the instruments are decoupled from specific school or country curricula. Each 3-year assessment round of PISA includes all three subjects (reading, mathematics, and science) with substantial depth in one of the three subject areas. In 2006 the focus was science with the next round to focus on science scheduled for 2015. Although science literacy is gathered when the focus is on reading or mathematics, no data are collected for engagement in science unless it is a science-focussed assessment. Therefore to better understand high-performing Indigenous students' engagement in science and their learning and teaching environments this study used the 2006 data set.

Since the year 2000 science literacy has been gathered every three years, even when the focus was on reading or mathematics. This means that several years of data for the different cohorts of 15 year-old students are available and trends in Indigenous and non-Indigenous students' literacy in science performance can be tracked over time. As seen in Table 1, there has been a longstanding difference in performance between Indigenous and non-Indigenous students' science literacy. In 2000 the Australian mean was 529 while the Indigenous student group mean was 448, a full 81 score points lower. In the next cycle of PISA assessment in 2003 the mean difference in performance between Indigenous and non-Indigenous students' science literacy was 91 points, followed by 86 points in 2006, 78 points in 2009 and back to 81 points in 2012 with Indigenous students consistently scoring lower for each PISA assessment cycle. Although these mean differences do not represent the same students over time, they do represent a longstanding pattern of vulnerability with regard to literacy in science for Indigenous students in Australia.

Table 1. Science literacy performance by Indigenous background in PISA 2000 to 2012.

	PISA 2000		PISA 2003		PISA 2006		PISA 2009		PISA 2012	
Student Group	Mean	SE*	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Indigenous	448	9.5	434	7.7	441	7.8	449	6.2	440	4.3
Non-Indigenous	529	3.5	527	2.0	529	2.3	530	2.4	524	1.7
Australia	529	3.5	525	2.1	527	2.3	527	2.5	521	1.8
OECD	500	0.7	500	0.6	498	0.5	501	0.5	501	0.5

*Standard Error

Measures[2]

The PISA 2006 science assessment assessed different *science competencies* (identifying scientific issues, explaining phenomena scientifically and using scientific evidence) as well as *contextualised interest in science*, embedded questions about students' attitudes to science within the context of the science competency questions (OECD, 2007, p. 22). The science competency and contextualised interest assessment took 120 minutes for students to complete. After a short break the two hour assessment was followed by a 30 minute *Student Questionnaire* with questions about family background, time spent studying, out-of-school science related activities, teaching and learning environments and attitudinal measures.

Science Literacy Performance

As mentioned previously, PISA assessments are based on holistic definitions of literacies in specific disciplines rather than a retrospective measure of how much science knowledge can be recalled. Science literacy as measured by PISA "take(s) a radically different approach to assess how well 15-year-old students' science knowledge, from whatever source, can be applied to the situations involving science beyond school that increasingly confront citizens." (Fensham, 2009. p. 885). Instead of using the traditional measure of science achievement and passive 'stores of knowledge', PISA science content assessments gauge students' ability to "actively use knowledge in new situations." (Fensham, 2009. p. 885). Thus, science achievement is more accurately referred to as students' "science literacy performance" to reflect the more holistic application of science knowledge to new situations.

Contextualised Interest in Science

Traditionally, affective variables have been separated from the achievement component of assessments that measure achievement and affect towards science. However, the PISA Science 2006 student assessment was different. Consistent with the "latest research and thinking on science education" (OECD, 2007, p.25), attitudinal questions were embedded in the science literacy performance component. The purpose of these questions was to "better understand students' views on particular science issues and to generalise these results into measures of students' interest in

---

[2] The terms *measures* and *variables* will be used interchangeably in this report.

science" (OECD, 2007, p. 25). There were 32 embedded questions that assessed contextualised interest in science. The stem for the contextualised interest items asked about students' interest in a specific topic and students chose from four options including *high interest*, *medium interest*, *low interest*, and *no interest*. Within the topic Tobacco Smoking, for example, students were asked "How much interest do you have in the following information?" and were given the following three statements:

(1) Knowing how tar in tobacco reduces lung efficiency
(2) Understanding why nicotine is addictive
(3) Learning how the body recovers after stopping smoking

Rather than relying on a conventional and general measure of attitudes towards science, contextualised interest in science represents students' curiosity in science and science related issues and endeavours and their willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods, in the context of each science competency (Fensham, 2007, p. 8).

Engagement in science

Multidimensional affective constructs such as *engagement in science*, and their associated component attitudinal constructs are seen as important outcomes of science and possible mediators of increased performance in science (Ainley & Ainley, 2010 p. 2). Beyond students' contextualized interest in science, the PISA variables linked to students' engagement in science included measures of students' (1) general interest in learning science (2) enjoyment of science; (3) personal value of science; (4) general value of science; (5) self efficacy in science; (6) science self concept; (7) instrumental motivation in science; and (8) future-oriented science motivation.

Specifically, PISA's index of general interest in learning science asks students to identify their interest from *high* to *no interest* for *physics, human biology, ways scientists design experiments* and other general topics.

PISA's index of *enjoyment of science* is 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* on a four-point scale with response categories "strongly agree", "agree", "disagree" and "strongly disagree".

Representing a more instrumental aspect, PISA's index of *personal value of science* reflects 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*. Similarly, PISA's measure of *general value of science* reflects levels of agreement with statements like: *advances in science and technology usually improve people's living conditions*; and, *science is valuable to society* (OECD, 2007).

PISA's index of *self-efficacy in science* assess students' beliefs in their ability to accomplish science-related tasks on their own (for example, their ability to recognise a science question underlying a report predicting how changes to an environment will affect the survival of certain species) using 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*.

The measure of *self-concept in science* stems 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. Positive values on this index for PISA 2006 indicate a positive self-concept in science (OECD, 2007).

The two variables that assessed students' motivation in science include instrumental motivation in science which reflects how much students 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' future-oriented science motivation to take up a science-related career was measured 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*.

Science learning and teaching

The 2006 round of PISA provided the opportunity to investigate students' self-reported descriptions of their science learning and teaching environments. Students reported on the *frequency* with which they experience learning activities in their science classes. Students were asked to rate how frequently they experienced classroom strategies for learning science. The stem for the science learning and teaching environments items asked how often specific activities occurred when learning the different science topics (biology, chemistry, etc.). Students responded on a scale that ranged from "In all lessons" to "Never or hardly ever". Science teaching types were grouped into the following four general categories.

Applications and Models. Four activities are associated with applications and models: *the teacher explains how a <school science> idea can be applied to a number of different phenomena* (e.g. the movement of objects, substances with similar properties) (Q 34g); *the teacher uses science to help students understand the world outside school* (Q34l); *the teacher clearly explains the relevance of <broad science> concepts to our lives* (Q34o); and *the teacher uses examples of technological application to show how <school science> is relevant to society* (Q 34q). These four teacher-led, explanation-oriented teaching approaches, when compared with the other types of science teaching, reflect the greatest degree of teacher-directed instructional activities

Hands-on Focus. The four activities associated with hands-on activities are, *students spend time in the laboratory doing practical experiments* (Q 34b); *students are required to design how a <school science> question could be investigated in the laboratory* (Q34c); *students are asked to draw conclusions from an experiment they have conducted* (Q34f); and *students do experiments by following the instructions of the teacher* (Q 34n). These four science teaching approaches reflect students participation in laboratory practical learning activities.

Interaction. Four activities are associated with interaction, *students are given opportunities to explain their ideas* (Q 34a), *the lessons involve students' opinions about the topics* (Q 34e), *there is a class debate or discussion* (Q34i) and *the students have discussions about the topics* (Q 34m). These four teaching types, when compared with the other types of science teaching, reflect student discussions and explanations about the topics.

Student Investigations. The three activities associated with student investigations 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 investigation-oriented approaches to teaching/learning science, when compared with the other types of science teaching, reflect the greatest opportunity for students to control how they interact with science content in their classrooms.

Out of school science-related activities

Students reported on their levels of participation in non-compulsory out-of-school science related activities. Using a frequency self-report lowers the need for students to make inferences, and increases the likelihood that students' self-reports of learning activities accurately reflect the situation in their out-of-school activities. Specifically, for out-of-school science related activities, students were asked to rate how often they participated in science-related activities including *watch TV programmes about science*, *borrow or buy books about science, visit website about science, listen to radio programmes about advances in science, read science magazines or science articles in newspapers and attend a science club*. Prompted by **"***How often do you do these things?***"** students respond on a scale ranging from "Very Often" to "Never or hardly ever".

Sample

In this research, we attempt to build on recent research (McConney, et al, 2011; Woods-McConney, et al, 2013; Woods-McConney, et al, 2014), by further analysing factors associated with science literacy performance and engagement in science as measured by OECD's PISA 2006 science assessment. A further understanding of these factors and the relationships among them for high-performing Indigenous students can help us identify patterns or relationships that appear important to Indigenous students' success in science, and patterns or relationships that may provide barriers to Indigenous students' success in science. We therefore aim to better understand both within-school and outside-of-school factors that facilitate Indigenous students' literacy and engagement in science.

The PISA 2006 student population

Stringent technical standards are established for student sampling because assessing comparable target populations across countries is a high priority for PISA. In addition to a focus on comparability across countries, maximum representation for all students is a high priority. Compared with other international comparisons such as TIMMS, PISA coverage for the target population of students was very high with only "2% in most and below 6.4% in all countries" students excluded from the assessment (OECD, 2007, p. 24). In order to reach a high level of coverage for each country's target population, specific sampling methods and numbers were designed to maximise student representation within the country context. For example, in Australia, the Australian Council for Educational Research (ACER) oversamples to ensure sufficient student numbers for statistical analysis. In 2006 there were 14,170 Australian students. Of these, 1080 students (7.6%) self-identified as Indigenous and 13,090 as non-Indigenous students (92.4%).

Defining high performance and high self-concept for Indigenous students

There are numerous alternatives for identifying *high-performing* and *high self-concept* students. However, since there are only 1080 self-identified Indigenous students in Australia, the option for identifying *high-performing* and *high self-concept* must ensure that the sample is large enough to draw statistically meaningful (or, defensible) conclusions.

One option is to use the PISA 2006 Proficiency Levels as the criterion to identify high-performing students. Proficiency levels are used to describe the science competencies that students at each level can demonstrate. There are six proficiency levels and each level is equal to 75 score points. Level 6 represents the highest level with a cut off score of 708 with 1.3% of students across OECD countries able to perform tasks at this level (OECD, 2007, p. 42). There were 5 Indigenous students in Proficiency Level 6, 32 Indigenous students in Level 5 and 130 Indigenous students in Level 4. If PISA Proficiency Levels 4-6 were used there would a total of 167 Australian Indigenous students with a cut off score of 559. This approach is defensible, but the low number of Indigenous students is a limitation with this option.

Other options for identifying *high-performing* are to use standard deviations (SD) above the science literacy performance scores. The mean score 1 SD above the Australian mean is 656 score points with 46 Indigenous students achieving at or above this cut off score. Another option would be to use the mean score 1 SD above the Australian Indigenous mean. This cut off is 598 score points and 191 Indigenous students achieved at or above this score. Again, this approach is defensible, but the low number of Indigenous students is a potential limitation.

A further option that results in a higher number of Indigenous students is to use the top 25% of students as the criterion for identifying high performance. Because the aim of this report is to better understand factors related to high-performing and high science self-concept Indigenous students it is reasonable to identify students *within* the reference population (Indigenous students). Furthermore, defining cut scores, the point at which we separate high performing from all others, based on criteria set outside of the group led to smaller numbers of students. For the purpose of this study *high-performing* and *high self-concept* are determined with a cut-score criterion of students at or above the 75th percentile for each measure, and for each student group, Indigenous and non-Indigenous.

The sample for high-performing and high-self-concept Indigenous and non-Indigenous students

As illustrated in Figure 1, the science literacy performance cut score is 515 for high-performing Indigenous students and 599 for high-performing non-Indigenous students. This grouping option resulted in 279 Indigenous students and 3,313 non-Indigenous students identified as high-performing in science literacy.
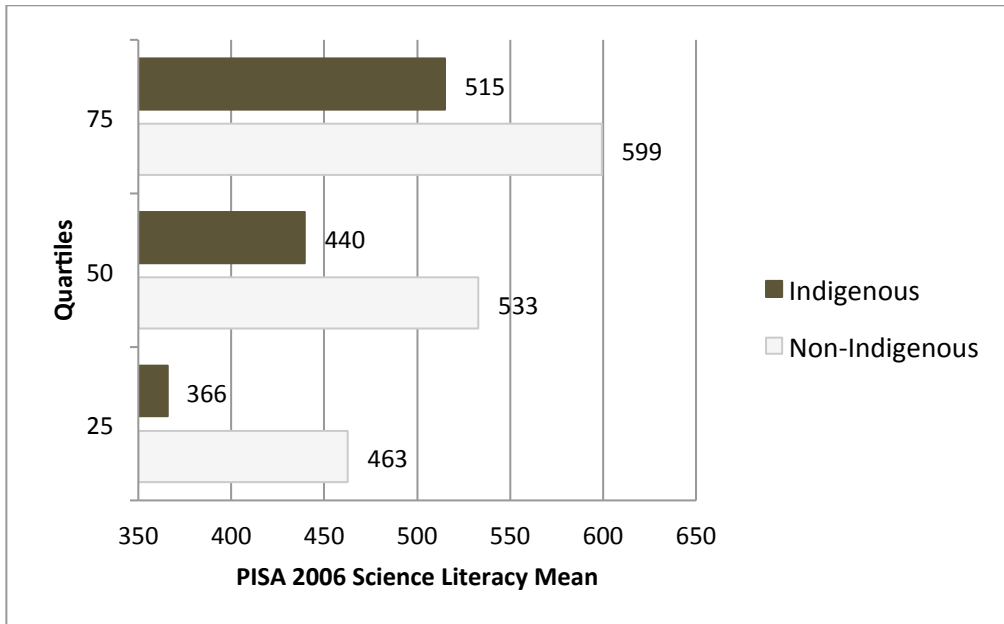
Figure 1. Science literacy by Indigenous status and quartile in PISA 2006.

For consistency, high science self-concept for Indigenous and non-Indigenous students was determined using the same rationale to identify high-performing Indigenous students. High science self-concept was determined with reference to the group rather than an outside measure. Because the aim is to understand Indigenous students with the highest science self-concept it is reasonable to identify students within the group rather than with a definition of high science self-concept. This is also a fair and appropriate approach given the small numbers of Indigenous students. As illustrated below in Figure 2 the scores for both Indigenous and non-Indigenous students in the top 75th percentile are positive while the other quartile scores are negative.
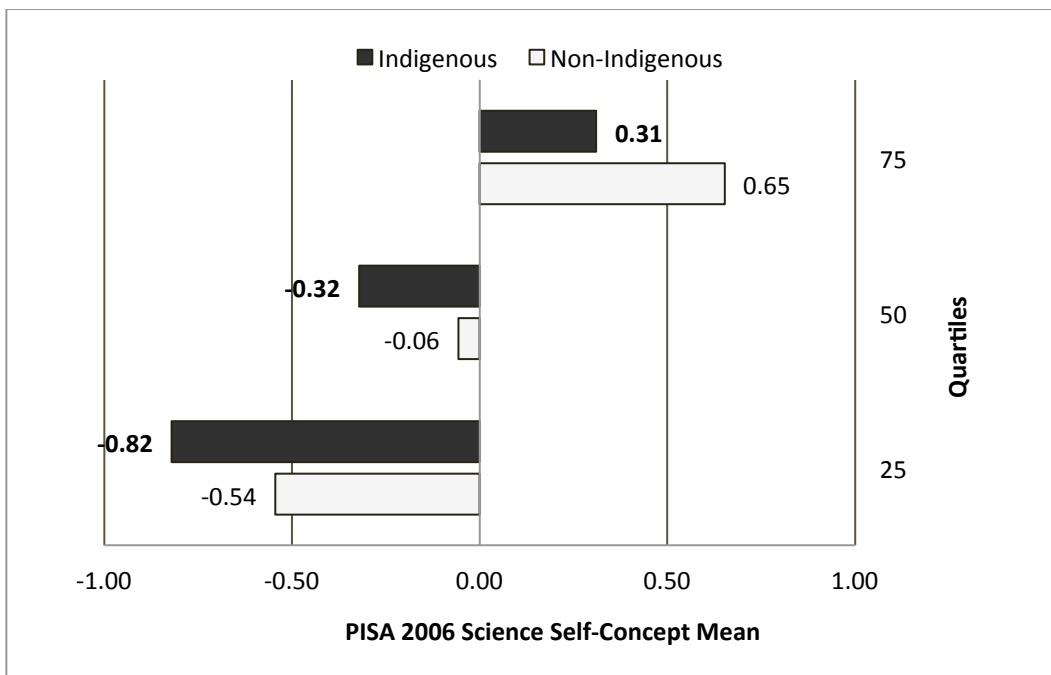
Figure 2. Science Self-Concept Quartiles for Indigenous and Non-Indigenous Australian Students in PISA 2006.

The cut score for science self-concept is 0.31 for Indigenous students and 0.65 for non-Indigenous students. This grouping process resulted in 248 Indigenous students and 3,356 non-Indigenous students identified as having high self-concept in science.

Where do the high-performing students live?
As indicated in Figure 3, most high-performing Indigenous students reside in Queensland (29%, 81 students) and New South Wales (24%, 67 students) followed by 45 students (16%) from Tasmania and 28 students (10%) from the Northern Territory. There are 16 high-performing Indigenous students from Western Australia and from the Australian Capital Territory while there are 11 students from South Australia and from Victoria. The number of high-performing Indigenous students from each state and territory is too small to analyse beyond percentages of state-wide distribution. It is interesting to note with the state-wide distribution and as shown in Figure 3, an interesting and intriguing comparison. In Queensland, Tasmania and the Northern Territory the percentage of high-performing Indigenous students is higher than the percentage of high-performing non-Indigenous students.
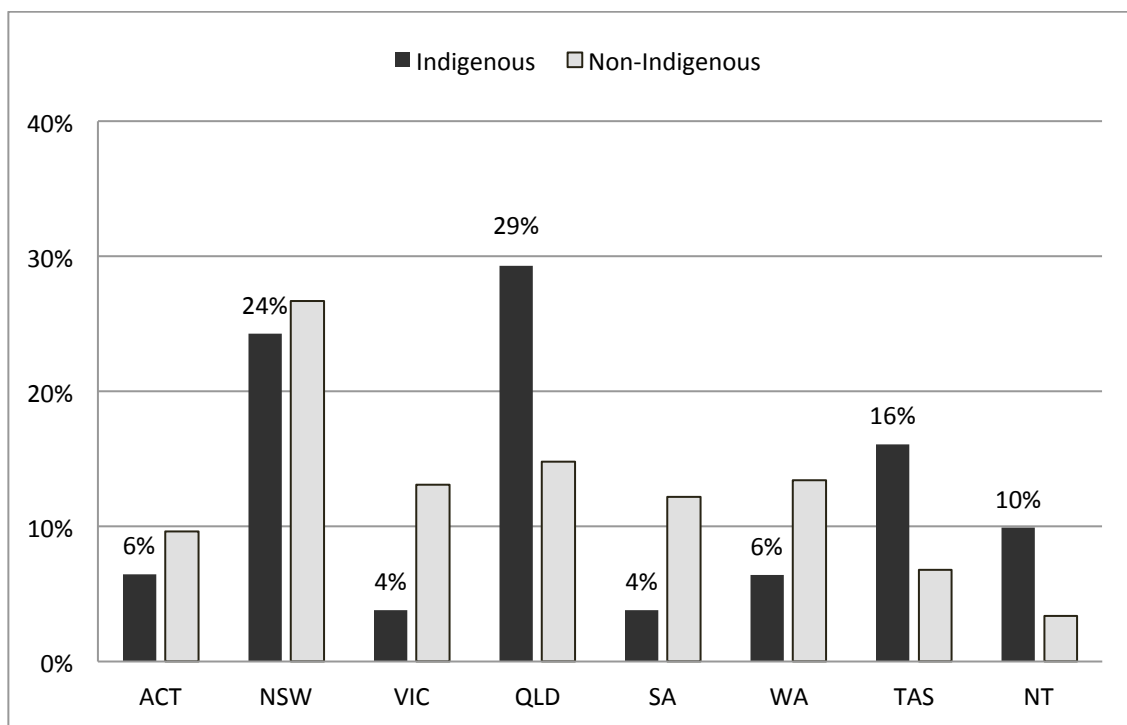
Figure 3. State and Territory Distribution of Indigenous and Non-Indigenous High-performing Students in PISA 2006

5. Research Questions and Answers

5.1 Learning and teaching environments of high-performing Indigenous students in science

> RQ1: What characterises the learning and teaching environments reported by high-performing Indigenous students in science as measured by PISA 2006? Are these learning environment characteristics different from those reported by all Indigenous students? Are these learning environment characteristics different from those reported by high-performing non-Indigenous students?

To characterise and compare the learning and teaching environments of high-performing Indigenous and non-Indigenous students in science, as measured in PISA 2006, we examined four groups:

- *High-performing Indigenous students* with science literacy at or above the 75th percentile for all Indigenous students in PISA 2006 (279 students);
- *High-performing non-Indigenous students* with science literacy at or above the 75th percentile for all non-Indigenous students in PISA 2006 (3,313 students);
- *All Indigenous students* in PISA 2006, Australia; and,
- *All non-Indigenous students* in PISA 2006.

Seven variables from PISA 2006 were used in this analysis:

- Science literacy performance;
- Science teaching: *Applications and models*;
- Science teaching: *Hands-on focus*;
- Science teaching: *Interactions*;
- Science teaching: *Investigations*;
- Science activities (a measure of science-related activities students engage in outside of school); and,
- Student-level socio-economic status (termed "economic, social and cultural status" [ESCS] in PISA): a composite index of highest parental occupational status, highest parental educational attainment (years of education), and economic and cultural resources in the home.

First, as explained earlier in this report, science literacy performance and Indigenous status were used to classify and group students into high-performing Indigenous and non-Indigenous groups. As shown in Table 2, this grouping process resulted in 279 Indigenous students and 3,313 non-Indigenous students identified as high performing (high literacy) in science. The descriptive statistics given in Table 2 also show that high performing Indigenous students had an average science literacy score of 574, considerably higher than the mean for all Indigenous students (441), and substantially

above the mean for all Australian students (527) and very substantially above the OECD average (500).

Table 2. Science Literacy for Indigenous and non-Indigenous Students in PISA 2006

Group	n	mean	se
Australia (all students)	14,170	527	2.3
All Indigenous students	1,080	441	7.8
All Non-Indigenous	13,090	529	2.3
Indigenous High Science Literacy	279	574	6.4
Non-Indigenous High Science Literacy	3313	644	5.9

Second, as shown in Table 3 and Figure 2, to answer this research question, descriptive statistics (means, standard errors) are provided for each of the four PISA variables representing the science teaching and learning environments students reported encountering in their science classrooms, organised by group. Additionally, because we already know from previous research that SES (Perry & McConney, 2010; McConney & Perry, 2010) and science-related activities outside of school (Woods-McConney, et al., 2013) also play significant mediating roles in students' scientific literacy, descriptive statistics are also provided for these variables.

As shown in Table 3, high-performing students reported experiencing higher frequencies, in comparison to their respective reference groups, for 3 of the 4 teaching and learning science variables (*Applications and models; Hands-on focus;* and, *Interaction*). It was also the case, however, that high-performing Indigenous students reported experiencing *Applications and models* and *Interactions* considerably less frequently than their high-performing non-Indigenous counterparts. In contrast, high-performing Indigenous and non-Indigenous students reported experiencing a *Hands-on focus* (students do experiments, spend time in lab, etc.) in their science classrooms at very similar frequencies.

It is also interesting to note that high-performing Indigenous and non-Indigenous students report experiencing the science learning activity, *Student investigations* (designing their own experiments, able to choose their own investigations, etc.), considerably less frequently in comparison to their respective reference groups (all Indigenous students and all non-Indigenous students). High-performing non-Indigenous students also experienced the science learning activity *Student investigations* less frequently than did their high-performing Indigenous counterparts. In other words, it appears that, in general, the extent to which these groups reported experiencing *Student investigations* in science is *inversely* related to the average science literacy of the group. These differences across groups in the extent to which various teaching and learning approaches are experienced in science classes are illustrated in Figure 4.

Table 3. Descriptive Statistics for PISA 2006 Variables that reflect the Learning & Teaching Environment in Science

Background & Teaching Variables		Australia (all students)	All Indigenous	All Non-Indigenous	Indigenous High Science Literacy	Non-Indigenous High Science Literacy
Socio-economic status (ESCS)	Mean	0.21	-0.35	0.22	-0.03	0.54
	SE	0.01	0.05	0.01	0.05	0.02
Science activities (outside of school)	Mean	-0.29	-0.34	-0.29	-0.12	0.13
	SE	0.01	0.04	0.01	0.06	0.02
Teaching: Applications & models	Mean	0.23	0.12	0.23	0.28	0.42
	SE	0.01	0.07	0.01	0.14	0.02
Teaching: Hands-on focus	Mean	0.38	0.33	0.38	0.40	0.41
	SE	0.01	0.04	0.01	0.11	0.02
Teaching: Interaction	Mean	0.21	0.05	0.22	0.18	0.36
	SE	0.02	0.06	0.02	0.09	0.03
Teaching: Student investigations	Mean	0.16	0.39	0.16	0.22	0.06
	SE	0.02	0.08	0.02	0.15	0.02

Importantly, the four variables representing the teaching activities students reported encountering in their science classrooms are *composite variables* that have each been constructed from students' responses to several (usually 3 or 4) items on the PISA *Student Questionnaire.* These items asked students to indicate the frequency with which they experienced quite specific learning and teaching activities in science. Consequently, our next step in the analysis of PISA data for Research Question 1 was to unpack the three composite teaching and learning variables on which clear differences were observed between Indigenous and non-Indigenous high performers in science (*Applications & Models, Interaction and Student investigations*). This helps us to understand at a finer level of detail potentially important differences in the learning experiences of Indigenous and non-Indigenous groups in science. Clear differences were not observed between Indigenous and non-Indigenous high performers in science for the learning activity *Hands-on Focus* so there was no further analysis for this learning activity.
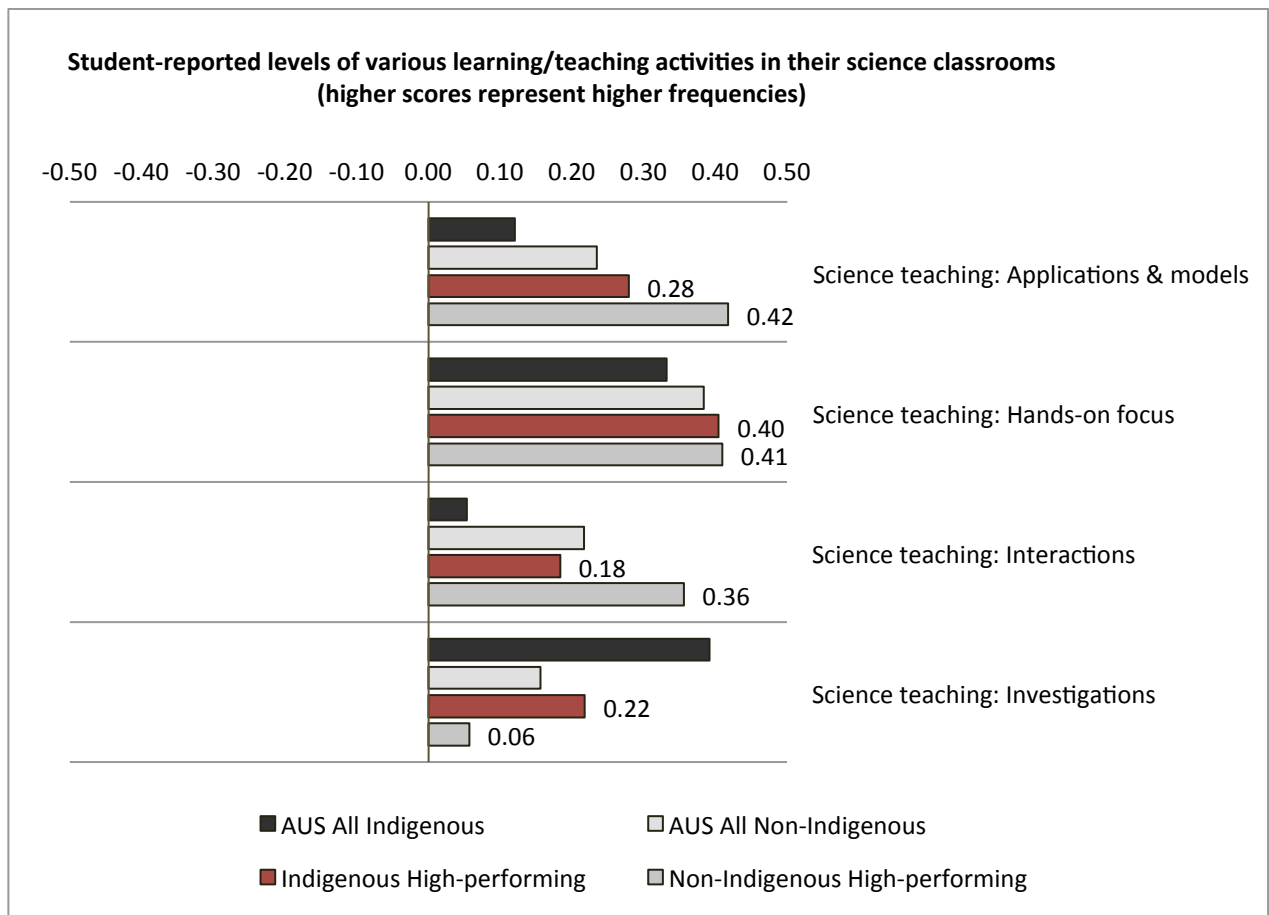
Figure 4. Frequency of various science teaching approaches reported by high-science literacy Indigenous and non-Indigenous students in PISA 2006.

In Figure 5, we have unpacked the composite variable representing the extent to which students experience *Investigations* in their science classrooms. For each of the 3 questions that comprise *Investigations,* high-performing Indigenous students reported experiencing the activity *less frequently* than their Indigenous peers generally, but slightly more frequently than did non-Indigenous high-performers. These relative frequencies for the 3 groups would seem to suggest that *Investigation* type teaching/learning strategies is *not* the differentiating factor facilitating higher science literacy for high-performing Indigenous students.

Figure 5. Percentages of Indigenous and non-Indigenous students who reported high frequencies for various _Student Investigations_ teaching and learning activities in science classrooms.

Using a similar logic, we also unpacked the composite variables _Applications and models_ and _Interactions_ to examine differences in their respective item frequencies across Indigenous and non-Indigenous student groups. These comparisons of specific teaching and learning strategies in science classrooms are shown in Figures 5 (_Interactions_) and 6 (_Applications and models_).

The _Interactions_ composite is comprised of four items reflecting interaction among students and their teachers and peers, as shown in Figure 6. Of these, students' responses to three items showed differences among the groups in line with observed differences in science literacy performance. Specifically, in comparison to all Indigenous students, greater percentages of high performing Indigenous students reported frequent opportunities to explain their ideas (Q34a), provide their opinions (Q34e), and have discussions about the science topic at hand (Q34m).

Similarly, the _Applications and models_ composite variable is composed of four items reflecting teacher-led, explanation-oriented teaching strategies. Together, these four items reflect a strong orientation to teacher-directed science teaching and learning. As shown in Figure 7, students' responses to two items reflected differences among the groups in alignment with observed differences in science literacy performance. Specifically, in comparison to all Indigenous students, greater percentages of high performing Indigenous students reported frequent teacher explanations about how science ideas can be applied to different phenomena (Q34g). Similarly, a greater percentage of high performing Indigenous students, in comparison to their Indigenous peers, reported frequent occurrence of their teachers clearly explaining the relevance of science concepts to their lives (Q34o).

Science Teaching: student interactions

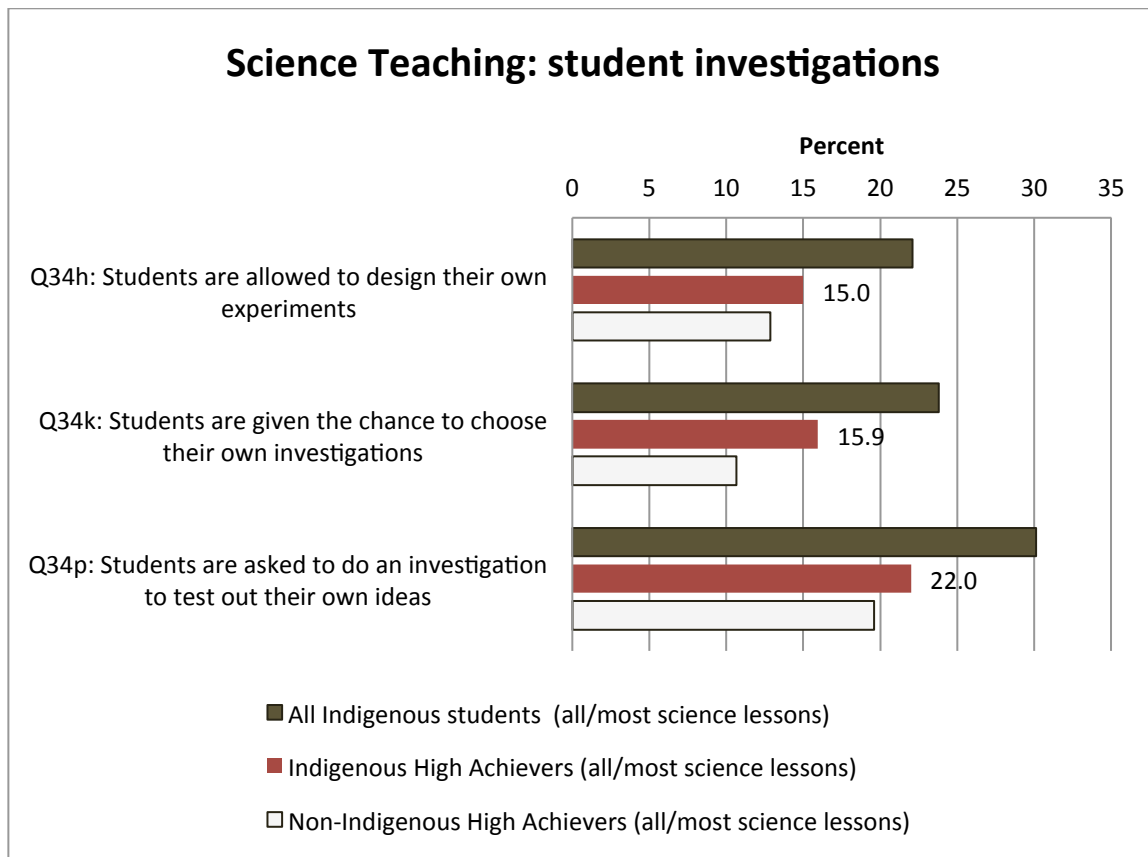**Figure 6. Percentages of Indigenous and non-Indigenous students who reported high frequencies for various *Interaction* teaching and learning activities in their science classrooms.**

The preceding descriptive statistics around various types of science teaching activities and the frequencies with which students reported experiencing them in PISA 2006, provide important clues as to the characteristics of teaching and learning environments in science for high-performing Indigenous students. We can see, for example, that a *somewhat* larger proportion of high-performing Indigenous students report frequent opportunities to explain their ideas, provide their opinions about science topics, and have discussions, in comparison to their Indigenous peers generally. We can also see that a *substantially* larger proportion of high-performing Indigenous students report frequent teacher explanations of how science ideas can be applied to different phenomena in comparison to all Indigenous students. It is also the case that greater percentages of high-performing non-Indigenous students—compared to high-performing Indigenous students— report frequent occurrence of all of these various science teaching and learning strategies.

We also know, however, that teaching and learning strategies, or more accurately the variables that we use to represent these strategies, do not operate in isolation. Teaching and learning strategies interact with each other and with other factors like students' science-related activities outside of school and various aspects of students' SES, and in complex combination influence science literacy performance. The preceding descriptive characterisation of high-performing Indigenous students' teaching and learning environments in science is limited because it does not represent the complexity of the related variables. Consequently, in addition to the group-wise descriptive

characterisations of the teaching and learning environments reported by students for their science classrooms, further analysis, within the limits of the variables provided by PISA 2006, is warranted.
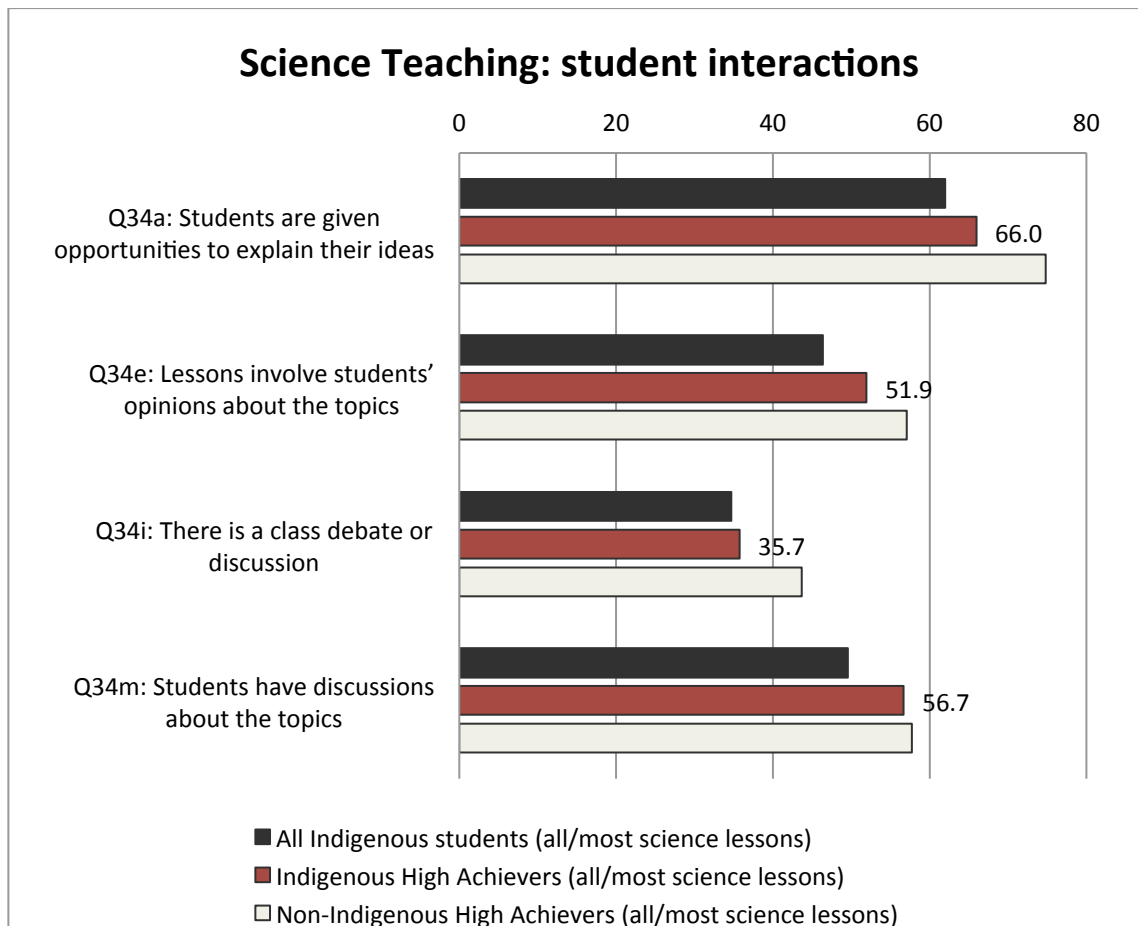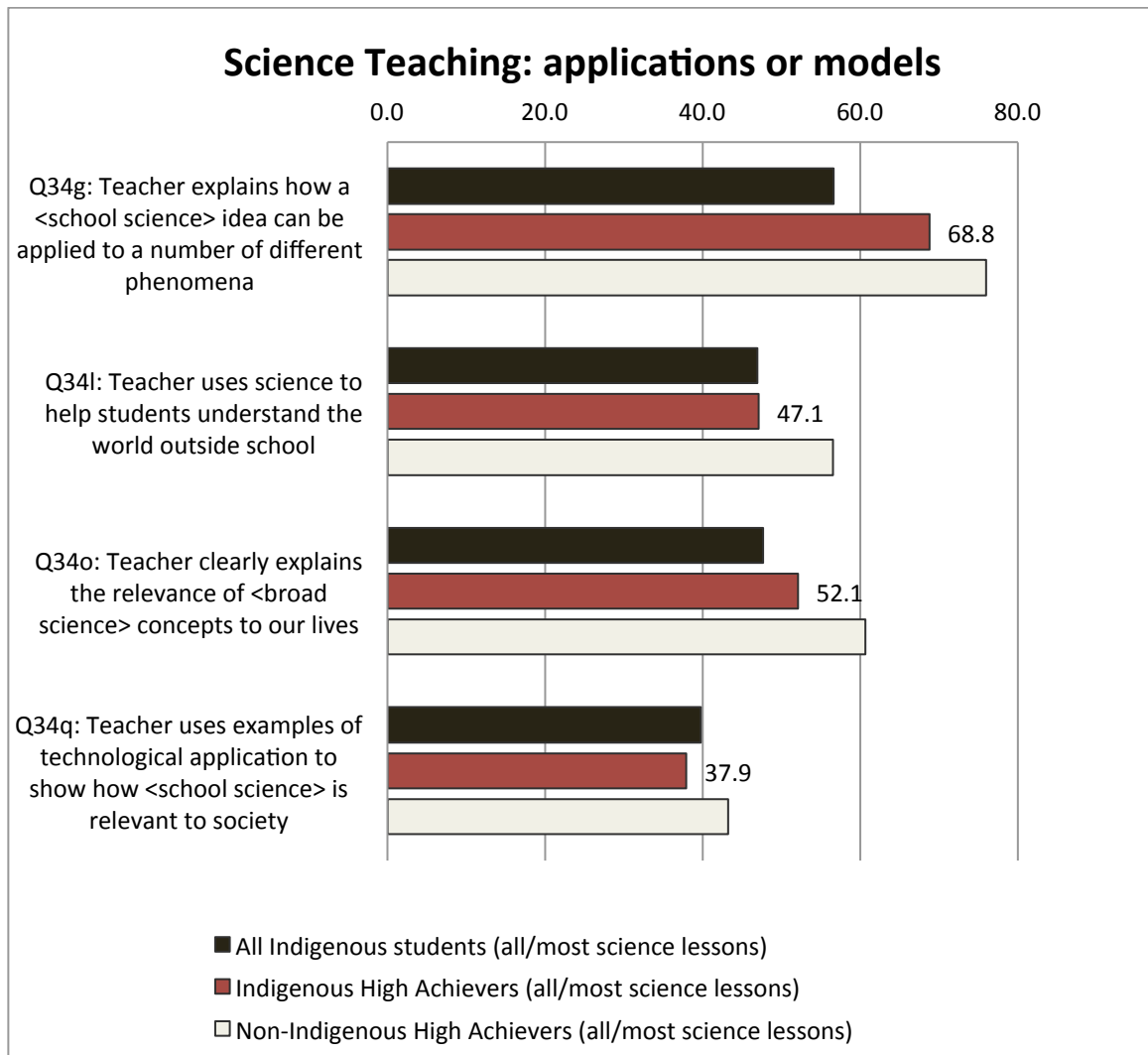

Figure 7. Percentages of Indigenous and non-Indigenous students who reported high frequencies for various *Applications and models* teaching and learning activities in their science classrooms.

To achieve a more realistic representation of the interrelated association of the teaching and learning and background variables measured in PISA, we used regression analysis. This type of analysis allows us to estimate the influence of any one variable, in the context of several other related variables we believe play an important role in the outcome (science literacy performance) being examined.

In answer to research question 1, as noted above, we included in our regression analysis for science literacy, all four teaching science composite variables, students' out-of-school science-related activities, and students' SES backgrounds. To further answer research question 1, we conducted two regression analyses, one for high-performing Indigenous students, and one for their high-performing non-Indigenous counterparts in PISA 2006. These equations are given in Figure 8.

(Predicted) Science Literacy for High-performing Indigenous students =
10.61(ESCS) + 11.41(SCIEACT) + 4.99(SCAPPLY) −13.42(SCHANDS) −2.32(SCINTACT)
−4.97(SCINVEST) + 580.40

(Predicted) Science Literacy for High-performing non-Indigenous students =
9.94(ESCS) + 11.22(SCIEACT) + 3.96(SCAPPLY) −4.36(SCHANDS) −1.96(SCINTACT)
−3.23(SCINVEST) + 638.89

Figure 8. Regression equations for Indigenous and non-Indigenous high-performers' science literacy as measured in PISA 2006

As would be expected, these two regression equations show that in explaining variations in science performance, students' SES background has a positive association with science literacy, for both Indigenous and non-Indigenous high-performing students. This unique positive association was evident for both groups even in the context of the additional teaching and out-of-school activities variables included in the regressions, and was a similar magnitude for Indigenous (10.61) and non-Indigenous (9.94) students. For both groups, the regression analysis shows that for every unit increase in SES, science literacy performance will increase by about 10 or 11 score points.

The two regression equations also show positive association between science literacy performance and science-related activities done outside of school (SCIEACT), of a similar magnitude for both Indigenous and non-Indigenous high-performing students, in the context of the other variables included. For Indigenous (11.41) and non-Indigenous (11.22) students, the analysis shows that for every unit increase in science activities students do outside of school, science literacy performance would increase by about 11 score points. The association between science activities outside of school and science literacy is statistically significant for both Indigenous and non-Indigenous high-performing students.

Of the four composite variables in PISA 2006 that reflect various approaches to teaching and learning in science classrooms, only one variable (*Applications and models*) showed a positive, albeit modest, association with science literacy, in the context of all other variables included in the regression model. This was the case for both high-performing Indigenous and non-Indigenous students. For both groups, each unit increase in *Applications and models* was estimated to be associated with a 4 to 5 score point increase in science literacy performance. As noted previously, *Science teaching: Applications and models* reflects a strong orientation to teacher-led science teaching and learning[3].

The other three teaching-related variables included in the regression analysis (*Hands-on focus, Student interactions,* and *Investigations*) all evidenced modest *negative* associations with science literacy performance, in the context of all other variables included in the regression model. For example, each unit increase in *Hands-on focus* for high-performing Indigenous students would be predicted to be associated with a 13 score point *decrease* in science literacy performance, on average. For both high-performing Indigenous and non-Indigenous students, therefore, teaching

---

[3] In PISA 2006, approximately 40 score points equates to one year of schooling. Four or five score points would therefore equate to about one-tenth of a year of schooling.

approaches characterised as *Hands-on, Interactions* or *Investigations* all had negative associations with science literacy performance.

TAKE HOME MESSAGES FOR RESEARCH QUESTION 1

■ **The top 25% of Indigenous Australian students (279 students) had a mean science literacy performance score of 574 (OECD average = 500). The top 25% of non-Indigenous students (3,313 students) had an average of 644 in science literacy. This difference equates to about 1¾ years of schooling.**

■ **Socio-economic status (SES) is an important consideration for both high-performing Indigenous and non-Indigenous students. For both groups, and to a relatively equal degree, higher SES is associated with higher performance in science.**

■ **Science-related activities outside of school have a substantial, positive association with science literacy performance for both high-performing Indigenous and non-Indigenous students. The magnitude of this association is similar for the two groups of high achievers (about ¼ of a school year, on average, for both groups).**

■ **For both high-performing Indigenous and non-Indigenous students only one of four teaching-related variables evidenced a positive association with science literacy performance, when student SES and outside-of-school activities are controlled. That variable (*Applications and models*) reflects a strong orientation to teacher-led science teaching and learning.**

■ **Within *Science teaching: Applications and models*, the component item that showed the largest differentiation between all Indigenous and high-performing Indigenous students, was the student-reported frequency of teacher explanations about how science ideas can be applied to different phenomena. A greater proportion of high-performing Indigenous students experienced teacher explanations frequently.**

5.2 Outside-of-school science-related activities of high-performing Indigenous students in science

> RQ2: In general, for Indigenous students in science, what relationships and co-relationships exist among non-school based experiences/characteristics and performance in science? Are these relationships different for high-performing students in comparison to other Indigenous students or their non-Indigenous peers?

We have already learned in the answers to research question 1 that science-related activities that students—both Indigenous and non-Indigenous—do outside of school play a strong role (about equal to that played by SES) in science literacy performance, as conceptualised and assessed in PISA. For each unit increase in the composite measure of science-related activities that both Indigenous and non-Indigenous high-performing students do outside of school, science literacy on average improves by about 11 score points, or about one-quarter of a typical school year's learning.

To systematically further compare the outside-of-school science related activities of high-performing Indigenous and non-Indigenous students in science, we examined four groups:

- *High-performing Indigenous students* with science literacy at or above the 75th percentile for all Indigenous students in PISA 2006 (279 students);
- *High-performing non-Indigenous students* with science literacy at or above the 75th percentile for all non-Indigenous students in PISA 2006 (3,313 students);
- *All Indigenous students* in PISA 2006, Australia; and,
- *All non-Indigenous students* in PISA 2006.

Seven variables from PISA 2006 were used in this analysis:

- Science literacy performance;
- Science activities (a measure of science-related activities students engage in outside of school);
- Science teaching: *Applications and models*;
- Science teaching: *Hands-on focus*;
- Science teaching: *Interactions*;
- Science teaching: *Investigations*; and,
- Student-level socio-economic status (ESCS in PISA): a composite index of highest parental occupational status, highest parental educational attainment (years of education), and economic and cultural resources in the home.

Students' self-reported outside-of-school science-related activities include watching TV about science, reading books and magazines about science, visiting websites about science, listening to science-related programs on radio and participating in science-related clubs. The descriptive statistics for this composite variable were previously included with the analyses of various science teaching and learning approaches detailed for research question 1. As shown in Table 3 (research question 1), and also in Figure 9 below, high-performing Indigenous students, on average, report participating at higher levels in out-of-school science-related activities in comparison to all

Indigenous students, and in comparison to all non-Indigenous students, despite having a negative average for this composite measure (-0.12). It is also the case, however, that high-performing Indigenous students had a substantially lower average for out-of-school science-related activities than the average observed for their non-Indigenous high-performing counterparts (0.13).
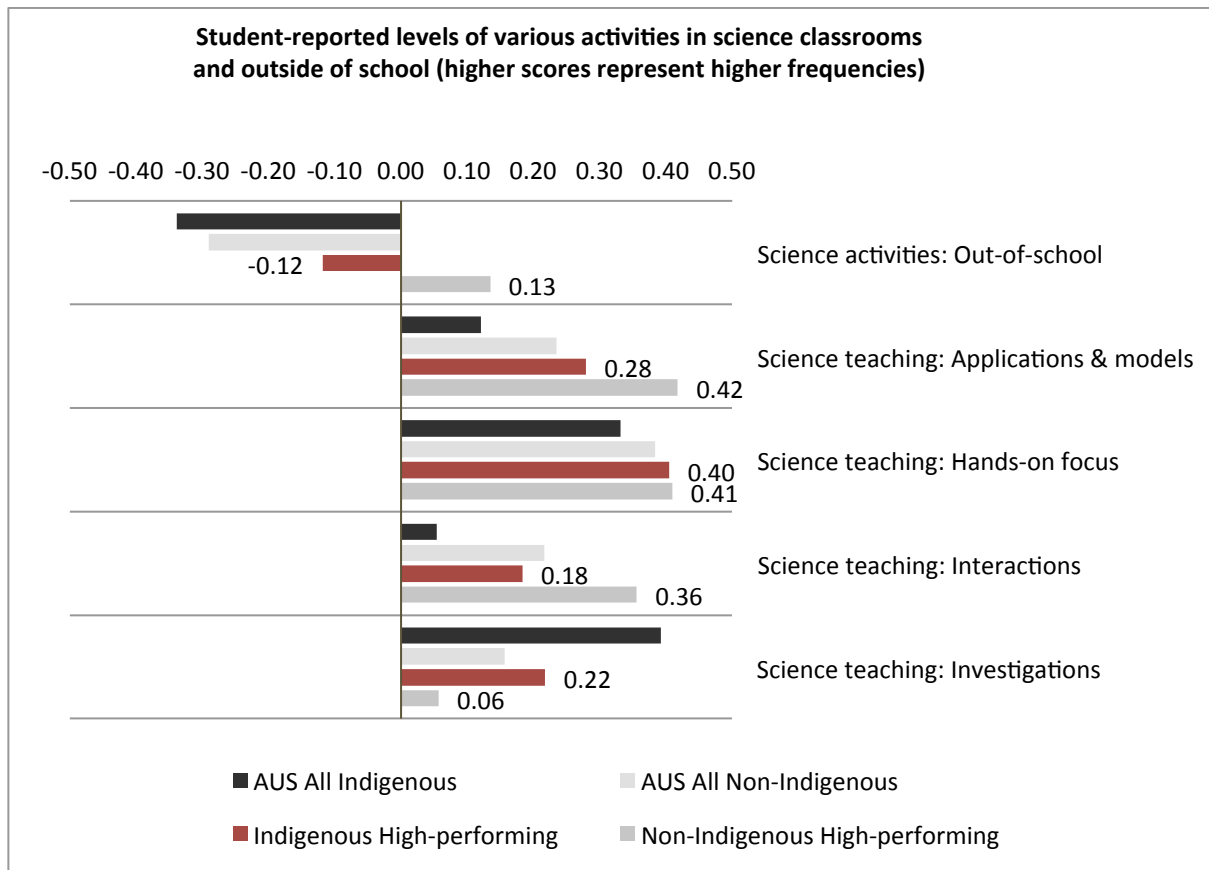
Figure 9. Levels (Frequency) of Various Science Teaching Types and Science Activities (outside of school) for High-Performing Indigenous and Non-Indigenous Students.

Similar to the four variables representing the various approaches to teaching and learning that students encountered in their science classrooms, the science activities outside of school variable is a *composite variable* that is constructed from students' responses to six items on the PISA *Student Questionnaire.* These items asked students to indicate the frequency with which they participate in specific science-related activities outside of school. Consequently, our next step in the analysis of PISA data for Research Question 2 was to unpack this composite variable to examine at a finer grain differences between Indigenous and non-Indigenous high performers in science. Figure 10 provides the relative frequencies with which the four groups of students reported participating "very often" or "regularly" for specific science-related out-of-school activities.

As shown in Figure 10, low percentages of all four student groupings examined for this research question reported frequent participation in science clubs (1% to 2%) or listening to science-related radio programmes (4% to 6%). On the other hand, higher percentages reported watching science-related TV, visiting science-related websites and reading science-related books and magazines. This

was especially so for non-Indigenous high-performing students, 25% of whom reported frequently watching science-related TV. By comparison, 22% of high-performing Indigenous students reported frequently watching science-related TV, a proportion somewhat higher than their reference group (18%) and all non-Indigenous students (16%). Similarly, the percentage of high-performing Indigenous students who reported frequently reading books on science (7%) is somewhat higher than that for all Indigenous students and all non-Indigenous students (5%), but not quite as high as their non-Indigenous high-performing counterparts (9%). In other words, relatively similar proportions of Indigenous and non-Indigenous high-performing students reported frequently watching science TV and accessing science-related books.
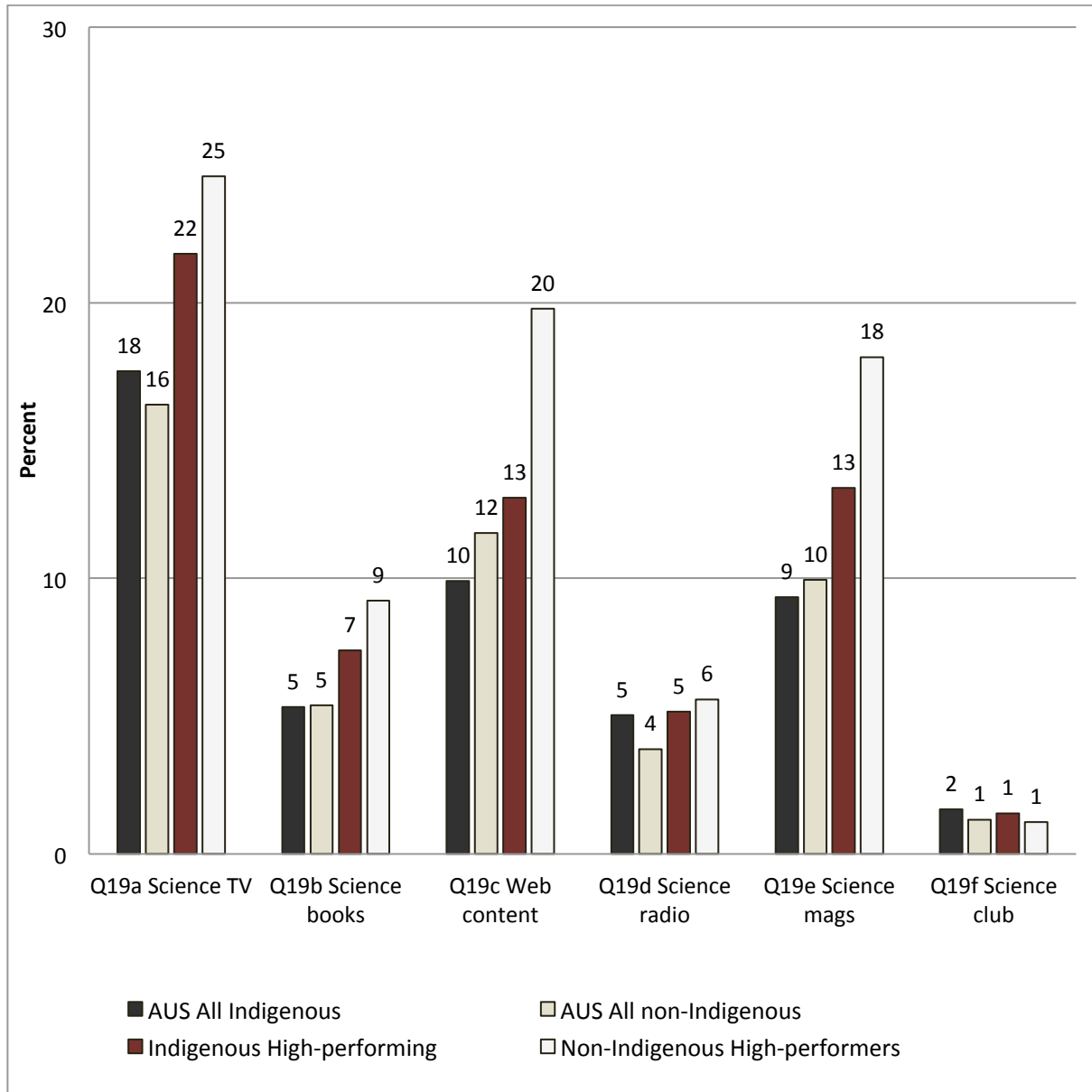

Figure 10. Percentages of students who report participating frequently in six out-of-school science-related activities.

A different picture emerged for accessing science-related web content and science-related magazines. For both of these outside-of-school activities, a greater percentage of high-performing Indigenous students reported accessing science via the web (13%), or via magazines (13%) in comparison to all Indigenous and all non-Indigenous student groups. It was also the case, however, that for both of these out-of-school activities, substantially greater percentages of high-performing non-Indigenous students reported frequently accessing science content on the web (20%) and science magazines (18%) in comparison to their high-performing Indigenous peers (13% and 13%, respectively).

From the regression equations examining science literacy given in answer to research question 1 we learned that SES plays a substantial role in science literacy—in addition to the strong association between science literacy and students' participation in outside-of-school science-related activities. This observed association is entirely consistent with previous research (Woods-McConney, et al., 2013). On average, each unit increase in PISA's measure of SES is predicted to result in an increase of between 10 and 11 score points, for both high-performing Indigenous and non-Indigenous students[4].

We believe that this "SES effect" also plays out in the relative percentages of students in each of the four groups investigated for this research question, who report frequent participation in the various out-of-school science-related activities. In order, the mean SES for all Indigenous students, high-performing Indigenous students, all non-Indigenous students, and non-Indigenous high-performing students is -0.35, -0.03, 0.22, and 0.54, respectively. It is quite clear that non-Indigenous students, on average, enjoy considerable SES advantage over their Indigenous peers (including the high-performing Indigenous students). Thus, it is quite likely that lower SES places real constraints on Indigenous students' access to science-related content or activities outside of school, particularly in terms of internet-dependent science content and science-related magazines. It is also likely that such barriers are more acute for Indigenous students in regional and remote schools (Sullivan, Perry, & McConney, 2013). These real barriers make it all the more remarkable that high-performing Indigenous students are able to participate to the extent they do in science-related activities outside-of-school.

---

[4] We acknowledge that this result is considerably more variable for Indigenous students, due to the relatively small number of students in the high-performing group.

TAKE HOME MESSAGES FOR RESEARCH QUESTION 2

■ Science-related activities that Indigenous and non-Indigenous students do outside of school play a strong role in science literacy. For each unit increase in the composite measure of science-related activities outside of school, science literacy on average improves by about 11 score points, or about one-quarter of a typical school year's learning, for both Indigenous and non-Indigenous high-performing students.

■ High-performing Indigenous students, on average, report participating at higher levels in out-of-school science-related activities in comparison to all Indigenous students, and in comparison to all non-Indigenous students, It is also the case that high-performing Indigenous students had a substantially lower average for out-of-school science-related activities than their non-Indigenous high-performing peers.

■ Quite similar percentages of high-performing Indigenous and non-Indigenous students reported frequently watching science-related TV and accessing science-related books.

■ In comparison to high-performing non-Indigenous students, lower percentages of high-performing Indigenous students reported frequently accessing science-related web content or magazines.

■ SES plays a substantial role in science literacy for both Indigenous and non-Indigenous students. It seems likely that this extends to placing barriers in the way of Indigenous students in terms of their ability to access key science-related activities and resources outside of school.

5.3 Learning and teaching environments of Indigenous students with high self-concept in science

RQ3: What characterises the learning and teaching environments reported by Indigenous students with high self-concept in science as measured by PISA 2006? Are these learning environment characteristics different from those reported by other Indigenous students or high-performing non-Indigenous students?

To characterise and compare the learning and teaching environments of Indigenous and non-Indigenous students with high self-concept in science, as measured in PISA 2006, we examined four groups:

- ***Indigenous students with high self-concept in science*** at or above the 75th percentile for all Indigenous students in PISA 2006 (248 students);
- ***Non-Indigenous students with high self-concept in science*** at or above the 75th percentile for all non-Indigenous students in PISA 2006 (3,356 students);
- ***All Indigenous students*** in PISA 2006, Australia; and,
- ***All non-Indigenous students*** in PISA 2006.

Ten variables from PISA 2006 were used in this analysis:

- Science self-concept;
- Science literacy;
- Science self-efficacy;
- Science teaching: *Applications and models*;
- Science teaching: *Hands-on focus*;
- Science teaching: *Interactions*;
- Science teaching: *Investigations*;
- Science activities (a measure of science-related activities students engage in outside of school); and,
- Student-level socio-economic status (termed "economic, social and cultural status" [ESCS] in PISA): a composite index of highest parental occupational status, highest parental educational attainment (years of education), and economic and cultural resources in the home.

First, science self-concept (SCSCIE) and Indigenous status were used to classify students into Indigenous and non-Indigenous groups with high self-concept in science. As for research question 1, "high" self-concept in science was defined as those Indigenous and non-Indigenous students with self-concept in science at or above the 75th percentile for all students in their reference groups (all Indigenous students and all non-Indigenous students in PISA 2006 for Australia, respectively).

As shown in Table 4, this grouping process resulted in 248 Indigenous students and 3,356 non-Indigenous students identified as having high self-concept in science. The descriptive statistics given in Table 4 also show that Indigenous students with high self-concept in science had an average

science literacy score of 476, considerably higher than the mean for all Indigenous students (441), but substantially below the mean for all Australian students (527) and the mean for high-performing (high science literacy) Indigenous students (574), and considerably below the OECD average (500). In contrast, non-Indigenous students with high self-concept in science had an average science literacy score of 587, considerably higher than the mean for all non-Indigenous students (529), and also substantially higher than the mean for all Australian students (527) and the OECD average. The mean for non-Indigenous students with high self-concept in science, however, was considerably below the average for non-Indigenous high-performing (high literacy in science) students (644), as was also the case for Indigenous students with high science self-concept.

On the other hand, it is noteworthy that Indigenous students with high self-concept in science also had mean interest in science (531) considerably higher than that for all Indigenous students (475), all Australian students (465) and importantly, considerably higher than the mean for non-Indigenous students with high self-concept in science (506). Furthermore, both Indigenous and non-Indigenous high science self-concept students demonstrate stronger science interest than their high-performing counterparts (Indigenous 482; non-Indigenous 490).

Table 4. Means and Standard Errors in Science Literacy, Interest and Self-Concept for Indigenous and Non-Indigenous Students with High Self-Concept in Science

	n	Science literacy		Science interest		Science Self-efficacy	
		Mean	SE	Mean	SE	Mean	SE
Australia	14,170	527	2.3	465	1.3	0.12	0.01
Indigenous	1,080	441	7.8	475	5.6	-0.35	0.05
Non-Indigenous	13,090	529	2.3	465	1.3	0.13	0.01
Indigenous High Science Self Concept	248	476	17.8	531	10.6	0.79	0.05
Non-Indigenous High Science Self Concept	3,356	587	3.4	506	1.9	1.08	0.01

Notwithstanding the descriptive statistics in Table 4 showing that Indigenous students with high self-concept in science as a group had lower science literacy in comparison to Australian students as a whole, and in comparison to the OECD average, we know from prior research that affective constructs such as students' interest and self-concept in science can be important mediators of science literacy, and that positive attitudes or interest in science can potentially lead to improved performance in science. Furthermore, the value of positive student affect in science in itself has been recognised as a worthy outcome of science education.

Our second step in answering research question 3, therefore, was to examine the bivariate correlations between students' science self-concept and science literacy for high-performing Indigenous and non-Indigenous students in PISA 2006. Additionally, science self-efficacy was included in this analysis for comparison purposes. The correlation matrix in Table 5 shows that relationships between science literacy and self-concept in science (0.26) and science literacy and science self-efficacy (0.38) are positive but only modestly strong for high-performing Indigenous students. Similarly, for high-performing non-Indigenous students these bivariate relationships were

positive but only modestly strong between science literacy and self-concept (0.29) and between literacy and science self-efficacy (0.31).

Table 5. Correlations among Science Literacy, Science Self-Concept and Science Self-Efficacy for High-performing Indigenous and Non-Indigenous Students.

High-performing Indigenous Students	Self-Concept	Self-Efficacy	Science Literacy
Self-Concept in Science (SCSCIE)	1.00	0.52	0.26
Science Self-Efficacy (SCIEEFF)	0.52	1.00	0.38
Science literacy (PV_SCIE)	0.26	0.38	1.00
High-performing Non-Indigenous Students	Self-Concept	Self-Efficacy	Science Literacy
Self-Concept in Science (SCSCIE)	1.00	0.49	0.29
Science Self-Efficacy (SCIEEFF)	0.49	1.00	0.31
Science literacy (PV_SCIE)	0.29	0.31	1.00

Despite the modest relationships with science literacy, the inherent value of science self-concept as a desirable, standalone outcome of science education provides sufficient reason to better understand the characteristics of the teaching and learning environments reported by Indigenous and non-Indigenous students with high self-concept in science.

The student-reported characteristics of the teaching and learning environments for students with high science self-concept are portrayed in Figure 8. Compared with their respective peers, students with high science self-concept (both Indigenous and non-Indigenous) report considerably more informal out-of-school science-related activities in comparison to all Indigenous or all non-Indigenous students. As described above, out-of-school science-related activities include activities such as watching TV about science, reading books about science and visiting science-related websites. Comparing Indigenous and non-Indigenous students with high science self-concept, the two groups are quite similar in their reports of the levels with which they engage in out-of-school, science-related activities.

Further comparing the science teaching and learning approaches they experienced, Indigenous and non-Indigenous students with high science self-concept report similar levels (frequencies) for *Applications and models* (teacher-led explanations of the applicability of science in the world); *Hands-on focus* (students do experiments, spend time in lab, etc.) and *Interactions* (students have discussions, explain their ideas, provide their opinions, etc.). For each of these three types of approach to teaching and learning in science, the levels reported by Indigenous and non-Indigenous students with high self-concept in science were considerably higher than those reported by their respective reference groups.

There was, however, a substantial difference between Indigenous and non-Indigenous students with high self-concept in the reported frequencies at which they experience *Investigations* (students design their own experiments, able to choose their own investigations, etc.). Indigenous students with high science self-concept reported experiencing *Investigation* approaches much more frequently than their non-Indigenous counterparts.
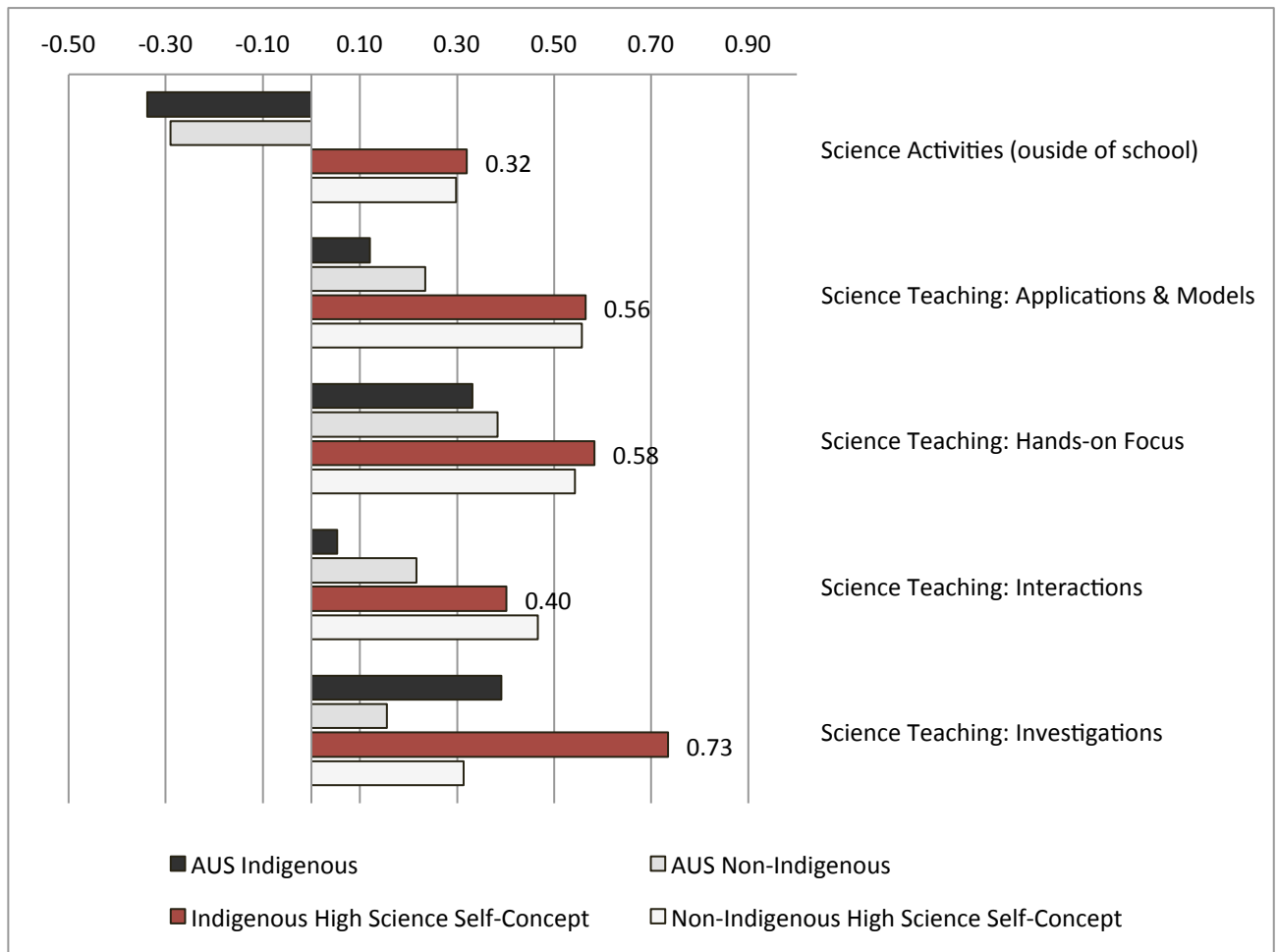
Figure 11. Frequency of various science teaching approaches reported by Indigenous and non-Indigenous students with high science self-concept in PISA 2006.

As explained previously, each of the four *Science Teaching* variables, and the *Science Activities* used in this analysis for research question 3 are composite variables, that each reflect student responses to several items on the PISA Student Questionnaire. The *Science Teaching* composite variables were unpacked in answering research question 1 to uncover potentially masked details. In this case, however, given the very modest bivariate correlations between science literacy and self-concept (Table 5), and the relatively low average science literacy for Indigenous students with high science self-concept (Table 4), there seemed little reason to further unpack the four *Science Teaching* composite variables.

Nevertheless, and as explained above, we also know that teaching and learning approaches in science do not operate in isolation. These variables (teaching constructs) clearly interact with each other and overlap other factors like students' science-related activities outside of school and

students' home backgrounds (SES) to influence students' science literacy performance. Consequently, as done for research question 1, in addition to the group-wise descriptive characterisations of the teaching and learning environments reported by students with high self-concept about their science learning and teaching experiences, further analysis is warranted.

To achieve a more realistic representation of the interrelated association of the teaching and learning and background variables measured in PISA, we used regression analysis. This type of analysis allows us to estimate the influence of any one variable, in the context of several other related variables we believe play an important role in the outcome (science literacy performance) being examined.

Similar therefore to our analytic approach for research question 1, we included in our regression analysis for science literacy, all four teaching science composite variables, students' out-of-school science-related activities, and students' SES backgrounds. To further answer this research question, we conducted two regression analyses, one for Indigenous students with high self-concept in science, and one for their non-Indigenous counterparts with high self-concept. These equations are given in Figure 12.

(Predicted) science literacy for Indigenous students with high science self-concept = 50.45(ESCS) + 1.45(SCIEACT) + 20.62(SCAPPLY) + 14.41(SCHANDS) −5.81(SCINTACT) −57.02(SCINVEST) + 507.02

(Predicted) science literacy for non-Indigenous students with high science self-concept = 32.28(ESCS) + 16.04(SCIEACT) + 13.86(SCAPPLY) − 12.86(SCHANDS) + 2.91(SCINTACT) −26.65(SCINVEST) + 575.32

Figure 12. Regression equations for science literacy performance of Indigenous and non-Indigenous students with high self-concept in science as measured in PISA 2006.

As given in Figure 12, the two regression equations show that in explaining variations in science literacy for students with high science self-concept, students' SES (ESCS) has a strong positive association, for both Indigenous and non-Indigenous students. This positive association was evident for both groups even in the context of the additional variables representing teaching and out-of-school activities included in the regressions. For Indigenous students with high science self-concept, each unit increase in SES would, on average, be associated with an increase in science literacy performance of 50 score points. For non-Indigenous students with high self-concept, the regression equation shows that each unit increase in SES would, on average, be associated with an increase in science literacy performance of 32 score points. Both of these associations are statistically meaningful[5].

The two regression equations also show positive association between science literacy performance and science-related activities done outside of school (SCIEACT). This association, however, is not of a similar magnitude for Indigenous and non-Indigenous high self-concept students, in the context of

---

[5] In PISA 2006, approximately 40 score points equates to one year of schooling. Four or five score points would therefore equate to about one-tenth of a year of schooling.

the other variables included. For Indigenous students, the association is positive but small (1.45) and not statistically meaningful. For non-Indigenous students, the analysis shows that for every unit increase in science activities students do outside of school, science literacy performance would increase by about 16 score points, a statistically significant association.

Of the four composite variables that reflect various approaches to teaching and learning in science classrooms in PISA 2006, two variables (*Applications and models* and *Investigations*) showed consistent associations with science literacy, for both Indigenous and non-Indigenous groups. In the context of all other variables, both Indigenous and non-Indigenous students evidenced moderately strong associations between levels of science literacy and *Science teaching: Applications and models*. This association was statistically meaningful for non-Indigenous students, but not for Indigenous students, related to the quite small size of the group.

In the opposite direction for both Indigenous and non-Indigenous students with high self-concept, *Teaching: Investigations* evidenced strongly negative associations with science literacy performance. For Indigenous students with high self-concept in science, each unit increase in *Investigations* as a science teaching approach was associated with a 57 point *decrease* in science literacy performance. Similarly for non-Indigenous students with high levels of science self-concept, each unit increase in *Investigations* was associated with a 27 point decrease in science literacy. Both of these associations were statistically meaningful.

Relationships between science literacy and the other two composite variables representing teaching approaches in science went in opposite directions for Indigenous and non-Indigenous students. For Indigenous students with high science self-concept, science literacy was moderately positively associated with a *Hands-on focus,* but this association was not statistically meaningful. The opposite was true for non-Indigenous students with high self-concept—a moderately strong negative association that was statistically significant. Similarly, with regard the association between science literacy and *Science teaching: Interactions,* the association for Indigenous students was quite modest and negative, and for non-Indigenous students small and positive. Neither of these were statistically meaningful.

TAKE HOME MESSAGES FOR RESEARCH QUESTION 3

■ The top 25% of Indigenous Australian students in terms of self-concept in science (248 students) had a mean science literacy performance score of 476 (OECD average = 500). The top 25% of non-Indigenous students (3,356 students) had an average of 587 in science literacy. Both of these averages are substantially lower than the averages seen for high-performing Indigenous and non-Indigenous students.

■ Indigenous students with high self-concept in science also had mean interest in science (531) considerably higher than that for all Indigenous students (475), all Australian students (465) and importantly, considerably higher than the mean for non-Indigenous students with high self-concept in science (506)

■ Socio-economic status (SES) is a very important factor for both Indigenous and non-Indigenous students with high self concept in science. For both, higher SES is associated with substantially higher performance in science, and this is particularly so for Indigenous students.

■ Science-related activities outside of school have a modest positive association with science literacy performance for non-Indigenous students; this does not seem to be the case for Indigenous students with high self-concept in science.

■ For Indigenous and non-Indigenous students with high self-concept, only one of four teaching-related composite variables evidenced a consistently positive association with science literacy performance, when student SES and outside-of-school activities are controlled. That variable (*Applications and models*) reflects a strong orientation to teacher-led science teaching and learning.

■ For Indigenous and non-Indigenous students with high self-concept, one teaching-related composite variable evidenced a consistently negative association with science literacy performance, when student SES and outside-of-school activities are controlled. That variable (*Investigations*) reflects a teaching and learning orientation to science which is largely student-led (students design their own experiments, choose their own investigations, etc.)

5.4 Engagement in science profiles for Indigenous students with high performance in science

RQ4: What profiles of engagement in science are evident for high-performing Indigenous students in science, as measured by PISA 2006? To what extent are profiles of engagement in science for high-performing Indigenous students different from those reported for other Indigenous students and for high-performing non-Indigenous students?

As noted earlier, students' *engagement in science* has come to be recognised as a valuable outcome of science education in its own right (Ainley & Ainley, 2011; Fensham, 2009; Woods-McConney, et al., 2013). Additionally, students' engagement in science has also been shown, albeit with some variability, as an important mediator of science literacy and achievement. On balance, a substantial body of research has shown that students who are strongly engaged in science typically also achieve strongly in science.

We have conceptualised engagement in science as a "meta-construct" that spans students' general interest in learning science, content-specific interest, enjoyment, general and personal valuing of science, science self-efficacy, science self-concept, and instrumental and future-oriented motivations towards science (Woods-McConney, et al., 2013, 2014). All of these component variables of the meta-construct were assessed in PISA 2006.

To characterise and compare the profiles of engagement in science for high-performing Indigenous and non-Indigenous students, as measured in PISA 2006, we examined four groups:

- *Indigenous students with high science literacy* at or above the 75th percentile for all Indigenous students in PISA 2006 (279 students);
- *Non-Indigenous students with high science literacy* at or above the 75th percentile for all non-Indigenous students in PISA 2006 (3,313 students);
- *All Indigenous students* in PISA 2006, Australia; and,
- *All non-Indigenous students* in PISA 2006.

Ten variables from PISA 2006 were used in this analysis:

- Science literacy;
- Science interest (content-specific);
- General interest in science;
- Science self-concept;
- Science self-efficacy;
- Enjoyment of science;
- General valuing of science;
- Personal valuing of science;
- Instrumental motivation for science; and,
- Future-oriented motivation in science.

Table 6 and Figure 13 provide answers to the fourth research question posed in this analysis.

Table 6. Means and Standards Errors (SE) for Science literacy and Nine Variables reflecting Students' Engagement in Science, assessed in PISA 2006.

		Australia	All Indigenous	All non-Indigenous	Indigenous High Achievers	Non-Indigenous High Achievers
	n	14,170	1,080	13,090	279	3,313
Science literacy	Mean	527	441	529	574	644
	SE	2.3	7.8	2.3	6.2	5.8
Science interest	Mean	465	475	465	482	490
	SE	1.3	5.6	1.3	8.3	1.9
General interest	Mean	-0.22	-0.43	-0.21	-0.01	0.22
	SE	0.01	0.05	0.01	0.09	0.01
Self-concept	Mean	-0.03	-0.26	-0.03	0.07	0.56
	SE	0.01	0.04	0.01	0.06	0.02
Self-efficacy	Mean	0.12	-0.35	0.13	0.33	0.85
	SE	0.01	0.05	0.01	0.07	0.02
Enjoyment	Mean	-0.08	-0.29	-0.07	0.20	0.55
	SE	0.02	0.05	0.02	0.09	0.02
General Value	Mean	-0.05	-0.41	-0.04	0.16	0.42
	SE	0.01	0.05	0.01	0.09	0.02
Personal Value	Mean	0.02	-0.22	0.02	0.15	0.56
	SE	0.01	0.04	0.01	0.09	0.02
Instrumental Motivation	Mean	0.11	-0.13	0.11	0.19	0.55
	SE	0.02	0.05	0.02	0.11	0.02
Future-Oriented Motivation	Mean	-0.07	-0.21	-0.07	0.04	0.42
	SE	0.01	0.05	0.01	0.09	0.02

Table 6 provides comparative data for science literacy and the nine science engagement variables assessed in PISA 2006. For all nine measures included under the conceptual umbrella of engagement in science, high-performing Indigenous students led their Indigenous reference group students, to varying, often substantial degrees. It was also the case that high-performing Indigenous students, on average, were more positive on all nine science engagement variables when compared to all non-Indigenous students, although to a lesser degree than the comparison to all Indigenous students. It is also instructive to note that high-performing Indigenous students evidenced, on average, levels of

engagement in science greater than the mean for every measure except "general interest in science".[6] Although generally positive on measures of engagement in science, and more positive in comparison to all Indigenous and all non-Indigenous students, the high-performing Indigenous group nevertheless were, on average, less positive on these nine engagement variables in comparison to their high-performing non-Indigenous counterparts.

The comparative patterning of science literacy performance and engagement in science variables for high-performing Indigenous and non-Indigenous students is portrayed in Figure 13.
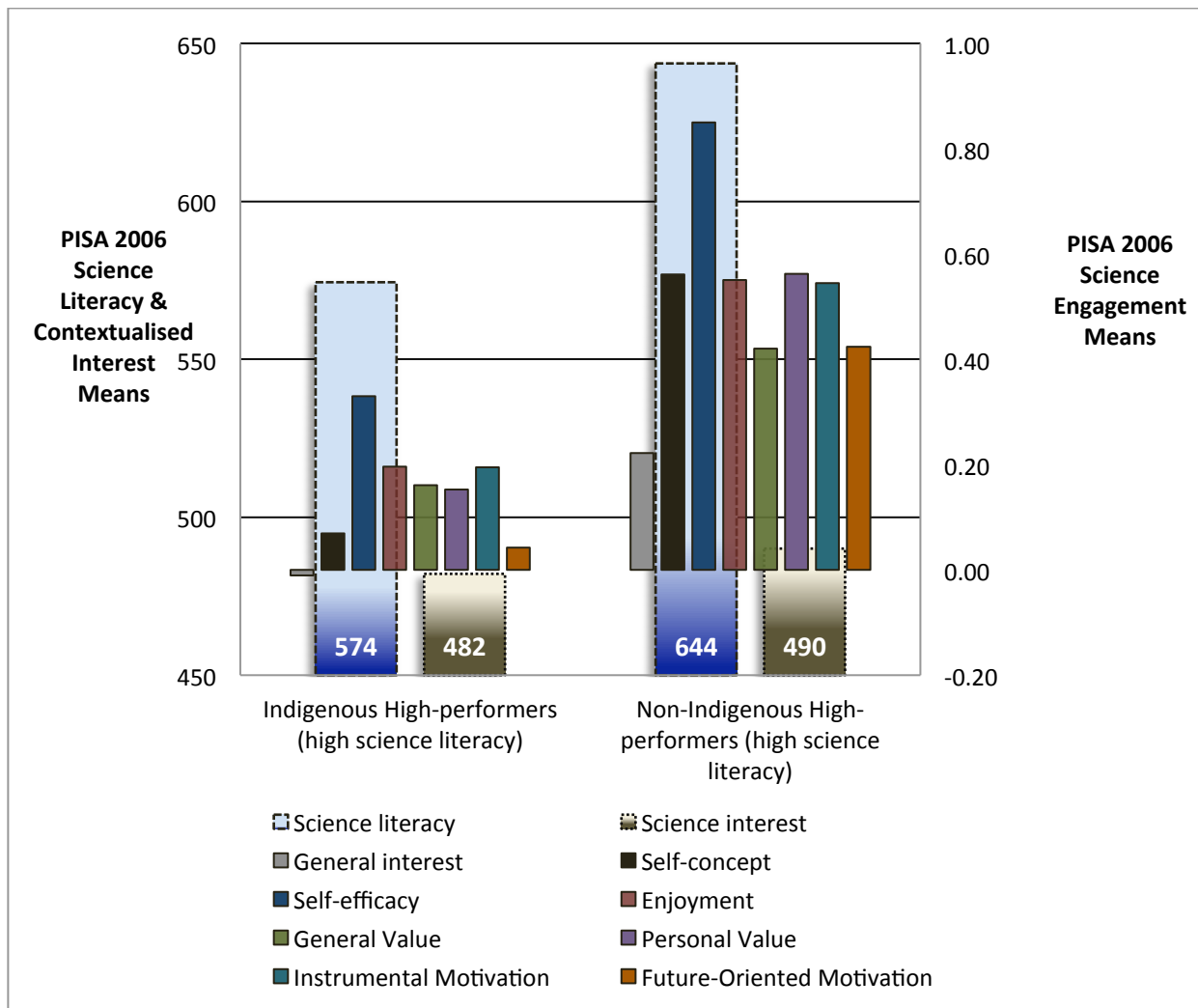
Figure 13. Engagement in science means for high-performing Indigenous and non-Indigenous students.

In Figure 13, science literacy is included to provide a graphical context for high-performing Indigenous students (mean = 574) and their non-Indigenous peers (mean = 644). Additionally, contextualised science interest, for which students' interest in science was assessed by questions embedded in specific areas of science content (e.g., tobacco smoking or acid rain), is provided for

---

[6] We again emphasise that because of the relatively small sample size of the group comprising high-performing Indigenous students, the standard errors associated with these means are relatively large, and hence any inferences drawn must be considered tentative.

both groups. Consequently, science interest is measured in the same way as science literacy and has the same scale. As shown, high-performing Indigenous students on average had somewhat less positive science interest (mean = 482) than their non-Indigenous counterparts (mean = 490), but both groups had substantially more positive interest in comparison to the overall Australian average (465), and in comparison to their respective reference groups (all Indigenous students, 475; all non-Indigenous students, 465).

As noted above, Figure 13 also shows that despite being generally positive for all measures of science engagement, high-performing Indigenous students were less positive in comparison to their high-performing non-Indigenous peers. The size of these differences varied, but in the majority of cases can be characterised as substantial for all measures included under the meta-construct engagement in science.

TAKE HOME MESSAGES FOR RESEARCH QUESTION **3**

- Nine PISA variables together comprise a *meta-construct* representing students' *engagement in science:* content-specific science interest, general interest in learning science, enjoyment, general and personal valuing of science, science self-efficacy, science self-concept, and instrumental and future-oriented motivations towards science.

- For all nine measures included under the conceptual umbrella of engagement in science, Indigenous students with high science literacy led their Indigenous reference population, to varying, often substantial degrees.

- High-performing Indigenous students, on average, were also more positive on all nine science engagement variables when compared to all non-Indigenous students, although to a lesser degree than when compared to all Indigenous students.

- High-performing Indigenous students evidenced, on average, levels of engagement in science greater than the mean for every measure except "general interest in science".

- High-performing Indigenous students were nevertheless, on average, less positive on nine science engagement variables in comparison to their high-performing non-Indigenous counterparts. The size of these differences between the two high performing groups varied, but in the majority of cases can be characterised as substantial.

5.5 Relationships among engagement variables and science literacy for Indigenous students with high literacy in science

> RQ5: In general, for high-performing Indigenous students in science, what relationships and co-relationships exist among engagement in science variables and performance in science? Are these relationships different for Indigenous high-performing students in comparison to other Indigenous students or their non-Indigenous high-performing peers?

In answering research question 4, we learned that Indigenous students with high literacy in science (the top 25% of all Indigenous students who participated in PISA 2006) also hold generally positive profiles of engagement in science. On average, Indigenous high performers have engagement in science profiles more positive than their reference population and more positive than non-Indigenous students generally. Nevertheless, it is also the case that the science engagement profiles of the top Indigenous students, on average, are less positive in comparison to the engagement in science profiles of their high performing non-Indigenous counterparts to varying but significant degrees.

To further compare the science engagement of high-performing Indigenous and non-Indigenous students in science, as measured in PISA 2006, we examined four groups:

- **Indigenous students with high science literacy** at or above the 75th percentile for all Indigenous students in PISA 2006 (279 students);
- **Non-Indigenous students with high science literacy** at or above the 75th percentile for all non-Indigenous students in PISA 2006 (3,313 students);
- **All Indigenous students** in PISA 2006, Australia; and,
- **All non-Indigenous students** in PISA 2006.

We used nine variables from PISA 2006 in this analysis:

- Science literacy;
- Science interest (content-specific);
- General interest in science;
- Science self-concept;
- Science self-efficacy;
- Enjoyment of science;
- General valuing of science;
- Personal valuing of science; and
- Student-level socio-economic status (ESCS in PISA): a composite index of highest parental occupational status, highest parental educational attainment (years of education), and economic and cultural resources in the home.

In addition, therefore, to the group-wise comparative profiling of engagement in science for Indigenous and non-Indigenous students reported in the previous question, further analysis within the limits of the variables provided by PISA 2006, was warranted. Consistent with our approach to

earlier research questions, to achieve a more authentic representation of the interrelated association of science engagement, science literacy and student background variables measured in PISA, we used regression analysis. As noted above, this approach allows us to estimate the influence of any one explanatory variable—in the context of several other related variables that have been shown to play an important role—to the outcome (science literacy) being examined.

In this instance, we included in our regression analysis for science literacy, students' SES backgrounds and seven variables grouped under the conceptual umbrella, engagement in science. We conducted two regression analyses, one for high-performing Indigenous students, and the other for their high-performing non-Indigenous counterparts in PISA 2006. The resulting regression equations are given in Figure 14. Due to the relatively modest number of students who comprised the high-performing Indigenous group, the responses for students' instrumental motivation for science and future-oriented motivation in science were not large enough to maintain a reasonable level of statistical power. Therefore we omitted these two variables from these regression analyses.

As shown in Figure 14, regression analysis showed a positive association between science literacy and SES (ESCS in PISA) for both high-performing Indigenous and non-Indigenous students. On average, each unit increase in ESCS would result in a 5 point increase in science literacy for high-performing Indigenous students, and an 8 score-point increased for non-Indigenous students. For high-performing Indigenous students, however, the association between science literacy and SES is not statistically significant in the context of the other engagement variables present in this regression analysis.

For this group of high-performing Indigenous students, two science engagement variables seemed to play significant roles in the context of the other engagement variables included in the regression. Specifically, for each unit increase in students' enjoyment of science, science literacy was predicted to increase by about 25 score points, on average. Similarly for Indigenous high performers, each unit increase in science self-efficacy was predicted on average to result in an increase of about 19 score points in science literacy. Both of these associations were statistically significant.

(Predicted) Science Literacy for High-performing Indigenous students =
5.12(SES) +3.78(general value of science) – 9.52(general interest in science)
+ 24.82(enjoyment of science)[**] – 12.98(personal value of science) **+ 18.70(science self-efficacy)**[**] + 2.12(science self-concept) +0.0(content-specific science interest) + 565.18

(Predicted) Science Literacy for High-performing Non-Indigenous students =
8.10(SES)[**] -1.01(general value of science) – 2.76(general interest in science)
+ 6.34(enjoyment of science)[**] +0.49(personal value of science) **+ 10.64(science self-efficacy)**[**] **+ 8.53(science self-concept)**[**] +0.1(content-specific science interest) + 618.10

Figure 14. Regression equations for Indigenous and non-Indigenous high-performers' science literacy on student's engagement in science as measured in PISA 2006.

Figure 14 portrays similar findings for non-Indigenous high-performing students. In addition to the significant positive association between science literacy and SES, three science engagement variables also had positive, statistically meaningful associations with science literacy, in the context of all other engagement variables in the model. As was the case for Indigenous high-performing students, non-Indigenous students' enjoyment of science and science self-efficacy played significant, although substantially smaller, roles in predicting science literacy. For example, each unit increase in enjoyment of science was predicted to result in a 6 score-point increase for non-Indigenous students, as compared to a 25-point increase for Indigenous students. In addition, and different to the case for Indigenous students, non-Indigenous students' self-concept in science also played a considerable role; each unit increase in non-Indigenous students' science self-concept would mean a 9-point increase in science literacy, a statistically significant association.

We again note that for Indigenous high-performing students, standard errors associated with estimated regression coefficients are quite high, related to the modest size of the sample. This means that associations can appear quite substantial but nevertheless not be statistically significant because of the limitations of the size of the group.

TAKE HOME MESSAGES FOR RESEARCH QUESTION 5

■ **For both Indigenous and non-Indigenous groups with high science literacy, once SES is accounted for, and in the context of several engagement in science variables, students' enjoyment of science plays a significant role in science literacy. The association between enjoyment of science and science literacy is considerably stronger for Indigenous students than it is for non-Indigenous students (more than 50% of a school year of learning science versus about 15%).**

■ **For both Indigenous and non-Indigenous groups with high science literacy, once SES is accounted for, and in the context of several other engagement in science variables, students' self-efficacy in science also plays a significant role in science literacy. The association between students' self-efficacy in science and science literacy is considerably stronger for Indigenous students than it is for non-Indigenous students (just under 50% of a school year of learning science versus about 25%).**

■ **High-performing non-Indigenous students also evidenced a significant relationship between self-concept in science and science literacy performance, once SES had been accounted for, and in the context of several other variables representing engagement in science. This was not evident for Indigenous students with high literacy performance in science.**

■ **We emphasise that because of the modest size of the group of high-performing Indigenous students, and hence the relatively high standard errors associated with regression coefficients for this group, the observed associations between science literacy and engagement in science variables should be interpreted cautiously.**

6. Concluding Thoughts

This study, in attempting to better understand factors associated with science literacy performance and engagement in science for high-performing Indigenous students has a number of key messages. First, it is important to recognise and acknowledge the Indigenous students who are achieving well. The mean for the top 25% of high-performing Indigenous students is 574, well above the overall Australian mean (527), the mean for all OECD countries (498) and the mean for all Indigenous students (441). These results call for a celebration rather than a focus on the gap. It is appropriate to pause and remember that students are doing well. At the same time it is appropriate to reflect on how to further support Indigenous students' success and engagement in science so more students can succeed in science.

We've tried to better understand high-performing Indigenous students with a secondary analysis of the teaching and learning variables provided by PISA 2006. Teacher led activities seem to add value whereas activities with a focus on student-led investigations do not seem to be paying dividends in terms of science literacy. Actually, the associations between student-led investigations and success in science are negative for both high-performing Indigenous and non-Indigenous students. These results seem to contrast the general consensus in science education that investigations, hands-on learning and inquiry result in concurrent science literacy performance and positive engagement in science. At the same time, these results are similar to results we found in a study that looks at inquiry, engagement and literacy in science for students in Australia, New Zealand and Canada (McConney, Oliver, Woods-McConney, Schibeci, & Maor, 2014). As described in the study, across the three countries, students who report high levels of inquiry-oriented learning activities in science are seen to have below average levels of science literacy but above average levels of interest in learning about science, and above average engagement in science. If, as we see in this current report, all Indigenous students in Australia are experiencing the teaching approach of *investigation* more frequently than other students there may be a connection since investigations are typically associated with inquiry learning. Teaching investigations can be quite difficult, especially if students or teachers do not have the science content knowledge or skills to complete the investigations with an in-depth understanding. Students, we would argue, cannot investigate without some knowledge about what they are investigating. Teachers also need to be skilled in facilitating investigations so that students learn from the activity. We would therefore argue that investigation activities are not created equally and without high quality investigations, student learning can suffer.

Perhaps more than anything else, it would be beneficial to mitigate the effects of SES. Literacy performance in science for both Indigenous and non-Indigenous students has a positive association with SES. It is worthwhile to think about how we can address this inequity. For example, we know that activities outside-of-school are related to science literacy. The ability of Indigenous students to participate in out-of-school activities such as science websites and science magazines seems to be hampered by low SES. Universal access to these out-of-school resources seems to be a high priority. For example, along with computer access students need Internet access to engage with science

websites. Further identification of the factors that are associated with SES and students success in science is warranted.

Indigenous students overall have a higher content specific interest in science compared with non-Indigenous students. High-performing Indigenous students' profiles of engagement in science are quite positive, more positive than all Indigenous students and all non-Indigenous students. We wonder why this interest in science is not being transferred to higher achievement. Positive indications on the affective side are not being universally translated to science literacy achievement, which represents a missed opportunity. A better understanding of the relationship between affective perspectives and cognitive achievement could help us capitalise on high affect towards science. Again, we believe that further research is needed.

It is essential that we go beyond PISA to understand the factors that facilitate success for Indigenous students. Datasets like PISA are large and high quality but they are also cross-sectional survey data collected at one point in time. They provide snapshots to inform our understanding but they have limitations. The secondary analyses of these large datasets do not allow strong causal models to explain students' science literacy or engagement in science. This is despite the conceptual care used in deciding the hierarchy of the explanatory models we have suggested. Further research with high-performing Indigenous students is needed to better understand the factors that lead to their success in science. It is important to put the explanatory models that have been developed to further empirical test. The robustness of our generalisable (normative) explanations based on the large datasets depends largely on the explanatory model's ability to undergo specific and individual case study testing. In other words it is essential to see how well results from the large datasets match individual student stories of what has influenced their science literacy and engagement.

7. Bibliography

Aikenhead, G., & Michell, H. (2011). Bridging cultures: Indigenous and scientific ways of knowing nature. Ontario: Pearson Education, Don Mills.

Aikenhead, G. S. and Elliott, D. (2010) 'An Emerging Decolonizing Science Education in Canada', *Canadian Journal of Science, Mathematics and Technology Education*, 10: 4, 321—338.

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology*, 36(1), 4–12.

Bussie`re, P., Knighton, T., & Pennock, D. (2007). Measuring up: Canadian results of the OECD PISA study—the performance of Canada's youth in Science, Reading and Mathematics. Ottawa: Canadian Ministry of Industry. Retrieved from http://www5.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno1⁄481– 590-X&chropg1⁄41&lang1⁄4eng

Fensham, P. J. (2009). Real World Contexts in PISA Science: Implications for Context-Based Science Education. *Journal of Research in Science Teaching*, 46(8), 884–896.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74(1), 59–109.

Lin, H.-S., Lawrenz, F., Lin, S.-F., & Hong, Z.-R. (2012). Relationships among affective factors and preferred engagement in science-related activities. *Public Understanding of Science*, 22(8), 941-954.

McConney, A., Oliver, M.C., Woods-McConney, A., Schibeci, R., & Maor, D. (2014). Inquiry, Engagement, and Literacy in Science: A Retrospective, Cross-National Analysis Using PISA 2006. *Science Education.* Article first published online: 14 SEP 2014 http://dx.doi.org/10.1002/sce.21135

McConney, A., & Perry, L. (2010). Science and mathematics achievement in Australia: The role of school socioeconomic composition in educational equity and effectiveness. *International Journal of Science and Mathematics Education*, 8(3), 429-452. doi:10.1007/s10763-010-9197-4.

McConney, A., Oliver, M., Woods-McConney, A., & Schibeci, R. (2011). Bridging the gap? A comparative, retrospective analysis of science literacy and interest in science for indigenous and non-indigenous Australian students. *International Journal of Science Education*, 33(14), 2017–2035. doi:10.1080/ 09500693.2010.529477.

OECD. (2004). Learning for tomorrow's world: First results from PISA 2003. Paris: Author.

OECD. (2007). PISA 2006: Science competencies for tomorrow's world. Paris: Author.

OECD. (2009). PISA 2006 Technical report. Paris: Author.

OECD. (2009). PISA 2009 Results: What Students Know and Can Do. Student performance in reading, mathematics and science. Paris: Author.

OECD. (2010). PISA 2009 Results: Executive Summary. Paris: Author.

OECD. (2010). The high cost of low educational performance. Paris: OECD Publishing.

Sadler. T. & Zeidler, D. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46(8), 909--921.

Sullivan, K., Perry, L., & McConney, A. (2013). How do school resources and academic performance differ across Australia's rural, regional and-metropolitan communities? *The Australian Educational Researcher*, Vol. 40 (*3*), pp. 353–372. Retrieved from http://dx.doi.org/10.1007/s13384-013-0100-5

Thomson, S., & De Bortoli, L. (2008). Exploring scientific literacy: How Australia measures up: The PISA 2006 survey of students' scientific, reading and mathematical literacy skills. Camberwell, Australia: Australian Council for Educational Research.

Thomson S., De Bortoli, L., & Buckley, L. (2013). PISA 2012: How Australia measures up. Camberwell, Australia: Australian Council for Educational Research.

Woods-McConney, A., Oliver, M., McConney, A., Maor, D., & Schibeci, R. (2013). Science engagement and literacy: A retrospective analysis for indigenous and non-indigenous students in Aotearoa New Zealand and Australia. *Research in Science Education*, 43, 233–252. Retrieved from http://dx.doi.org/10.1007/s11165-011- 9265-y.

Woods-McConney, A., Oliver, M. C., McConney, A., Schibeci, R., & Maor, D. (2014). Science engagement and literacy: A retrospective analysis for students in Canada and Australia. *International Journal of Science Education*, 36(10), 1588–1608. Retrieved from http://dx.doi.org/10.1080/09500693.2013.871658.