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Gender Gap in School Science: Are Single-Sex Schools Important?

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Abstract This paper compares science subject choices and science-related career plans of Australian adolescents in single-sex and coeducational schools. Data from the nationally representative Longitudinal Survey of Australian Youth collected from students who were 15 years of age in 2009 show that, in all schools, boys are overrepresented in physical science courses and careers, while girls are overrepresented in life science. It appears that students in all-girls schools are more likely to take physical science subjects and are keener on careers in physics, computing or engineering than their counterparts in coeducational schools. However, multi-level logit regressions reveal that most apparent differences between students in single-sex and coeducational schools are brought about by differentials in academic achievement, parental characteristics, student's science self-concept, study time and availability of qualified teachers. The only differences remaining after introducing control variables are the higher propensity of boys in single-sex schools to plan a life science career and the marginally lower propensity of girls in girls-only schools to study life science subjects. Thus, single-sex schooling fosters few non-traditional choices of science specialization. The paper discusses the likely consequences of gender segregation in science and a limited potential of single-sex schools to reduce them. The results of the current analysis are contrasted with a comparable study conducted in Australia a decade ago to illustrate the persistence of the gender gap in science field choices.

Keywords Single-sex schools · Gender segregation in science · Science and gender · Australian education · Occupational expectations of adolescents · Science subject choice

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Introduction

The extent to which single-sex (SS) schooling entrenches or undermines the power of gender stereotypes in shaping adolescent attitudes and behavior has been vigorously debated in last decade, particularly in the UK and the USA (Bigler and Signorella 2011; Datnow and Hubbard 2002; Ivinson and Murphy 2007; Mael et al. 2005). Since science is often perceived as a traditionally masculine field, a substantial part of this debate sought to understand the persistence of the gender gap in students' science achievement and participation (Baker et al. 1995 in Belgium, New Zealand, Japan and Thailand; Halpern et al. 2011; Kalkus 2012 in the USA).

Although the literature frequently notes the specialization of genders in different science fields (Ainley and Daly 2002 in Australia; Cherney and Campbell 2011 in the USA; Feniger 2011 in Israel), its main focus has been on differentials in cognitive performance and self-esteem of students (Signorella et al. 2013; Smyth 2010). In contrast, recent comparative research informed by the culturalist theory of gender essentialism highlights the persistence of gender segregation *within* science (Charles and Bradley 2009). This is why the current paper explores the extent to which gender-segregated schooling may encourage choices of science subjects and careers which defy traditional gender stereotypes. Although this is a single-country study based on a nationally representative sample of Australian youth who were 15 years of age in 2009, it has international relevance. The data used here come from the longitudinal extension of the OECD's Programme for International Student Assessment (PISA). PISA is a survey involving 15 years old conducted every 3 years in many countries (OECD 2012b). The key advantage of PISA samples for the purpose of analyzing SS schooling is that they are representative of school as well as student populations. The current paper illustrates, on the case of Australia, how comprehensive assessment of single-sex education may be undertaken with such data. The analysis involves multilevel regressions with plausible values, denoting student achievement, and weights necessary to correctly handle stratified samples. It also replicates a nationally representative Australian study of science subject choices (Ainley and Daly 2002) conducted a decade ago, before the launch of the PISA project. As more country-specific longitudinal surveys based on PISA emerge, the approach presented here may interest researchers in other countries.

Is Gender Segregation of Science Fields both Local and Global?

On the one hand empirical evidence documents many country-specific features of SS schooling (Signorella et al. 2013). On the other hand, the culturalist theory of gender essentialism (Charles and Bradley 2009) argues that gender stereotypes operate similarly across many countries. The concentration of males and females within different science fields, known as horizontal gender segregation, showed no signs of convergence in the last three decades in Europe (Barone 2011). This segregation is stronger in affluent long established democracies than in developing and transitioning nations even in locales where overall science participation or achievement are no longer differentiated by gender (Sikora and Pokropek 2012). This type of horizontal segregation was found in higher education enrolments in 44 affluent and developing countries (Charles and Bradley 2009) and in science-oriented occupational expectations of 15 years old in 50 countries which participated in PISA 2006 (Sikora and Pokropek 2012). The culturalist theory argues that gender segregation of study fields is particularly intense in advanced industrial countries, where growing service sectors offer plenty of employment opportunities in female-labeled professions. In these countries expression of gendered identities through vocational choices is widely accepted (Charles and Bradley 2009). Moreover, comprehensive education systems enable adolescents to exercise considerable freedom in field-of-science specialization (Charles and Bradley 2009). This theory expects that as more nations expand their service sectors and move towards the comprehensive education model, horizontal gender segregation may become the key form of educational inequality.

Gender essentialism in this context refers to the widely shared beliefs that certain fields of study, like psychology, medicine or biology, are culturally and functionally compatible with what is perceived as naturally feminine skills of nurturance, care or human interaction. In contrast, abstract analytical thinking and problem-solving are construed as naturally masculine skills (Charles and Bradley 2009; Feniger 2011). The evidence from over 60 countries comprising data on student career plans and higher education enrolments is consistent with the view that cultural stereotypes encourage girls and women to flock into science fields that are related to living systems and healthcare, while boys and men concentrate on engineering, physics, geology and advanced mathematics (OECD 2012a). If gender essentialism sustains systematic gender differences in field-of-science choices, the question that arises is whether single-sex schools curb its effects. If SS schooling reduces the influence of gender stereotypes, students in these schools should be less likely to align their subject choices and career plans with the traditional divide between the 'masculine' and 'feminine' domains of science.

Challenges of Comparing Single-Sex and Coeducational Schooling

In the debate over the merits of single-sex (SS) education its advocates view it as a learning environment conducive of better achievement among boys and girls, supporting their case with data from high school seniors in Seoul, Korea (Park et al. 2011). Their opponents assert that educational segregation, far from being beneficial, fosters sexism and entrenches enduring gender stereotypes. Both sides of the debate, however, present evidence which is subject to the *omitted variables* problem. Thus, any apparent academic benefits of SS education are believed to be attributable to preexisting differences in the socio-economic status of students, in school resources as well as a host of other characteristics (Halpern et al. 2011). In short:

> 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? (Smyth 2010, p. 53)

While comparisons of the two types of schooling can certainly be challenging, valid conclusions can be drawn from studies which account for key characteristics of both school and student populations. Evidence from the USA suggests that it is essential to recognize the variation among single-sex schools with respect to teacher quality, school resources and selectivity in student admission procedures (Halpern et al. 2011; Signorella et al. 2013) .

In English-speaking countries, students in single-sex schools differ from other students with respect to their socioeconomic status and prior academic achievement (Smyth 2010), so these characteristics need systematic consideration. High achievers often receive preferential treatment in admission to single-sex schools (Hayes et al. 2011) and this can foster student self-selection. Reciprocal reinforcement between school- and student-level selectiveness encourages individuals with higher academic motivation and self-concept to seek entry to single-sex schools because of their reputation for academic excellence (Hayes et al. 2011).

In the same group of countries, gender-segregated schooling is overrepresented within the private sector which charges tuition fees (Smyth 2010). Consequently, parental wealth and socio-economic status are crucial to take into account when assessing net benefits that flow on to students. Furthermore, in these countries ethnic and racial characteristics are also routinely considered as control variables because different niches of the single-sex and coeducational sectors cater to different ethnic and racial groups (Ho 2011; Signorella et al. 2013; Smyth 2010). In addition to these factors, the present study also takes into account, as control variables, such forms of parental cultural capital which embody the knowledge wherewithal, values and preferences associated with maternal or paternal employment in science (van de Werfhorst 2010). Although within-family socialization may be relevant to placing girls in gender-segregated high schools, it has been rarely considered.

Can SS Schooling Foster Non-Traditional Choices of Science Fields?

Single-sex schools are commonly seen as learning environments which effectively encourage girls to take up the study of science, technology, engineering and mathematics (Signorella et al. 2013). By analogy, they are also believed to encourage boys' engagement with fields of study which are not usually considered to be masculine (Ivinson and Murphy 2007). The basic argument is that in single-sex environments youth do not feel pressure to enact their gendered identities before peers of the opposite sex and thus can more freely engage in activities culturally constructed as incongruent with their gender (Ivinson and Murphy 2007). A similar logic underpins psychological arguments about gender stereotype threat, so single-sex schools are often seen as contexts which weaken its adverse effects (Cherney and Campbell 2011).

Overall, the literature in this area suggests that understanding of the long-term impact that SS schooling has on science-specialization of youth requires data on multiple educational and social outcomes. Therefore, in addition to student achievement differentials, the effects of SS schooling should be assessed for curricular and occupational choices of students. A recent meta-analysis of international studies on youth interest in science also recommends attention to a broader range of outcomes, as many students who do well in science subjects or courses do not plan further science education or careers (Osborne et al. 2003).

Why Australia?

The Australian education system is particularly well suited to considering the relationship between SS schooling and gendered participation in science. It is a comprehensive system, devoid of early vocational tracking or a long-established standard national curriculum. Australian adolescents study five or six *best performance* subjects of their choice in Years 11 and 12 (Ainley and Daly 2002). SS schooling has a long history in Australia which has been classified as a moderately segregated education system (Wiseman 2008). Secondary schooling comprises a sizeable non-government sector which caters to more than a third of students divided between the Catholic and Independent schools (Marks 2010). Nearly two thirds of all Australian students attend government schools which are almost entirely coeducational (ABS 1997). The choice of school is commonly seen as parental prerogative with parents likely to seek better reputed schools not only between sectors but also within the public sector within a commuting distance (Campbell et al. 2009). A small number of public single-sex schools exist in different Australian states as historical remnants of what used to be a strongly gender-segregated system (ABS 1997). Some schools admit students on prior achievement, others benefit from their established reputation for academic excellence, which attracts migrant families who seek lower cost quality education (Ho 2011). This is why accounting for selectivity in student admission is essential.

Most single-sex schools in Australia belong in either the Catholic or the Independent sector (ABS 1997). The former adhere to ethical values of Catholicism, although they often cater to non-religious students, while teaching philosophies of Independent schools may involve some elements of Protestantism, non-Christian religions or be entirely non-denominational (Campbell et al. 2009). Catholic and Independent schools charge tuition fees ranging from affordable to quite prohibitive, which makes them elitist to various degrees. Academically, students in Independent schools tend to outperform other students in science and they come from more advantageous socio-economic backgrounds (Kelley and Evans 1999, 2004). Finally, Australia is one of the countries in which student populations in public and private schools and also in single-sex and coeducational schools are strongly differentiated by students' ethnic backgrounds (Ho 2011).

Prior Australian Research on Gendered Choices of Science Subjects

Australian research on science-related course choices of students in the final year of high school in 1998 found that girls' odds of studying physical science, defined as a physics or chemistry course, were equal to only 38 % of boys' odds. In contrast, girls' odds of studying non-physical science were greater by 20 % than the odds of boys (Ainley and Daly 2002). This pattern of horizontal segregation by gender in the uptake of particular science subjects corresponds closely to patterns found by Sikora and Pokropek in students' career expectations in 50 countries which participated in PISA 2006 (2012). In Australia, the gender gap in science course choices in 1998 was similar in single-sex and coeducational schools after a number of pre-existing differences had been taken into account. They included the school sector, the English language skills of students, their socio-economic status, place of residence, and their former academic achievement. Ainley and Daly (2002) concluded that SS schooling made no difference to gendered choices of science subjects in Year 12. To revisit this conclusion a decade later, when the contours of the Australian single-sex education have changed, the present analysis seeks to establish whether, more recently, such schooling has had any de-segregating effects on student science choices.

Gender in Life and Physical Science Participation

Gender differences in science participation can be considered at the level of particular science subjects, as was done in a recent study on nationally representative data for Jewish students in Israel (Feniger 2011). Yet, when career interests are also part of the study design, an analysis at a more aggregate level is necessary. Australian science educators have long been aware that girls and boys tend to concentrate in different fields of science, as this pattern emerged in small-scale qualitative studies and in analyses of data for nationally representative samples of adolescents (Dawson and O'Connor 1991; Fullarton and Ainley 2000). There is no consensus on the terminology which best describes this. Some authors, who examined PISA 2006 data for many countries, distinguished soft and hard sciences (Kjrnsli and Lie 2011), while others, who studied secondary data from multiple sources in the USA, used the labels of life and quantitative sciences (Kessel and Nelson 2011). While this paper uses the labels of *physical* and *life* science, any categorization of science fields is arbitrary, therefore it is important to review the list of science fields included in these two categories which has been provided in Appendix 1. In principle, subjects with significant biology, health-related or environment-focused content are treated in this analysis as life science while subjects with physics, chemistry or geology content are treated as physical science. Likewise, occupational plans related to biology and health services are assumed to relate to so defined life science, while a broad range of occupations, including engineering as well as mathematical and computing occupations are assumed to relate to physical sciences. This latter categorization is adopted from the OECD framework used for international comparisons (Sikora and Pokropek 2011). To understand the rationale for such a conceptualization two things must be borne in mind. First, the Australian science education at upper-secondary level comprised, between 2009 and 2011, a number of school subjects (listed in Appendix 1) that differed across states and territories. High school science courses for the current analysis have been coded after consulting online documentation for each course listed in Appendix 1 in each relevant locale. Second, verbatim reports of student occupational preferences involve many job titles. Thus the two broad categories of science distinguished here are a pragmatic compromise between treating science as one homogenous domain, which conceals the gender gap, and attempting an overly complex classification with too few students in each category.

Research Hypotheses

In light of previous research documenting persistent gender segregation in student science interests and participation, it is plausible to expect a substantial gender gap in student science subject choices and career choices, regardless of the type of school attended. This issue informs Hypotheses 1, 2, 5 and 6 which are listed below. The other four hypotheses expect SS schooling to boost non-traditional choices of science subjects and careers among students of each gender. This boost is hypothesized to occur despite pre-existing differences in school and student characteristics. The following list of hypotheses guides the analyses that follow.

1. Regardless of the type of school attended, girls are over-represented among Year 12 students taking life science courses.
2. Regardless of the type of school attended, boys are over-represented among Year 12 students taking physical science courses.
3. Attendance of single-sex school increases the uptake of life science subjects among boys net of students' socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.
4. Attendance of single-sex school increases the uptake of physical science subjects among girls net of students' socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.
5. Regardless of the type of school attended, girls are over-represented among 15-year-olds who plan a career in life science.
6. Regardless of the type of school attended, boys are over-represented among 15 years old students who plan a career related to physical science.
7. Attendance of single-sex school increases the likelihood that boys plan a career in life science net of their socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.

8. Attendance of single-sex school increases the likelihood that girls plan a physical science career net of their socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.

Method

This paper uses data from upper secondary school students who participated in the 2009 Longitudinal Survey of Australian Youth cohort, known as Y09, and who were, at that time between 15 and 16 years of age (NCVER 2012). Y09 began with the OECD's Programme for International Student Assessment 2009 survey which focused on students' literacy and reading skills (OECD 2012b). It was conducted on a two-stage stratified representative sample of all Australian students. Sampling involved first selecting a random sample schools, stratified by sector and state or territory, and then selecting students within them. Of 14,251 students who partook in PISA/Y09 in 2009, 8,759 participated in Y09 in 2010 and 7,626 participated in 2011 (NCVER 2012, p. 12). The initial PISA/Y09 survey was administered to students in schools (see Chapter 4 in OECD 2012b for the details of PISA sampling). The longitudinal follow-up surveys in 2010 and 2011 were conducted over the phone (NCVER 2012).

Occupational Expectations

Students were asked about their expectations to work in science-related occupations in 2009. Verbatim answers to "What occupation do you expect to work in at 30 years of age?" were matched with the codes of the Australian and New Zealand Standard Classification of Occupations (ABS 2006) and then converted, using the listings of job titles in Appendix 1, into two zero–one variables denoting "a plan to work in a physical science occupation" and "a plan to work in a life science occupation". Missing data on occupational expectations have been imputed using the multiple chained equations procedure (Royston 2004) resulting in the analytical sample of 14,251 students.

Year 12 Science Subjects

The information about student subject choices was collected in 2010 and 2011. As PISA/Y09 sample is age-based, most students were in Year 10 in 2009 but some were at other grade levels. For the analysis in this paper the information about curricular choices in Year 12 was obtained, in 2010, from 1,747 students and, in 2011, from 4,488 students. Because the analysis had to be constrained to students who did not change schools since 2009, which was the only time when school information was collected from school principals, the resulting sample for the subject choice analysis is 5,318 students.

Gender Composition of Schools

The information about gender composition of schools was collected only in 2009. Although Australia has been classified as a country in which a significant proportion of students attend single-sex schools (Baker et al. 1995; Wiseman 2008), the Y09 data suggest otherwise. The representative sample of 353 schools includes 19 all-boys and 26 all-girls schools which catered to only 6 % of boys and 9 % of girls. This contrasts with late 1990's when over 20 % of upper secondary students attended single-sex schools (ABS 1997; Ainley and Daly 2002). So it appears that, in contrast to the USA (Signorella et al. 2013), Australia has seen a recent decline rather than growth in SS schooling. This can be significant, as cross-national research based on data from nationally representative samples of Year 12 students in Belgium, New Zealand, Japan and Thailand (Baker et al. 1995) suggests that when single-sex schools become rare, they become more elitist and likely to produce distinct outcomes for their students.

Pre-Existing Differences among Schools and Students

This analysis controls for a broad range of pre-existing differences between students and schools, which, in the literature reviewed here, have been identified as factors confounding the apparent relationship between science participation and SS schooling. Individual characteristics of students including their ethnic background indicated by language spoken at home, migration status, urban or rural residence, economic and cultural status of the family, academic performance in science, weekly time devoted to science study and science self-concept have been included in the analyses. School level variables include the government, the Catholic and Independent sectors, the state in which schools were located, the information on schools' selective admission policies and the principal's reports about teachers' shortage. The measurement details of all these variables are in Appendix 2.

Methods of Analysis, Including Weights

As Y09 sample is clustered by school, all multivariate analyses are based on multilevel logit models which utilized the OECD recommended estimation and weighting procedures for PISA samples. However, the longitudinal extension of the PISA survey, i.e. Y09, necessitates accounting for attrition of respondents in each subsequent follow-up survey. In line with LSAY technical documentation, the approach adopted here is to utilize as predictors in models all variables used in the Y09 weight construction (Lim 2011). These included state, school sector, Aboriginal and migrant status of students, gender, plausible values indicating academic achievement and urban versus rural residence. Full details of the modeling strategy and weighting are provided in Appendix 2.

Results

The key challenge in comparing single-sex and coeducational schools is to distinguish what can reasonably be attributed to the gender composition of schools and what must be seen as a function of pre-existing student and school characteristics (Signorella et al. 2013). Before proceeding to testing hypotheses in multilevel regression models, this section contrasts bivariate distributions of school and student characteristics across coeducational and single-sex schools.

Descriptive Statistics

In Australia, most SS secondary schools are in the non-government sector (Table 1, Panel 1), therefore it is particularly easy to mistake the advantages of the latter for the former. In 2009 most single-sex schools were concentrated in the Catholic sector where they catered for 41 % of students, of whom 17 % were in boys-only environments while 24 % attended girls-only schools (Table 1, Panel 2). Within the Independent sector only 17 % of students studied in segregated environments, with 8 % of youth in boys-only and 9 % in girls-only schools. The government sector was almost entirely coeducational. In it, only 2 % of students attended all-boys schools while 3 % attended all-girls schools (Table 1, Panel 2). Contrary to what might be expected, admission of students based on prior academic achievement is equally likely to happen in segregated and coeducational settings (Table 1, Panel 3: values of 0.70, 0.61 and 0.59 have overlapping confidence intervals). However, in line with the perception that single-sex schools are better resourced, they are significantly less likely to face problems with recruitment of qualified mathematics, English or science teachers (Table 1, Panel 3).

The proportion of Australian youth in gender-segregated education diminished significantly between mid-1990's and 2009. Ainley and Daly (2002) reported that in mid-1990's 55 % of students in the Catholic sector and 45 % of students in the Independent sector attended single-sex schools. By 2009 these proportions decreased to 41 and 17 %, respectively (Table 1). Nevertheless, students in SS schooling still come from privileged social backgrounds, and have advantageous academic and motivational characteristics. Before examining these backgrounds in more detail, student choices of science subjects and careers by gender, school type and type of science have been provided in Fig. 1.

Bars to the left of Fig. 1 leave little doubt that life science subjects and careers are less popular among boys than girls. Exactly the opposite applies to physical science subjects and careers, which are depicted to the right of Fig. 1 and are more popular among boys. However, at least in this bivariate summary, single-sex schools appear to bridge somewhat the gendered divide in these preferences. Boys in single-sex schools are more interested in life science occupations (17 versus 10 %). Moreover, girls' interest in physical science careers

Table 1 School characteristics by school gender composition

	1. Boys-only schools	2. Co-educational schools	3. Girls-only schools	N
Panel 1: Proportions of schools				
Government school	.01	.96	.03	217
Catholic school	.16	.63	.21	73
Independent school	.06	.86	.08	63
Panel 2: Proportions of students				
Government school	.02	.95	.03	8,511
Catholic school	.17	.60	.24	3,144
Independent school	.08	.83	.09	2,595
Panel 3: Mean or proportion for schools (min, max)				
Schools which admit students based on prior academic achievement, proportion (0,1)[*]	.70	.61	.59	353
Shortage of qualified teachers[a], mean (−1.02, 2.24)[**]	−.33	.29	−.51	353

Data: Y09, unweighted estimates

[a] Shortage of qualified teachers is a scale combining school principal's reports that shortages of 1) qualified science teachers 2) qualified mathematics teachers 3) qualified English language teachers and 4) qualified teachers of other subjects hinder the school's capacity to provide instruction. Positive values indicate that shortage is a greater problem

[*] Not different statistically between school types at $p<0.05$

[**] Statistically different between single-sex and coeducational schools at $p<0.05$

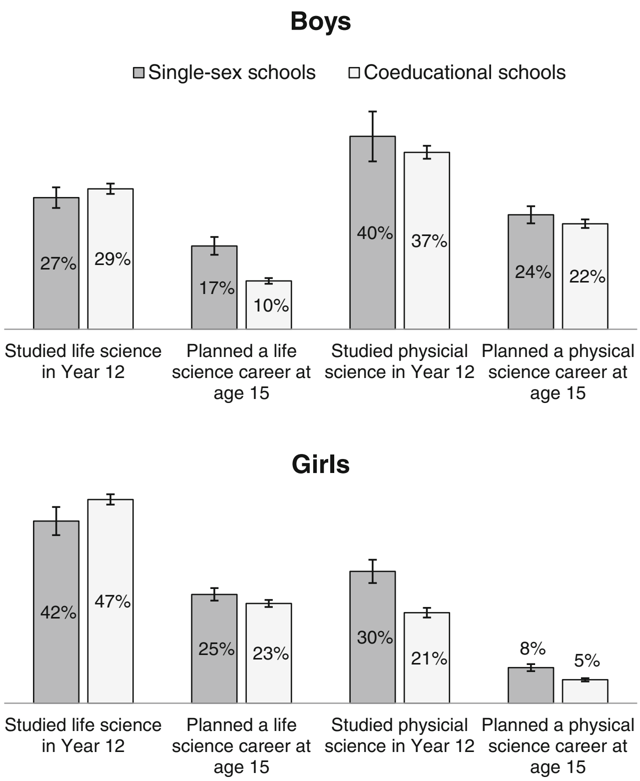

Fig. 1 Science-related subject choices and career plans by gender and type of school

appears to be stronger in single-sex schools (8 versus 5 %) and so does their participation in physical science study in Year 12 (30 versus 21 %).

Other variables attest to few differences between school types. The proportions of boys who study life science in Year 12 are similar between both types of schools (27 and 29 %). Likewise, the proportions of boys in SS and coeducational schools who study physical science are not statistically different (40 versus 37 % with overlapping confidence intervals). By contrast, the uptake of life sciences among girls is higher in coeducational schools, although only by a small margin (47 versus 42 %).

Table 2 shows that the propensity to study some science subject in Year 12 is similar among both genders in all types of schools (Table 2), so the distinction between life and physical sciences is necessary to reveal the gender gap. While boys in boys-only schools seem keener on science careers (41 %) than other students, girls in single-sex schools identify such careers as their personal goals at the rate (33 %) comparable to boys in coeducational settings (32 %).

While school types align with some differentials in student science participation, they also tend to cater to students with markedly different social characteristics. Students in single-sex schools are more likely to come from bilingual or multi-lingual backgrounds than students in coeducational schools, as the latter group are more likely to grow up in families in which both parents have been born in Australia. Moreover, students attending single-sex schools reside almost exclusively in urban areas, with the majority of schools situated in metropolitan areas. Undeniably, the advantages of SS schooling overlap closely with the cultural benefits of urban living. These advantages are less accessible to Aboriginal students of whom nearly 7 % receive coeducational education while only 2 % are equally divided between girls-only and boys-only schools. Students in single-sex schools have also the benefit of higher socio-economic status and richer cultural capital related to educational resources available at home. Mothers and fathers of these students are also more likely to work in science professions, although as these are high status jobs, the relative impact of parental socio-economic status and science-related cultural capital can be teased out only in multivariate analyses.

Furthermore, Australian students in single-sex schools perform on average better in science than their counterparts elsewhere (Table 2). The average achievement score for boys in single-sex schools was 553 and for girls it was 551 in contrast to the 523 achieved by both boys and girls in mixed environments. Yet, single-sex schools in Australia do not seem to expose their students to longer science class times. In fact the number of minutes devoted to science study at school is not significantly different between the two types of schools or between genders. Students' science self-concept is also largely comparable across school types and genders, but with one exception. Girls attending coeducational schools have weaker faith in their science skills than girls in single-sex schools. The latter report science-related confidence levels on a par of those reported by boys.

The data in Table 2 resemble quite closely the profile of youth in single-sex education constructed by Ainley and Daly (2002) from the 1998 data for Year 12 students. Those youth were in a similar position of advantage relative to their peers in coeducational environments with regard to their academic performance in science and socio-economic status.

Multilevel Models

Systematic tests of research hypotheses guiding this analysis have been conducted in multilevel regression models which are presented in Tables 3 and 4.

Hypothesis 1

Regardless of the type of school attended, girls are overrepresented among Year 12 students taking life science courses.

There is strong support for this hypothesis in the Y09 data as girls' odds of studying a life science subject in Year 12 are 2.53 times larger than the comparable odds for boys (Table 3). It is remarkable that gender remains such a strong predictor of participation in life science courses, net of a broad range of student and school characteristics. Standardized coefficients, which can be directly compared between predictors regardless

Table 2 Student characteristics by type of school and gender: proportions and means

	Boys in boys-only schools	Boys in coeducational schools	Girls in coeducational schools	Girls in girls-only schools	Min	Max	N
Proportions	.06	.43	.42	.09			14,251
Studied science subject in Year 12	*.59*	*.57*	*.56*	*.59*	0	1	5,251
Studied life science subject in Year 12	*.27*	*.29*	.47	.42	0	1	5,251
Studied physical science subject in Year 12	*.40*	*.37*	.21	.30	0	1	5,251
Planned a science career at age 15	.41	*.32*	.28	*.33*	0	1	9,385
Planned a life science career at age 15	.17	.10	.23	.25	0	1	9,385
Planned a physical science career at age 15	*.24*	*.22*	.05	.08	0	1	9,385
English spoken at home	.87	*.92*	*.92*	.83	0	1	13,880
Australian born to Australian parents	.53	*.59*	*.59*	.42	0	1	13,864
Foreign born	.35	*.31*	*.30*	.42	0	1	13,864
Parent foreign born	*.12*	*.11*	*.11*	.16	0	1	13,864
Village - under 15, 000 inhabitants *	.00	.19	.19	.00	0	1	14,251
Town - up to 100,000 inhabitants	.00	*.22*	*.22*	.05	0	1	14,251
City - under 1 million inhabitants	*.35*	*.24*	*.25*	*.32*	0	1	14,251
Large city - over 1 million *	.65	.35	.34	.63	0	1	14,251
Indigenous student *	.01	.03	.04	.01	0	1	14,251
Economic, cultural status of family	.72	*.30*	*.29*	.56	-3	2.98	14,251
Father employed in science *	.17	.12	.11	.17	0	1	13,202
Mother employed in science *	.16	.13	.12	.17	0	1	13,404
Academic performance in science *	553.0	523.0	523.0	551.0	2	905	14,251
Minutes per week study science *	*215.7*	*219.8*	*217.7*	*224.2*	0	1000	12,192
Self-confidence in science skills	*63.2*	*61.7*	57.3	*60.2*	0	100	11,621

Data: Y09, weighted estimates before multiple imputations of missing data

Coefficients in italics in Table 2 are not statistically different from each other within each row at $p<0.05$

With the exception of rows annotated with * all coefficients are statistically different from other coefficients in the same row at $p < .05$

* Coefficients within types of schools not statistically different at $p < .05$

of their metrics, reveal that gender is the strongest predictor of Year 12 life science study (0.24) which is also closely related to the weekly time devoted to science study (0.14) and science self-concept (0.09).

Hypothesis 2

Regardless of the type of school attended, boys are overrepresented among Year 12 students taking physical science courses.

This conjecture is also supported by the data. The odds of studying a physical science subject for girls are less than half of the odds of boys (0.49 in Table 3) in the presence of many control variables. This 'mirror image' gender gap in life and physical science course uptake is consistent with the decade-old findings of Ainley and Daly (2002). In Australia, the participation in these two types of science courses remains strongly segregated by gender, regardless of the type of school adolescents attend.

Hypothesis 3

Attendance of single-sex school increases the uptake of life science subjects among boys net of students' socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.

Table 3 Study of life science and physical science in Year 12: coefficients from two-level logit models

	Life science subject in Year 12				Physical science subject in Year 12			
	Unstd coeff	Std error	Odds ratio	Std coeff	Unstd coeff	Std error	Odds ratio	Std coeff
Fixed effects								
Student characteristics								
Female	.93**	.08	2.53	.24	−.72**	.08	.49	−.15
English spoken at home	−.20	.13	.82	−.03	−1.18	.15	.31	−.13
Australian born/Australian parents	–				–			
Foreign born student	−.11	.11	.90	−.02	.80**	.13	2.23	.10
Parent foreign born	−.02	.07	.98	.00	.32**	.09	1.38	.06
Village - under 15, 000 inhabitants	–				–			
Town-up to 100,000 inhabitants	.10	.16	1.11	.02	−.21	.16	.81	−.03
City-under 1 million	.07	.14	1.07	.02	−.16	.15	.85	−.03
Large city-over 1 million	−.04	.14	.96	−.01	−.18	.15	.83	−.04
Aboriginal student	−.38**	.17	.69	−.03	−.44	.28	.65	−.03
Economic & cultural status of family	.07	.05	1.07	.03	.14**	.07	1.15	.04
Father employed in science	−.10	.09	.90	−.02	.33**	.10	1.39	.05
Mother employed in science	.30**	.09	1.35	.05	.07	.11	1.07	.01
Academic performance in science	.10**	.04	1.10	.04	.83**	.05	2.28	.30
Minutes per week study science	.24**	.03	1.27	.14	.41**	.04	1.51	.19
Science self-concept	.01**	.00	1.01	.09	.03**	.00	1.03	.30
School characteristics								
Coeducational school	–				–			
Boys-only school	−.08	.19	.93	−.04	.09	.19	1.09	.06
Girls-only school	−.36**	.13	.70	−.23	.20	.17	1.22	.17
Government school	–				–			
Independent school	.07	.13	1.08	.07	.18	.11	1.20	.23
Catholic school	.16	.11	1.17	.15	−.16	.12	.85	−.20
Selective admission to school	.04	.06	1.04	.07	.04	.06	1.05	.11
Shortage of teachers	.01	.04	1.01	.01	−.12**	.05	.88	−.38
(constant)	−2.73**	.34			−7.77**	.39		
Random effects								
Variance between schools	.17**	.04			.06	.04		
Number of students	5,318				5,318			
Number of schools	312				312			

This model controls also for states and territories, coefficients not shown to conserve space

Unstd coeff Unstardardized coefficient

Std error Standard error

Std coeff Standardized coefficient

** Statistically different from zero at p=0.01

–a reference category

This hypothesis is not supported by the Y09 data as boys are equally likely to study life science subjects in single-sex and coeducational settings. The coefficient depicting the effect of attending a boys-only school in Table 3 is not different from zero, which is consistent with the pattern evident in bivariate relationships depicted by Fig. 1.

Hypothesis 4

Attendance of single-sex school increases the uptake of physical science subjects among girls net of student's socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission

Table 4 Student career plans related to life science or physical science/computing/engineering: coefficients from two-level logit models

	Student expects a life science career				Student expects a career in physical science, computing, engineering			
	Unstd coeff	Std error	Odds ratio	Std coeff	Unstd coeff	Std error	Odds ratio	Std coeff
Fixed effects								
Student characteristics								
Female	1.20**	.06	3.33	.30	−1.52**	.07	.22	−.36
English spoken at home	−.41**	.11	.67	−.06	−.26**	.12	.77	−.03
Australian born to Australian parents	–				–			
Foreign born student	.07	.09	1.08	.01	.08	.10	1.09	0.01
Parent foreign born	.00	.05	1.00	.00	.11	.06	1.11	.02
Village-under 15, 000 inhabitants	–				–			
Town-up to 100,000 inhabitants	.18**	.09	1.20	.04	.17	.09	1.18	.03
City-under 1 million	−.03	.09	.97	−.01	.17	.09	1.18	.04
Large city-over 1 million	.01	.09	1.01	.00	.26**	.09	1.29	.06
Aboriginal student	.10	.11	1.11	.01	−.05	.17	.95	.00
Economic & cultural status of family	.10**	.04	1.11	.04	.06	.04	1.07	.02
Father employed in science	.17**	.08	1.19	.03	.21**	.08	1.24	.03
Mother employed in science	.17**	.07	1.18	.03	−.08	.08	.92	−.01
Academic performance in science	.26**	.03	1.30	.14	.44**	.03	1.56	.22
Minutes per week study science	.17**	.02	1.00	.09	.05	.03	1.00	.03
Self-confidence in science skills	.01**	.00	1.01	.14	.01**	.00	1.01	.11
School characteristics								
Coeducational school	–				–			
Boys-only school	.62**	.12	1.86	.58	−.02	.10	.98	−.04
Girls-only school	−.03	.10	.97	−.04	.20	.11	1.22	.40
Government school	–				–			
Independent school	.31**	.07	1.37	.49	−.09	.09	.92	−.26
Catholic school	.18**	.07	1.20	.30	.02	.07	1.02	.06
Selective admission to school	.01	.04	1.00	.01	−.02	.04	.98	−.14
Shortage of teachers	−.02	.03	.98	−.07	.04	.03	1.04	.33
(constant)	−4.89**	.22			−4.47**	.23		
Random effects								
Variance between schools	.02	.02			.01	.02		
Number of students	14,251				14,251			
Number of schools	353				353			

This model controls also for states and territories, coefficients not shown to conserve space

Unstd coeff Unstardardized coefficient

Std error Standard error

Std coeff Standardized coefficient

** Statistically different from zero at $p=0.01$

–a reference category

policies of schools, private versus public school sector and the availability of qualified teachers.

The apparent propensity of girls to study more physical science in single-sex schools cannot be attributed to the impact of gendered school environments (insignificant coefficient of 0.09). Rather, it reflects differences in pre-existing characteristics of girls in SS and other schools. So Hypothesis 4 is not supported by the data. Enrolment in physical science courses is most dependent on academic performance (standardized coefficient of 0.30 in Table 3) and a positive science self-concept (0.30). The next most important factor is class time devoted to science study (0.19) while gender, fourth in the order of importance, exerts considerable influence (−0.15). At the school level, the only relevant characteristic predicting participation in physical science courses is the shortage of qualified teachers which, unsurprisingly, reduces the likelihood of participation. Finally, ethnicity is an important predictor of the physical science uptake. Students who speak only English at home are underrepresented in these courses (odds ratio of 0.31 in Table 3) while first generation migrants are twice as likely as other students to study physical science in Year 12 (odds ratio of 2.23 in Table 3). The odds of second generation migrants are 1.38 times as high as the odds of other students. While gender segregation of school environments cannot be seen as a means to boost higher physical science uptake among girls, girls in these schools are marginally less likely to study life science in Year 12 (Table 3). Yet, as their odds equal to 70 % of the odds for other students, this difference is moderate.

The tests of hypotheses regarding student career plans are presented in Table 4.

Hypothesis 5

Regardless of the type of school attended, girls are overrepresented among 15-year-olds who plan a career in life science.

Hypothesis 5 is fully borne out in the Y09 data, as the odds of planning a life science career for girls are over 3 times higher than the odds for boys (3.33 in Table 4).

Hypothesis 6

Regardless of the type of school attended, boys are overrepresented among 15 years old students who plan a career related to physical science.

Girls' odds of planning a career related to physical science are only 22 % of boys' odds. The pattern depicted by Hypotheses 5 and 6 corresponds closely to patterns of horizontal gender segregation in science career interests of youth found in 50 countries for 15 years old participants of the PISA 2006 survey (Sikora and Pokropek 2012a).

The odds ratios depicting gender gaps in Table 4 suggest that a greater gender divide exists in occupational expectations of students than in their school science participation. This corresponds to the findings from a nationally representative study of Australian students who were 15 in 2006, known as the Y06 cohort, which suggested that although schools succeed to some extent in involving students of both genders in all types of science, later educational pathways of youth become more gender-segregated (Sikora 2014), in line with students' early occupational plans and the existing labor market segregation in Australia.

Hypothesis 7

Attendance of single-sex school increases the likelihood that boys plan a career in life science net of their socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.

Boys in single-sex schools are significantly keener on careers in life science in line with Hypothesis 7, with their odds being 1.86 times greater than the odds of students elsewhere (Table 4). Medicine and physiotherapy are the fields of life science that particularly appeal to these boys. Compared to the government sector students, students from Independent schools are significantly more likely to plan life science careers, as are students from Catholic schools. At the individual level, the strongest predictor of propensity to aim for future employment in this area is gender (standardized coefficient of 0.30), followed by positive science self-concept (0.14).

Hypothesis 8

Attendance of single-sex school increases the likelihood that girls plan a physical science career net of their socio-economic status, ethnic background, parental science employment, time devoted to science study, selective admission policies of schools, private versus public school sector and the availability of qualified teachers.

This hypothesis is not supported, as attendance of girls-only schools has no net effect on the chances of planning a career related to physical sciences. Individual student gender is the strongest predictor of this outcome (standardized coefficient of −0.36 for females in Table 4), followed by academic success in school science (standardized coefficient of 0.22) and positive science self-concept (0.11) with other factors contributing relatively little.

Overall, while gender-segregated schooling is relatively unimportant for science participation in Australian high schools, gender remains the key factor driving student specialization in life versus physical sciences. Girls are significantly more likely to dedicate themselves to the former and boys to the latter. These tendencies showed no signs of convergence in the decade between 1998 and 2009 regardless of what was happening within the Australian single-sex school sector. Previous studies, including the Ainley and Daly analysis (2002), found that the apparent benefits of SS schooling in Australia were entirely attributable to pre-existing characteristics of schools or student populations which were unrelated to gender compositions at the school level. This analysis reaffirms this conclusion, even though the SS sector in Australia has significantly shrunk over time, and thus, most likely, has become more selective and specialized (Baker et al. 1995).

Discussion

Single-sex education in Australia comprises mostly select, non-government schools, which are located in large urban complexes and cater to students with above-average socio-economic status and achievement in science. These schools make little difference to gendered patterns of student science specialization. While girls-only schools appear to foster more participation in physical science courses or to encourage more interest in physical careers among their students, these differences are attributable to factors other than gender compositions of schools. Moreover, girls in gender-segregated settings are actually marginally less likely than girls elsewhere to study life science subjects in Year 12. Boys-only schools have students who are particularly interested in physiotherapy and medicine but these boys take life and physical science subjects at similar rates to boys in coeducational settings.

With a substantial growth in the share of private education in the 1990's (Kelley and Evans 2004) the Australian education system is arguably strongly marketized and thus shaped by parental choices (Campbell et al. 2009). These choices are enabled by socio-economic power of particular families, the technical versus communicative orientation of their cultural capital, their religious preferences and their beliefs about gender equality. Yet, in Australia these factors do not lead to strong parental preference for SS schooling. In fact, the gradual shrinking of the single-sex education documented in this paper indicates that Australian parents have doubts about the merits of single-sex education, particularly outside of the Catholic sector. Although parents employed in science have a marginally greater propensity to send their children to single-sex schools this, in its own right, does little to bridge the gender gap in youth science specialization.

The gender gap in preferences for different fields of science is evident in subject choices and career expectations of students but it is more pronounced in the latter. This is in line with research on longitudinal data from the representative sample of Australians who were 15 in 2006, which documents that adolescent career choices are good predictors of fields of study specialization in tertiary science education, net of the history of school subjects uptake (Sikora 2014). Adolescent career plans are also surprisingly good predictors of later employment (Sikora and Saha 2011) which suggests that they are an important outcome which should be taken into account in assessment of SS schooling and its effects.

Although these effects are negligible in Australia, the overall gender gap between students across all schools is of utmost importance because of its size and its persistence but also its potential consequences. If it continues to remain substantial and perhaps even grow, the gender divide in science specialization may have serious adverse consequences for future availability of diverse talent pool, individual productivity and creativity related to technological development. Young men and women continue to be significantly constrained in their science career choices by the operation of powerful gender stereotypes and this trend is no different for the most recent generation of Australian adolescents despite parental and pedagogical efforts to generate more gender equity in education.

The situation in Australia is different from reports about single schools in Korea, the United States and 14 other countries in which 15-year-olds participated in the PISA 2006 survey (Law and Kim 2011). This stipulates that while gender segregation of student science interests has some global and universal features (OECD 2012a), the success of single-sex schools in managing gender stereotypes in science education may vary greatly by historical and local contexts.

This between-country variation warrants extreme caution in extolling the potential of SS schooling to reduce the power of culturally entrenched gender stereotypes. Firstly, statistical evidence from countries with small single-sex sectors must be seen as problematic. In other words, where there are few single-sex schools, a large number of potentially confounding factors is likely to render apparent differences between schools ultimately insignificant. Secondly, if historical trends in particular countries show a systematic decline in the proportion of students in SS schooling, even significant differences between school types may be of little consequence. Where SS schooling is available only to a select group of parents and students who are able to afford substantial tuition fees, to accept particular religious credos or to commit to specific teaching philosophies, it cannot be seen as a realistic avenue of educational reform. The debate over persisting gender stereotyping in science specialization of young people is thus primarily a debate unlikely to benefit from the focus on SS schooling. In any case the empirical identification of its apparent advantages must include a broad range of educational and social outcomes.

This analysis, which involved two different dependent variables denoting science specialization among adolescents, adds to the growing body of evidence attesting to the limited potential of SS schooling as an effective panacea for gender stereotyping in education. In the nearest future parents, educators and students in all Australian schools will continue to face the problem of bridging the gender gap in science interests and its likely subsequent consequences. For now there is little doubt that within and outside of single-sex schools, Australian students continue to specialize predominantly in those fields of science which are deemed to be culturally compatible with their gender.

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Appendixes

Appendix 1 Coding of occupations and subjects

Science subjects listed below have been coded based on their content rather than titles. Online documentation for each subject available from state boards of secondary study has been used.

Physical Science Subjects

Chemistry, Earth and Environmental Science, Earth Science, Geology, Physical Sciences, Physics.

Life Science Subjects

Agricultural Science, Agriculture and Horticulture, Applied Science, Biological Science, Biology, Contemporary Issues and Science, Environmental Science, Geography, Human Biological Science, Life Science, Marine and Aquatic Practices, Marine Studies, Multi-Strand Science, Psychology, Science Life Skills, Science 21, Scientific Studies, Senior Science, Tasmanian Natural Resources.

Physical Science Occupations

These are occupations related to computing, engineering, mathematics or physical sciences. The numerics are the Australian Bureau of Statistics codes (ABS 2006).

1351 information and communication technology managers
2232 information and communication technology 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 information and communication technology professionals
2610 business and systems analysts, and programmers
2611 information and communication technology business and systems analysts
2612 multimedia specialists and web developers
2613 software and applications programmers
2621 database and systems administrators, information and communication technology security specialists
2630 information and communication technology network and support professionals
2631 computer network professionals
2632 information and communication technology support and test engineers
2633 telecommunications engineering professionals

Life Science Occupations

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 anesthetists
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

Appendix 2 Details of measurement and methodology

Independent Variables

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. Urban versus rural residence is denoted by a series of dummy variables: small town is up to 15, 000 inhabitants, town is up to 100,000 inhabitants, city-is up to 1 million, and large city denotes locations with over the population of over 1 million.
7. Aboriginal student is a self-report coded 1 for all Aboriginal students and 0 for everyone else.

Other variables

1. Economic & cultural status of family is the PISA Index of Educational, Social and Cultural Status (ESCS) (OECD 2012b). 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, which denotes the availability of own room, internet and other possessions in the household; the PISA index of home educational resources which include textbooks, computer and educational software ownership; and the PISA index of cultural possessions including assets such as books of poetry or works of art in the family home (OECD 2012b). This index is standardised to the mean of 0 and the standard deviation of 1, across the OECD countries. The Cronbach's alpha reliability of this index in 2009 for Australia was 0.59. ESCS is a conceptually strong measure of student socio-economic advantage as it includes a broad range of cultural resources pertinent to student educational outcomes.
2. Academic performance in science is measured by PISA's five plausible values (OECD 2009) which indicate students' ability to use science-related concepts in adult life. More detail on plausible value methodologies and the use of Balanced Repeated Replication (BRR) weights with Fay's adjustment (OECD 2009) is in Methods of Estimation below, but for a comprehensive explanation of these methodologies the reader is referred to the PISA Data Analysis Manual (OECD 2009).
3. Minutes per week study science is science learning time at school computed by the OECD by multiplying the number of minutes on average in each science class by number of class periods per week (OECD 2012b). It was divided by 100 to facilitate the 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 ranged from 'very poorly' denoted by 0 to 'very well' denoted by 1.

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.
3. State or territory: New South Wales, Queensland, Australian Capital Territory, Victoria, Western Australia, Northern Territory, Tasmania.

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?'which was converted to two answer categories: '0' Never and '1' which combines Sometimes + Always.
2. Shortage of teachers is the OECD Index on Teacher Shortage constructed from four questions measuring the principal's perceptions of potential factors hindering instruction at school: 'Is your school's capacity to provide instruction hindered by any of the following issues? A lack of qualified science teachers? A lack of qualified mathematics teachers? A lack of qualified English teachers? A lack of qualified teachers of other subjects? The Cronbach alpha for this index in Australia in 2009 was 0.84 (OECD 2012b).

Methods of Estimation

Multivariate analyses in this paper are two-level hierarchical logit models with school-level and student-level covariates (OECD 2012b; Raudenbush and Bryk 2002). The dependent variables denote the chances of studying 1) one or more life science subjects in Year 12) one or more physical science subjects in Year 12, 3) expectation at age 15 of a career related to life science, 4) expectation at age 15 of a career related to physical science. The two-level logit model, best suited to such variables, has the following functional form:

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

where Y_{ij} denotes the dependent variable for student i in school j and γ_{00} is the average intercept across schools. **X** is a vector of student-level explanatory variables and **β** is a vector of regression coefficients corresponding to variables in vector **X**. **Z** is a vector of school-level covariates corresponding to the vector of regression coefficients η. 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 and Bryk 2002).

To measure student achievement Y09 uses PISA's plausible value methodologies and an incomplete balanced matrix design, which means that students answer a sample of, rather than all science 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 by the OECD-recommended methods, including balanced-repeated replicate weights with Fay adjustment (OECD 2009).

Because of the use of plausible values and imputations of missing values (Mislevy et al. 1992), all estimates in 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 and Rubin 1987) as per OECD recommendations (OECD 2012b). For estimations of multilevel models MPlus version 7 was used because of its ability to handle complex weights in hierarchical estimations.

The Y09 sample is representative of 15 years old, not of students in any particular grade. All analyses of career plans in this paper have been weighted back to the original PISA/Y09 population, while all analyses of subject choices have been weighted to such subpopulation of students, as remained after 1) those who failed to participate in the survey's subsequent waves and 2) who changed schools after 2009, or 3) who did not answer the question about changing school since 2009, were excluded from the analysis. Only student level weights have been used, as Y09 data have been collected with a sampling mechanism that is invariant across the sample clusters, so school weights are not necessary (Asparouhov 2004).

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