

NATIONAL VOCATIONAL EDUCATION
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OCCASIONAL PAPER

Single-sex schools and science engagement

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AUSTRALIAN NATIONAL UNIVERSITY

NCVER Building Researcher Capacity
Fellowship Program 2012 participant



Australian Government
Department of Industry

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This document should be attributed as Sikora, J 2013, *Single-sex schools and science engagement*, NCVER, Adelaide.

ISBN 978 1 922056 68 9

TD/TNC 113.18

Published by NCVER, ABN 87 007 967 311

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About the research

Single-sex schools and science engagement

Joanna Sikora, Australian National University

This paper considers whether single-sex schooling affects gendered patterns in the uptake of science courses in Year 11 and the development of science-related career paths. In particular, the author is interested in exploring gender differences relating to the take-up of the life and physical sciences. To investigate these issues, the author analyses data from the 2009 cohort of the Longitudinal Surveys of Australian Youth (LSAY).

This research was funded through the National Centre for Vocational Education Research (NCVER) fellowship program, which encourages researchers to use NCVER datasets to improve our understanding of education. A second paper is further investigating gender segregation in youth science engagement by looking at gendered pathways into post-secondary science study.

Key messages

- Across all schools, male and female students systematically select different science subjects and prefer careers in different fields of science, as did their counterparts ten years ago.
- With respect to science subjects, students' gender, science performance and science self-confidence levels have a consistent positive influence on both life and physical science engagement. The latter two are more prominent in the take-up of physical science subjects.
- Single-sex schooling does not affect the likelihood of boys taking up physical or life science subjects while at school. However, boys from boys-only schools are more likely to plan a life science career, such as physiotherapy and medicine, than their male counterparts in coeducational schools.
- Girls in girls-only schools are more likely to take up physical science subjects than their female counterparts in coeducational schools. However, single-sex schooling does not affect the likelihood of girls planning a physical science career.

After controlling for a number of student and school characteristics, the author concludes that, although some benefits of sex-segregated schooling exist, the overall effects are small. Moreover, it is unlikely that these effects have a lasting impact on young people's educational and career pathways later in life, which questions whether programs designed to extend single-sex schooling into the government sector should be introduced.

Rod Camm
Managing Director, NCVER

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Introduction

The concerns over falling rates of interest in science among youth have been growing over the last decade (Ainley, Kos & Nicholas 2008). In Australia the interest in science has been declining steadily among students of both genders, a trend accompanied by the tendency of adolescents to select themselves out of the areas of science that are non-traditional for their sex (Sikora & Pokropek 2012a). For instance, the introduction of psychology into high school science curricula led to the steady overrepresentation of girls amongst students taking this subject (Ainley, Kos & Nicholas 2008). Certain fields of science, such as psychology or biology, are seen as culturally and functionally compatible with the ‘naturally’ feminine skills of nurturance, care or human interaction. In contrast, high-level abstract analytical thinking and problem-solving are construed as ‘naturally’ masculine skills (Charles & Bradley 2009). It is for these cultural reasons that girls and women flock into science fields related to living systems and healthcare, while boys and men concentrate on engineering, physics, geology and high-level mathematics (Organisation for Economic Co-operation and Development [OECD] 2012a).

This type of gender segregation could be seen as a potential equity concern because girls and boys might, as a consequence of these sorting tendencies, lose out on opportunities to enter particular science-related careers later in life (Ainley & Ainley 2011; Ceci, Williams & Barnett 2009; Charles 2011; Hill, Corbett & Rose 2010; Kessel & Nelson 2011; Sikora & Pokropek 2011). The shortage of qualified scientists and the underrepresentation of either gender in science can be detrimental not only to economic productivity but also to social integration (Anker 1997). Such concerns have spawned a large literature on gendered patterns of science engagement overseas as well as informed a number of studies in Australia (Ainley & Daly 2002; Ainley, Kos & Nicholas 2008; Ainley & Ainley 2011). In this literature, one of the more prominent strands is the ongoing debate over the merits of single-sex education.

This occasional paper revisits the relationship between single-sex education and science engagement, using recent data from the first three waves of the Longitudinal Surveys of Australian Youth (LSAY), which collected information on the educational experiences from young people who turned 15 years of age in 2009. In particular, I assess the extent to which girls and boys in sex-segregated schools select science subjects and plan science-related careers in defiance of traditional gender stereotypes. The focus of this paper is thus on the following questions. First, do male and female students still opt for different science subjects? Second, are the science-related occupational plans of these students still strongly gender-typed? Finally, are these gender-typing tendencies different in single-sex and coeducational environments? In Australia some of these research questions were last explored using the LSAY95 data (Ainley & Daly 2002), with the conclusion that single-sex schooling had no net effect on science subject choice. Over a decade later, the time has come to reassess the impact of segregated schooling on the science engagement of more recent cohorts of adolescents.

Opening with a review of the literature on gender-segregated schooling and science participation in Australia and overseas, the paper comments on the current state of the debate over the merits of single-sex versus coeducational settings. Following this, the research questions are introduced and addressed with descriptive and multivariate analyses of the LSAY09 data. The presentation of the results precedes the discussion of the findings and their potential implications for future educational policy.

The debate over merits of single-sex schooling

The question of whether students learn better in sex-segregated classes and schools has been in the minds of educators for decades (American Association of University Women Educational Foundation 1998; OECD 2006). Overall evidence in this politicised and heated debate remains inconclusive. Some authors believe that sex-segregated education actually promotes gender equity and thus should have a greater role in national education systems (Salomone 2003). In apparent support of this proposition, some international literature suggests that in recent years girls have been performing better in the quantitative sciences in single-sex schools, where they are not at risk of distraction from ratings by the other sex. Similar arguments have been put forward about the benefits of single-sex schooling for boys (Salomone 2003; Streitmatter 2002).

The usual line of reasoning offered by this camp is that girls' self-confidence in science and mathematics is undermined by the physical presence of boys, because these fields continue to be viewed as functionally and culturally masculine domains. Therefore, the enactment of a feminine identity is at odds with success in mathematics and 'masculine' fields of science (Salomone 2003). A high level of mathematical skill and being identified as a 'nerd' are unfeminine and thus girls who find themselves topping their class in advanced mathematics, physics or geology might experience various forms of negative stereotyping (Hill, Corbett & Rose 2010). Students who take part in experiments designed to capture the impact of the gender stereotype threat are primed about 'natural' gender differences in maths performance and subsequently given a quantitative science test. Girls usually fare worse than boys and, interestingly, the performance gap is systematically larger following a briefing on these so-called gender differences, in contrast to occasions when none is offered (Cherney & Campbell 2011). It is worth noting that some single-sex schools in Australia routinely join their students with students of the opposite sex from other schools for various activities, including specialised science classes. Therefore, it is possible that the actual mechanisms through which the physical presence of boys makes a difference to girls' confidence and performance might vary according to group context. While anxiety about the opinions of the opposite sex might have an undermining effect in coeducational schools, between-school competition might boost girls' science outcomes in girls-only schools.

Dismissing such deliberations, other authors make a strong case against single-sex schooling (Halpern et al. 2011), positing that its alleged benefits are mere artefacts of poor study design. This camp proposes that the apparent benefits of single-sex schooling are attributable to selectivity on socioeconomic background or academic achievement. For example, Smyth argues (2010, p.53):

It is difficult to systematically compare single-sex and coeducational schools or classes. In many countries, single-sex schools are highly selective in their social and ability profile; even in countries with a larger number of single-sex schools, the two school sectors differ in their intake. How then do we 'control' for these differences in assessing the impact of single-sex education?

This puts a question mark over what really accounts for the science success of students in single-sex educational establishments (Leonard 2007). According to the opponents of single-sex education, when flaws and omissions in conceptualisation and analyses are rectified, it should be accepted that '[t]here is no well-designed research showing that single-sex education improves students' academic performance, but there is evidence that sex segregation increases gender stereotyping and legitimizes institutional sexism' (Halpern et al. 2011, p.1706).

The main focus in studying the relationship between single-sex schooling and science has so far been on differences in students' academic performance, mainly because up to the late 1980s girls lagged

behind boys in science performance. However, in recent times in Australia and in many other countries girls have performed on a par with boys (OECD 2007a; Sikora & Pokropek 2012a). Nevertheless, students who do well in science do not necessarily plan to embark on science-related tertiary education or careers (Archer et al. 2010; Osborne, Simon & Collins 2003). In the United States, a recent study found that girls in girls-only schools had more self-confidence in their science ability than girls elsewhere but that this did not lead them to planning science, technology, engineering and mathematics (STEM) careers (Cherney & Campbell 2011). Given this, it is desirable to better understand not only gender differences in science performance but also in subject uptake and career plans. So far, however, the number of studies devoted to these issues has been small (exceptions include Ainley & Daly 2002 and Ainley, Kos & Nicholas 2008).

Prior Australian research in this area concluded that single-sex schooling made no real difference once the variation between schools in student intake policies and other student characteristics was taken into account (Ainley & Daly 2002). Most of the literature reviewed by Ainley and Daly that described the effects of single-sex schooling in Great Britain and Ireland in the 1990s arrived at similar conclusions. Contemporaneous comparisons of data from many countries suggested that single-sex schooling was beneficial to students only in educational systems where it was uncommon and quite elitist (Baker, Riordan & Schaub 1995). Yet, a more recent study found no systematic association between the share of single-sex education and the mathematics achievement of students in 16 countries (Law & Kim 2011), leaving the debate as inconclusive as it has ever been.

Research questions

LSAY09 offers a unique opportunity to re-evaluate this debate with recent data and in the context of the major changes that have affected the science participation of Australian students in the last decade (Ainley, Kos & Nicholas 2008). The goal of this paper is, thus, to establish whether single-sex schooling continues to make little difference to the gendered patterns of science participation of the recent cohorts of students and whether the gender gap in science participation is as it was a decade ago.

Although this paper briefly considers the differences in science performance between adolescents attending single-sex and coeducational schools, it aims to focus attention on two other aspects of science participation. The first is science subject choices in Year 11, since the upper secondary stage of schooling is the first opportunity for most Australian high school students to specialise, by selecting themselves out of certain fields of study. The second form of science engagement examined here is a student's career plan, reported between their fifteenth and sixteenth birthdays.

With respect to these two forms of science engagement, the research questions posed in this paper are as follows:

- Across all schools, do boys and girls continue to select different science subjects and formulate different science-related career plans?
- Are gendered patterns of science engagement systematically different between students in single-sex and coeducational settings?

It must be noted that, while the literature on gendered patterns of science participation pays attention primarily to the disadvantage of girls, segregation is not necessarily disadvantageous for one sex only. Gender segregation is a phenomenon with the potential to adversely affect both young men and women. Given that comparable numbers of young women and men engage in science (Sikora &

Pokropek 2011 and table 3), if girls are underrepresented in certain fields, boys must be underrepresented in others.

How are life and physical sciences defined in this paper?

The concentration of males and females in different fields of science has been well documented (Hill, Corbett & Rose 2010; OECD 2006; Sikora & Pokropek 2012a). In Australia, Fullarton and Ainley (2000, p.v1) noted in their analyses of subject choice among Australian students:

Gender was found to be one of the student characteristics accounting for the greatest proportion of variation in student enrolments. As found in previous subject choice reports, males predominate in the areas of mathematics, particularly in higher level mathematics, physical sciences, technical studies, computer studies and physical education.

There is no established and widely accepted terminology to denote the distinction between ‘feminine’ and ‘masculine’ fields of science, although its existence is well known to science educators. Some authors refer to it as the contrast between ‘soft’ and ‘hard’ sciences (Kjrnslie & Lie 2011), or between ‘life’ and ‘quantitative’ sciences (Kessel & Nelson 2011), or between ‘physical’ and ‘life’ sciences (Ainley & Daly 2002). This paper uses Ainley and Daly’s labels of *life* and *physical* sciences, but any choice of labels is to a degree arbitrary and thus it is important to peruse the list of science fields included in each category (provided in appendix B). In principle, fields and courses with significant biology, health-related or environment-focused content are treated in this analysis as ‘life science’, while fields with explicit physics, chemistry or geology content are treated as ‘physical science’. Occupational plans related to biology and health services are assumed to relate to life science, while engineering, mathematical and computing occupations are assumed to relate to physical science. This latter distinction is adopted from the OECD framework previously used for international comparisons (Sikora & Pokropek 2011). Analysis at the level of particular subject titles or occupational titles is impossible because of the large numbers of science subjects offered across the states and territories and the equally large numbers of occupational titles that group relatively few students. Therefore, some categorisation of science fields along the dimensions of care versus technology (Barone 2011) is necessary to highlight the gendered concentration of students within particular areas of science, technology, engineering and mathematics. In contrast, treating science as one homogeneous field of study conceals systematic gendered differences in science engagement (Anlezark et al. 2008).

Data and measurement

This paper utilises data from the upper secondary school students who participated in LSAY and who were between 15 and 16 years of age in 2009 – LSAY09. The 2009 Program for International Student Assessment (PISA) constitutes the first wave of LSAY09. It was conducted in Australia on a two-stage stratified representative sample of students, generated by sampling first schools and then students within schools. Schools were stratified by sector and state or territory. In 2010 and 2011 respondents of the initial PISA 2009 survey were contacted for an annual follow-up interview. Of 14 251 students who participated in PISA, 8759 participated in LSAY in 2010 and 7626 participated in 2011 (NCVER 2012, p.12).

What is science engagement in this paper?

This study first considers science subject uptake and then science-oriented vocational plans, since recent studies suggest that a high level of academic achievement in science does not necessarily lead students to pursue science at tertiary level (Anlezark et al. 2008).

Although it has been pointed out that ‘the combination of subjects studied by students in the senior secondary years says more about a student’s educational orientation than does enrolment in any given subject’ (Ainley & Daly 2002, p.250), enrolment in a life science course or a physical science course is a good indicator of two different types of patterns of science course taking. For this reason this analysis relies on modelling enrolment in at least one life science subject or one physical science subject in Year 11. Science in this instance excludes mathematics courses (as per listing in appendix B), as they are not only outside the scope of this paper, but they also require a different coding scheme, one which distinguishes advanced and applied courses. A small number of science subjects could not be classified into either physical or life science categories because of the broad scope of their content (see appendix B) and were omitted from the analysis. However, this omission does not bias results, because the numbers of students enrolled in these subjects were negligible. Students who took a life science subject were coded 1 on the relevant dummy variable and all other students were coded zero. A similar procedure was applied to create a dummy variable that denotes taking a physical science subject, so all students with information on subject taking were included in the analyses. It is important to note that the patterns of science engagement for Year 12 in this dataset strongly resemble those of Year 11. As Year 11 data are less affected by attrition,¹ they are the focus of this analysis.

A high level of academic achievement in science does not necessarily lead students to pursue science as a profession; therefore, a student’s plan to work in science-related occupations is another focus of this paper. Students in LSAY09 were asked what occupation they expected to work in when they reached 30 years of age. This is the indicator of a science-related career plan, converted into two dichotomous variables, named a ‘plan to work in a physical science occupation’ and a ‘plan to work in a life science occupation’, which were created using the list of occupations at the end of appendix B. Students who named one of them were coded 1 on the relevant variable, while others were coded 0.

¹ Reliance on Year 11 data necessitates the imputation of information on subject choices for students who were in Year 11 in 2009 as they were not asked the relevant questions. The advantage of this strategy, as opposed to reliance on data from Year 12 students (see figure 1), is that the entire spectrum of socioeconomic (SES) backgrounds of students is reflected in the analyses. As science engagement is known to be closely related to SES and as low-SES students are more likely to drop out of LSAY by Wave 2, the analysis of data from Year 12 students would be somewhat biased towards higher SES backgrounds.

Missing data on these variables, which amount to 32% in LSAY09, have been imputed using multiple chain imputations (Royston 2004).

PISA 2009 and LSAY09 sampling designs

Since data were collected from the population of 15-year-olds, regardless of their grade level, this paper, although not longitudinal in nature, utilises information collected in different years (known as survey waves, as illustrated in figure 1). Occupational expectations were measured in Wave 1, while the information about subject choices in Year 11 is pooled over three years (figure 1).

Figure 1 Data by school year and wave in LSAY09

		<u>LSAY09 cohort</u>			
Wave 1	2009	Wave 2	2010	Wave 3	2011
Year	n	Year	n	Year	n
9 or below	1 502	10 or below	892	10	16
10	10 093	11	5 342	11	694
11	2 646	12	1 747	12	4 488
12	10				
Not at school	0	Not at school	778	Not at school	2 428
Total	14 251	Total	8 759	Total	7 626

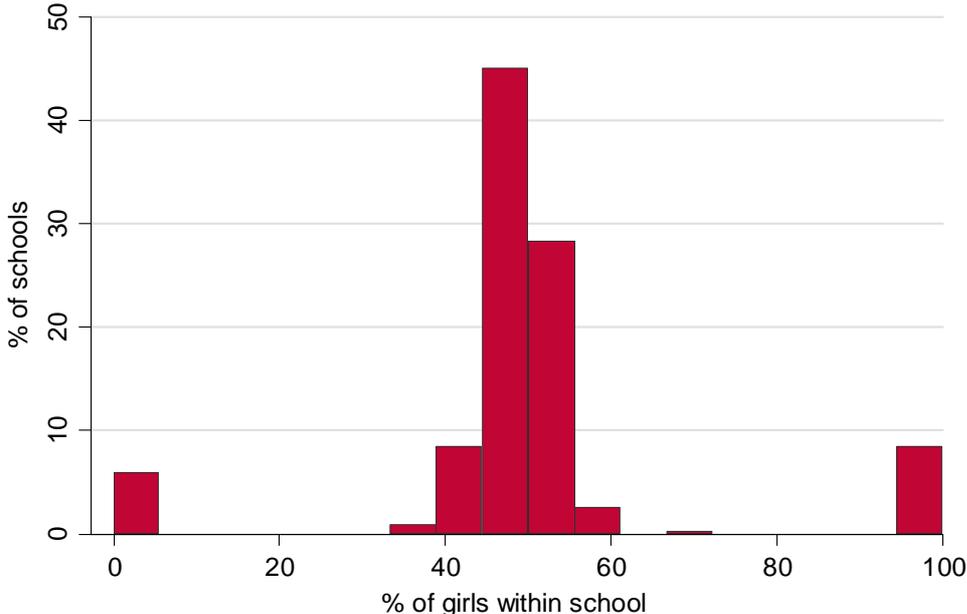
Weighted estimates

The LSAY09 sample is not ideal for estimations of how school characteristics influence subject choice in Years 11 and 12. This is because the information about schools was collected in 2009 when most students were in Year 10. Therefore, this analysis is based on data from students who provided information about subjects in Year 11 (shaded rows of figure 1) except for 822 students (a weighted estimate) who changed schools after 2009. Despite these limitations, the LSAY data remain the best available source of information on the school characteristics, career plans, subject participation and science performance of secondary school students. There is no other survey which covers all these topics.

Although Australia is often considered a country where a significant proportion of secondary students attend single-sex schools (Ainley & Daly 2002; Baker, Riordan & Schaub 1995), the proportion of students in single-sex schools is not high in LSAY09. Among 353 schools for which data are available, there are only 19 boys-only schools and 26 girls-only schools, which make up 5.4% and 7.4% of schools respectively (figure 2).

Furthermore, sex-segregated education seems to be declining in Australia in line with trends documented in the 1980s and 1990s (Australian Bureau of Statistics [ABS] 1997) and reported for other English-speaking countries (Ainley & Daly 2002). In 1998, about 24% of students attended single-sex schools, with a larger proportion of girls than boys receiving education in segregated settings. This trend is also evident in the LSAY03 data, in which 10% and 9% of students attended girls-only and boys-only schools respectively. By 2009 the proportions of students in sex-segregated environments had further declined as, among 15-year-olds, only 9% of girls and 6% of boys were not in coeducational schools.

Figure 2 Gender compositions of schools in LSAY09



Source: LSAY09.

Thus, even though Australia arguably represents a moderately sex-segregated system (Wiseman 2008), the actual proportion of students in sex-segregated upper secondary school settings is low and seems to be decreasing with time.

Results

One of the perennial problems affecting attempts to assess the impact of single-sex schooling on science engagement is the difficulty of disentangling the effect of school sector (private versus government) from the effect of gender composition of student populations within schools. Fortunately, in LSAY09 not all single-sex schools belong either in the Catholic or the independent sectors. Therefore, there is some scope for dealing with this problem, even though a mere 2% of students in the government sector are in boys-only settings, and only 3% of students in this sector attend girls-only schools (table 1).

The largest degree of sex segregation is present in the Catholic sector, where 17% of 15-year-olds attend boys-only schools and nearly a quarter of students, that is, 24%, receive education in girls-only environments.

The comparison of the data in table 1 to the estimates reported by Ainley and Daly (2002) for 1998 reveals that at both points of time 40% of students in upper secondary education attended non-government schools.

However, 55% of students in the Catholic sector and 45% students in independent schools were in single-sex environments in 1998 (Ainley & Daly 2002, p.244), but by 2009 the corresponding proportions were only 41% in the former and 17% in the latter (table 1). Thus it appears that the independent sector halved its share of students in sex-segregated settings in the decade between 1998 and 2009.

Table 1 Student characteristics, by type of school

	Boys-only %	Coeducational %	Girls-only %	Total single- sex schools	N
Government	2	95	3	5	8 511
Catholic	17	60	24	41	3 144
Independent	8	83	9	17	2 595
Total	6	85	9	15	14 251
Metropolitan	8	80	12	20	10 662
Provincial	0	99	1	1	3 400
Remote	0	100	0	0	188

Source: LSAY09, weighted estimates.

As expected, single-sex schools are concentrated in metropolitan locations (table 1) and provide education to students who score significantly higher on science tests (table 2). On a science performance scale with the mean of 500 and the standard deviation of 100, the average score of a student from a single-sex school exceeded by about 30 points, or close to one-third of a standard deviation, the scores typical for coeducational schools (table 2). Students in single-sex schools come from more advantageous family backgrounds, just as was the case a decade ago. Ainley and Daly reported the advantage of about 0.4 of a standard deviation (2002, p.244), which is comparable with that found in LSAY09. The difference between the economic and socio-cultural background of students in boys-only and coeducational schools is 0.42 of a standard deviation, while the typical socioeconomic status of students in girls-only schools is 0.57, which is significantly higher than the average of 0.29 for their peers in coeducational settings. Comparisons of gender-segregated and

coeducational schools often point out that the former tend to be small in size. However, in LSAY09 the mean size (as well as the median, not shown here) of boys-only schools exceeds the average number of students attending coeducational settings, which is contrary to such expectations (table 2).

Table 2 Student characteristics, by type of school and gender of students

	Boys in single-sex schools	Boys in coeducational schools	Girls in coeducational schools	Girls in single-sex schools	N
Average academic achievement score in science (plausible values, overall mean = 527)	553	523	523	551	14 251
Average science self-concept	63	62	57	60	11 621
Average economic, cultural and social status of family in standard deviations, overall mean (0.34)	0.72	0.30	0.29	0.57	13 933
Average school size	1 197	973		942	14 251

Source: LSAY09, weighted estimates.

Before examining the average differences in subject choice and career plans between single-sex and coeducational schools, it is worth considering whether the individual tendency for boys and girls to select different science subjects changed between 2009 and earlier points of time. For illustration, table 3 contrasts the relevant estimates between LSAY03 and LSAY09.

Table 3 Uptake of science subjects in Year 11 and science-related career plans by gender: comparison between LSAY03 and LSAY09

	LSAY03		LSAY09	
	Boys %	Girls %	Boys %	Girls %
At least one science subject in Year 11	60	64	62	61
Physical science subject in Year 11	38	26	41	28
Life science subject in Year 11	30	50	33	50
Plans to work in science	33	30	33	29
Plans to work in physical science	24	6	22	6
Plans to work in life science	9	24	11	23

Source: LSAY03 and LSAY09, weighted estimates.

There are striking similarities in the proportions of boys and girls in these cohorts who studied science in Year 11. Moreover, the size of the gender gaps in the uptake of life and physical sizes is comparable for Australian adolescents who turned 15 years of age in 2003 and those who were aged 15 in 2009. By analogy, the proportions of students interested generally in science careers and specifically in life and physical science occupations are almost the same in both groups of adolescents. Physical science careers attract relatively few girls (24% of boys versus 6% of girls in 2003 and 22% boys versus 6% of girls in 2009), while life science is less popular among boys (9% of boys versus 24% of girls in 2003 and 11% of boys versus 23% of girls in 2009). These patterns also resemble the proportions reported in the 1990s (Ainley & Daly 2002; Ainley, Kos & Nicholas 2008). They clearly indicate, with respect to the first research question posed in this paper, that the tendency for boys and girls to cluster in different science courses persists over time, with no sign of decreasing, even though the actual titles of science courses and their curricula change.

Do single-sex schools make much difference to these self-sorting tendencies? Figure 3 compares males and females in sex-segregated and coeducational settings. Boys in single-sex schools are more likely

(17%) than their counterparts in coeducational schools (10%) to plan a life science career. However, their interest in physical science jobs and their uptake of physics courses in either Year 11 or 12 are comparable across coeducational and single-sex schools. By the same token, the proportions of boys taking life science subjects are similar in different types of schools in Years 11 and 12. So, segregated environments make no difference to boys' inclination to study science, although they seem to encourage more boys to think of life science careers, which are reputed to attract more girls.

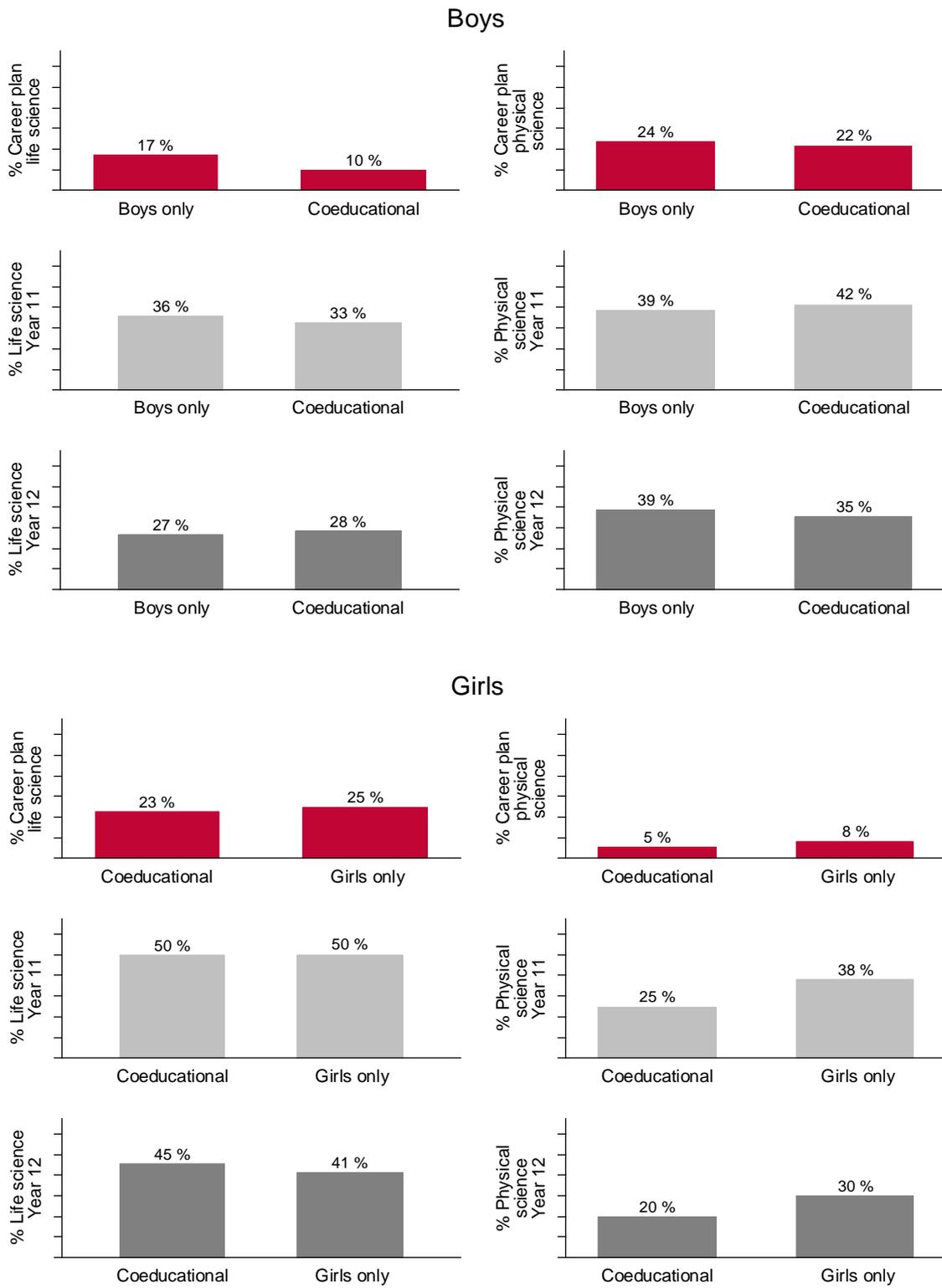
The patterns for girls shown in the lower panel of figure 3 reveal little differentiation by school type with respect to life science subjects or careers. However, girls in girls-only schools seem to be more likely to consider a career in physical science (8%) than girls in coeducational settings (5%). Moreover, more girls in segregated schools study physical sciences (38% versus 25% in Year 11) and this tendency persists into Year 12 (30% versus 20%), even though the proportion of girls taking science subjects falls between Years 11 and 12.

This decreased interest in science in Year 12 is apparent in all groups of students considered here, with the single exception of boys studying physical science in single-sex schools, for whom the estimates are 39% in both Years 11 and 12.

The key question that arises, however, is whether these differences persist once a host of other characteristics of students and schools have been taken into account. Many previous studies, including the Ainley and Daly analysis (2002), found that what appeared as the benefits of single-sex schooling were really attributable to the specific features of the student populations or school settings. To provide a strong test of this hypothesis, the multivariate analyses presented in tables 4 and 5 include not only all the variables previously taken into account (Ainley & Daly 2002) but also a large number of other characteristics named in the literature as the potential real causes of the apparent benefits that single-sex schools bestow on science engagement. (The details of the model estimation and independent variables are in appendix A.) Apart from the variables shown in tables 4 and 5, earlier estimations controlled also for the size of school, the average economic, social and cultural status of families within each school, and the school average of students' science self-confidence, but as these variables made no difference to the results they were omitted to conserve space.

In contrast to the analysis of science subject uptake conducted for the 1998 data (Ainley & Daly 2002), this paper finds that single-sex schools encourage a higher level of engagement in physical science among girls (0.49** in table 4). However, an apparently stronger commitment to physical science careers among these girls is explained by other variables, so single-sex schools do not, in their own right, succeed in encouraging adolescent girls to target physical science occupations any more than coeducational schools.

Figure 3 Boys' and girls' science engagement, by type of school



Source: LSAY09, weighted estimates.

Table 4 Studying a Year 11 subject in life science and in physical science, unstandardised coefficients from multilevel random intercept models

	Life science subject in Year 11		Physical science subject in Year 11	
	Unstandardised coefficient	Standard error	Unstandardised coefficient	Standard error
Fixed effects				
<i>Student characteristics</i>				
Female	0.84**	0.06	-0.71**	0.06
English spoken at home	0.08	0.10	-0.78**	0.12
Australian-born to Australian parents	--		--	
Foreign-born student	0.04	0.10	0.28**	0.10
Parent foreign-born	0.02	0.05	0.24**	0.07
NSW	--		--	
ACT	-0.73**	0.20	-0.45**	0.16
Victoria	0.46**	0.10	0.20*	0.09
Queensland	0.08	0.09	0.14	0.09
South Australia	0.13	0.11	0.41**	0.11
Western Australia	0.23**	0.09	-0.09	0.09
Tasmania	-1.93**	0.27	0.56**	0.19
Northern Territory	-0.15	0.13	0.21	0.17
Metropolitan area	--		--	
Provincial town	0.33**	0.08	0.06	0.09
Remote location	0.59**	0.19	0.31	0.21
Indigenous	-0.21	0.14	-0.35	0.19
Economic and cultural status of family	0.08*	0.04	0.09*	0.04
Academic performance in science	0.11**	0.03	0.87**	0.04
Minutes per week study science	0.05*	0.02	0.05	0.03
Self-confidence in science skills	0.005**	0.00	0.02**	0.00
<i>School characteristics</i>				
Coeducational school	--		--	
Boys-only school	0.21	0.13	-0.21	0.13
Girls-only school	-0.18	0.09	0.49**	0.11
Government school	--		--	
Independent	0.23**	0.08	0.24**	0.08
Catholic	0.25**	0.07	-0.09	0.08
Selective admission to school	0.21	0.13	0.08	0.05
(constant)	2.24**	0.23	6.49**	0.26
Random effects				
Variance between schools	0.05**	0.02	0.02	0.02
Number of students	7 660		7 660	
Number of schools	335		335	

Notes: * Statistically different from zero at $p = 0.05$.
 ** Statistically different from zero at $p = 0.01$.
 -- a reference category.

Table 5 Planning a career related to life science or physical science, unstandardised coefficients from multilevel random intercept models

	Life science career plan		Physical science career plan	
	Unstandardised coefficient	Standard error	Unstandardised coefficient	Standard error
Fixed effects				
<i>Student characteristics</i>				
Female	1.12**	0.06	-1.52**	0.07
English spoken at home	-0.44**	0.10	-0.31**	0.11
Australian-born to Australian parents	-		-	
Foreign-born student	0.11	0.09	0.20*	0.10
Parent foreign-born	0.10	0.05	0.11	0.06
NSW	--		--	
ACT	0.06	0.10	-0.02	0.15
Victoria	0.29**	0.07	0.25**	0.09
Queensland	0.08	0.08	0.33**	0.08
South Australia	0.22**	0.08	-0.04	0.11
Western Australia	0.24**	0.09	0.22	0.11
Tasmania	0.20	0.11	-0.04	0.13
Northern Territory	0.23	0.13	0.23	0.14
Metropolitan area	--		--	
Provincial town	0.11	0.06	0.01	0.07
Remote location	0.28	0.15	-0.37	0.22
Indigenous	0.09	0.11	-0.08	0.14
Economic and cultural status of family	0.13**	0.04	0.04	0.04
Academic performance in science	0.25**	0.03	0.41**	0.03
Minutes per week study science	0.15**	0.02	0.05*	0.02
Self-confidence in science skills	0.01**	0.00	0.01**	0.00
<i>School characteristics</i>				
Coeducational school	--		--	
Boys-only school	0.55**	0.11	0.02	0.09
Girls-only school	0.02	0.08	0.03	0.08
Government school	--		--	
Independent	0.31**	0.07	-0.03	0.04
Catholic	0.19**	0.07	4.24	0.25
Selective admission to school	0.06	0.04	0.02	0.09
(constant)	4.73**	0.20	4.24**	0.25
Random effects				
Variance between schools	0.01	0.02	0.03	0.02
Number of students	14 251		14 251	
Number of schools	353		353	

Notes: * Statistically different from zero at $p = 0.05$.
 ** Statistically different from zero at $p = 0.01$.
 -- reference category.

Another important aspect of this finding and one which is not evident in the examination of logit coefficients is that the benefit of single-sex schooling for girls' uptake of physical science is moderate. In predictions informed by a model analogous to the one found in table 4 but run only for female students it was ascertained that, if all the girls in LSAY09 switched schools to girls-only institutions, their average level of physical science uptake in Year 11 would rise from 28% to 34.5%, all else being equal. While this is not a negligible difference, it is by no means staggering.

With respect to boys, single-sex schooling makes no difference in the uptake of science subjects in Year 11, once a range of school and student characteristics is taken into account. However, boys in boys-only schools are more likely, all else being equal, to target careers in physiotherapy or medicine than boys in coeducational schools.

While not all effects of single-sex schooling are explained away by control variables, single-sex schools are not particularly powerful factors in encouraging enrolments in science courses or science-oriented career plans.

With respect to science subjects, students' gender, science performance and science self-confidence levels have a consistent positive influence on both life and physical science engagement (table 4). These latter two variables are more salient for taking up physical science subjects. There is also some indication that science subjects are taken more frequently by students from higher socioeconomic backgrounds. The socio-cultural status of a student's family in this analysis includes both material and cultural resources, including parental education and cultural possessions (OECD 2007b). Furthermore, physical sciences appeal more to ethnic minority students, as shown by the positive coefficients associated with students' place of birth and a negative one for English spoken at home.

The controls for the school sector and state or student residence, while essential, are less informative in this analysis. As these variables were used as sampling strata and because science subject titles vary between particular states and territories, these controls are necessary. It is interesting to note the apparent higher uptake of science subjects in Victoria than in New South Wales, but this may be partially an artefact of subject coding, even though this difference appears also in students' career expectations in table 5. Multilevel models in tables 4 and 5 control for a wide range of indicators of students' abilities, background and opportunities (Ainley & Daly 2002). As was the case in previous studies, it is impossible to control for 'constrained curriculum' effects, which denote the availability of subjects, but a number of variables, including school location (metropolitan versus other), students' prior academic achievement and school sector, are used as proxy variables to address this issue (Ainley & Daly 2002). At the school level (table 4) students in both independent and Catholic schools are more likely to take life science subjects, although only independent schools foster a higher likelihood of enrolment into physical science in Year 11.

Arguably, the benefits of science engagement in high school may be short-lived if students do not plan further study or careers in science-related fields. This is why, in assessing the potential benefits of single-sex schooling, it is worth considering the career expectations of students in both types of schools. Plans for careers in physical science are not significantly related to sector or the gender composition of schools. The only effect at school level is the propensity of boys in sex-segregated schools to opt a little more frequently for life science professions (0.55**, in bold type in table 5). Students in Catholic and independent schools are more likely than government-sector students to plan life science careers, but overall it is more individual than school-level factors that make a significant difference to the vocational plans of students. Ethnic minority students are not only more likely to take physical science courses in Year 11 (-0.78** for English spoken at home in table 4) but also to

plan a career in science-related fields (-0.44** and -0.31** in table 5). Foreign-born students are more interested in physical science compared with their Australian-born peers. There are a number of state differences, of which Victorian students, who were also more likely than students in New South Wales to take science courses in Year 11, stand out as more keen on science-related employment. Academic success in science is conducive to science subject uptake and the forming of science-oriented vocational plans, although more so for physical (0.87** in table 4 and 0.41** in table 5) than life science occupations (0.11** in table 4 and 0.25** in table 5). Higher levels of science confidence boost all forms of science engagement, while the time devoted to studying science is a significant predictor of science-related occupational expectations. The latter demonstrates an extra commitment to science study on the part of those students who are intent on future careers in this area.

Conclusions

In contrast to an earlier study conducted on the LSAY95 data, this paper concludes that single-sex schooling moderately benefits girls by fostering higher rates of engagement in physical science courses in Year 11. However, while girls study physical science more frequently in these schools, they are no more likely than girls elsewhere to aspire to careers related to these subjects. Conversely, for boys in LSAY09 the attendance of single-sex schools made no difference in the uptake of life and physical science courses, but these boys were more likely than boys in coeducational schools to plan life science careers.

These results need to be considered in the broader context of the Australian education system. First, it seems that sex-segregated education is on the decline, after a long period of accounting for about 20% of student enrolments. Therefore, the analyses performed in this paper are necessarily based on low numbers of students in girls-only and boys-only schools. Furthermore, the benefits of single-sex schooling for science engagement identified in this paper are moderate in size. Finally, the question that arises is to what extent is the greater involvement in physical science of girls in Year 11 of lasting benefit, if this form of science engagement is not accompanied by plans to enter the associated careers? Likewise, while the tendency for boys in single-sex schools to nominate a future life science career as their ambition might be construed as a proof of more gender-integrated school cultures, alternative explanations are equally plausible. For instance, the cultural capital of parents related to their field of employment is likely to influence youth career aspirations. A recent international study confirms that the sons of fathers who work in life science occupations are more likely than other students, all else being equal, to plan a similar career for themselves (Sikora & Pokropek 2012b).

While it is impossible in this analysis to dismiss a positive impact of single-sex schooling, it must be borne in mind that the numbers of students likely to attend single-sex schools are declining, that the benefits are not equal for life and physical sciences, and that factors which encourage girls in girls-only schools to study physical science do not foster hopes for careers in these fields. Thus, it is doubtful whether these moderate benefits are of a long-lasting nature and could justify a serious consideration of programs designed to extend single-sex education into the government sector. In response to ‘What if we had girls’ or boys’ schools, or some schools offering single-sex classes?’ asked by the ACT Government, Education and Training (2010) in the context of brainstorming about future reforms to local government schools, this paper suggests, if only in terms of science engagement, that such changes would have very moderate effects. Far more likely is that the gender segregation enforced and perpetuated by powerful factors outside the school environments will be reflected in students’ choices of science courses and science careers, regardless of the type of school they attend. Most Australian schools will remain coeducational. If they were all to be converted into single-sex schools, the potential benefits would be negligible, as it is highly unlikely that single-sex schooling is an effective remedy for reducing gender segregation in all forms of school activities, including science engagement. Furthermore, sex-segregated schooling is even less likely to ameliorate the gender segregation which affects the later life outcomes of young people (Sullivan, Joshi & Leonard 2010, 2011).

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Appendices

Appendix A Details of methodology and measurement

Methods of estimation

PISA 2009, which is the first wave of LSAY09, uses plausible value methodologies to measure student achievement. It also uses an incomplete balanced matrix design, which means that students answer a sample of, rather than all, test questions. This is why descriptive estimates of student achievement in science in this paper are based on five plausible values for each student and computed with the OECD-recommended analytical techniques, including balanced-repeated replicate (BRR) weights with Fay adjustments (OECD 2009). All analyses have been performed on the data in which missing values had been replaced by the estimates from a multiple chained imputation procedure available in Stata 12 (Royston 2004). The imputation model included, as predictors, all the variables from the analyses in this paper, except for the dependent variables.

Because of the use of imputations and plausible values (Mislevy et al. 1992), all estimates in the multivariate analyses have been obtained using multiple imputation methodology. This involves fitting five sets of models, each with one plausible value, and then combining these values using the Rubin rule (Little & Rubin 1987), as per OECD recommendations (OECD 2007b). For the estimations of multilevel models, MPlus version 6 was used because of its ability to handle complex weights in hierarchical estimations.

The PISA 2009 sample is representative of 15-year-olds, not of students in any particular grade. All analyses of career plans in this paper have been weighted back to the original PISA population, while all analyses of subject choices have been weighted to such subpopulation of PISA students as remained after 1) those who failed to participate in the survey's subsequent waves and 2) who changed schools after Wave 1, or 3) who did not answer the question about remaining in the original PISA school, were excluded from the analysis. Only student-level weights were used, as per OECD recommendations (OECD 2012b), as PISA data have been collected with a sampling mechanism that is invariant across sample clusters, so school-level weights are not necessary (Asparouhov 2004).

Multivariate analyses in this paper are two-level hierarchical logit models with school-level and student-level covariates (OECD 2012b; Raudenbush & Bryk 2002). Logit models are suitable for predictions regarding binary variables. Here dependent variables denote the chances of studying at least one life science subject in Year 11 and at least one physical science subject in Year 11 as well as expectations of a career related to life science and expectations of a career related to hard science. The two-level logit model has the following functional form:

$$\text{logit}(Y_{ij}) = \gamma_{00} + \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\boldsymbol{\gamma} + u_{0j}$$

where Y_{ij} denotes the dependent variable for an observation for student i in school j , γ_{00} is the average intercept across schools. \mathbf{X} is a vector of student-level explanatory variables and $\boldsymbol{\beta}$ is a vector of regression coefficients corresponding to variables from vector \mathbf{X} . \mathbf{Z} is a vector of school-level explanatory variables and $\boldsymbol{\gamma}$ is a vector of regression coefficients corresponding to variables from vector \mathbf{Z} . The error component u_{0j} varies between schools. In multilevel logit models, the individual error term, denoted by e_{ij} , is omitted due to identification problems (Raudenbush & Bryk 2002).

Measurement

Student characteristics

Dummy (zero-one) variables

1. Female: coded 1 for females and 0 for males
2. English spoken at home: coded 1 for students who spoke English at home and 0 for everyone else
3. Australian-born to Australian parents: coded 1 for students who were born in Australia and whose both parents were Australian-born.
4. Foreign-born student: coded 1 for students born overseas with both parents also born overseas
5. Parent foreign-born: coded 1 for students born in Australia with at least one parent born overseas
6. NSW, ACT, Victoria, Queensland, South Australia, Western Australia, Tasmania, Northern Territory
7. Metropolitan area, provincial town, remote location
8. Aboriginal student

Other variables

1. Economic and cultural status of family: the PISA variable known as students' economic, social and cultural status (ESCS). This composite construct comprises the International Socio-Economic Index of Occupational Status (ISEI); the highest level of education of the student's parents, converted into years of schooling; the PISA index of family wealth; the PISA index of home educational resources; and the PISA index of possessions, including cultural assets such as books of poetry or works of art in the family home (OECD 2007b). This index is standardised to the mean of 0 and the standard deviation of 1 across the OECD countries.
2. Academic performance in science: measured by PISA's five plausible values (OECD 2009; Wu 2005), which indicate ability to use science-related concepts in adult life. Plausible value methodologies, including the use of balanced repeated replication (BRR) weights with Fay's adjustment (OECD 2007b, p.55, and Chapter 4), have been used in this paper.
3. Minutes per week study science: the number of minutes devoted to studying science each week reported in Wave 1. Divided by 100 to facilitate presentation of coefficients.
4. Self-confidence in science skills is a single question indicator of how well the student thought they did in science. Five answer categories range from 'very well' to 'very poorly'.

School characteristics

Dummy (zero-one) variables

1. Boys-only school and girls-only school are indicators identifying schools with 0% and 100% of female students
2. Government school, independent school, Catholic school

Other variables

1. Selective admission to school is a three-category question 'How often student's record of academic performance (including placement tests) is considered when students are admitted to your school?': 0 Never, 0.5 Sometimes, 1 Always.

Appendix B Details of coding of occupations and subjects

Physical science subjects

- 6 Chemistry
- 8 Earth and environmental science
- 9 Earth science
- 14 Geology
- 21 Physical sciences
- 22 Physics

Life science subjects

- 1 Agricultural science
- 2 Agriculture and horticulture (VET)
- 3 Applied science
- 4 Biological sciences
- 5 Biology
- 7 Contemporary issues and science
- 10 Environmental science
- 13 Geography
- 15 Human biological science
- 17 Life science
- 18 Marine and aquatic practices (VET)
- 19 Marine studies
- 20 Multi-strand science
- 23 Psychology
- 25 Science life skills
- 27 Science 21
- 28 Scientific studies
- 29 Senior science
- 30 Tasmanian natural resources

Note: General science, Integrated science and Other science are not classified as either life or physical science and a small number of students were left out of analysis when this distinction is made.

Physical science occupations ANZSCO (ABS 2006)

Note: these occupations are related to computing, engineering, mathematics or physical sciences.

'Physical science' is used as a short label for this entire group of occupations

- 1350 ICT Managers
- 1351 ICT Managers
- 2232 ICT Trainers
- 2241 Actuaries, mathematicians and statisticians
- 2300 Design, engineering, science and transport professionals
- 2310 Air and marine transport professionals
- 2311 Air transport professionals
- 2312 Marine transport professionals
- 2320 Architects, designers, planners and surveyors
- 2321 Architects and landscape architects
- 2322 Cartographers and surveyors
- 2326 Urban and regional planners
- 2330 Engineering professionals
- 2331 Chemical and materials engineers
- 2332 Civil engineering professionals
- 2333 Electrical engineers
- 2334 Electronics engineers
- 2335 Industrial, mechanical and production engineers
- 2336 Mining engineers
- 2339 Other engineering professionals
- 2340 Natural and physical science professionals
- 2344 Geologists and geophysicists
- 2349 Other natural and physical science professionals
- 2600 ICT professionals
- 2610 Business and systems analysts, and programmers
- 2611 ICT business and systems analysts
- 2612 Multimedia specialists and web developers
- 2613 Software and applications programmers
- 2620 Database and systems administrators, and ICT security specialists
- 2621 Database and systems administrators, and ICT security specialists
- 2630 ICT network and support professionals
- 2631 Computer network professionals
- 2632 ICT support and test engineers
- 2633 Telecommunications engineering professionals

Life science occupations ANZSCO (ABS 2006)

2341	Agricultural and forestry scientists
2343	Environmental scientists
2345	Life scientists
2346	Medical laboratory scientists
2347	Veterinarians
2500	Health professionals
2510	Health diagnostic and promotion professionals
2511	Dieticians
2512	Medical Imaging professionals
2513	Occupational and environmental health professionals
2514	Optometrists and orthoptists
2515	Pharmacists
2519	Other health diagnostic and promotion professionals
2520	Health therapy professionals
2521	Chiropractors and osteopaths
2522	Complementary health therapists
2523	Dental practitioners
2524	Occupational therapists
2525	Physiotherapists
2526	Podiatrists
2527	Speech professionals and audiologists
2530	Medical practitioners
2531	Generalist medical practitioners
2532	Anaesthetists
2533	Internal medicine specialists
2534	Psychiatrists
2535	Surgeons
2539	Other medical practitioners
2540	Midwifery and nursing professionals
2541	Midwives
2542	Nurse educators and researchers
2543	Nurse managers
2544	Registered nurses

The coding of occupations has been conceptually informed by the OECD coding framework for PISA 2006 data (Sikora & Pokropek 2011).

Building researcher capacity initiative

This paper is produced as part of NCVET's building researcher capacity initiative, which is funded under the National Vocational Education and Training Research (NVETR) Program. The NVETR Program is coordinated and managed by NCVET on behalf of the Australian Government and state and territory governments. Funding is provided through the Department of Industry (formerly the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education).

The aims of the building researcher capacity initiative are to attract experienced researchers from outside the sector, encourage early career researchers and support people in the sector to undertake research.

The building researcher capacity initiative includes the following programs: NCVET fellowships, PhD top-up scholarships, postgraduate research papers and community of practice scholarships for VET practitioners. These grants are awarded to individuals through a selection process and are subject to NCVET's quality assurance process, including peer review.



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